Best Practices Join in Parallel Professions

Audiovisual and Information Transport Systems (ITS) Sharing Expertise

BICSI and InfoComm International are pleased to offer our first joint design reference manual, the *AV Design Reference Manual* (*AVDRM*). BICSI is the association of professionals serving nearly 25,000 members of the Information Transport Systems (ITS) Industry. Architects, building industry consultants, cabling contractors, manufacturers, systems integrators, electrical contractors, end users, and other ITS professionals in more than 90 countries make up the BICSI membership. InfoComm International is the trade association of the professional audiovisual (AV) and information communications industries. Established in 1939, the association's 4000 member companies (representing tens of thousands of individuals) include manufacturers, systems integrators, dealers, distributors, independent design consultants, programmers, rental and staging companies, end users, and multimedia professionals from more than 60 countries.

For years, professionals in the structured cabling and AV industries have lived parallel professional lives, separated only by boardroom walls. Each industry has its own set of best practices and its distinct way of getting the job done. Each industry is firmly rooted in professional excellence and comprehensive continuing education—yet the walls and ceilings continue to divide us.

Rather than focusing on what separates the AV and structured cabling industries, the leadership teams at BICSI and InfoComm International decided that the time has come to share our expertise and strength for the continued benefit of both professions. Just as cables and wiring pass through the walls and ceiling, so will our pipeline of knowledge.

The joint authorship of this definitive design reference manual is merely the first step in the free flow of industry information and education. Members of each association can now participate in the other's curriculum programs (and many offerings that are provided at member pricing). BICSI's continuing education credits (CECs) or InfoComm's Renewal Units (RUs) can be earned for BICSI's RCDD® and InfoComm's CTS certification programs by completing classes offered by the other association. Each organization will offer select training programs at the other's trade shows. Please visit www.bicsi.org or www.infocomm.org for more detailed information.

We hope you will take advantage of these new educational opportunities and embrace the coming together of our two related industries. To the readers that are from outside our associations we say, "Welcome to the family!"



John Bakowski, RCDD®/NTS/OSP Specialist
President
BICSI



Tom Peters, CTS
Chairman of the Board
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AV Design Reference

M A N U A L

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BICSI® World Headquarters
8610 Hidden River Parkway
Tampa, FL 33637-1000 USA
Tel.: +1 813.979.1991 or
Tel.: 800.242.7405 (USA/Canada toll-free)
Fax: +1 813.971.4311
E-mail: bicsi@bicsi.org
Web: www.bicsi.org

InfoComm International®
11242 Waples Mill Rd
Fairfax, VA 22030
Tel.: +1.703.273.7200 or
Tel.: 800.659.7469 (USA/Canada toll-free)
Fax: +1.703.278.8082
E-mail: customerservice@infocomm.org
Web: www.infocomm.org;
www.infocommshow.org

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David C. Cranmer, RCDD, Interim Executive Director and CEO

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BICSI/InfoComm Project Managers:		Patricia Boyland, CAE, Director of Professional Development and Credentialing, *BICSI* Melissa Taggart, Vice President of Education and Workforce Development, *InfoComm International*
***AVDRM* Project Leads:**		Jeffrey Coil, RCDD, Sales Manager, *Graybar Electric* Tony M. Warner, CTS-D, CSI CDT, Director of AV Design, *RTKL Associates, Inc.*
Chapter 1 Introduction	**Chapter Chair:**	Tony M. Warner, CTS-D, CSI CDT, Director of AV Design, *RTKL Associates, Inc.*
Chapter 2 Foundations	**Chapter Chair:**	Tony M. Warner, CTS-D, CSI CDT, Director of AV Design, *RTKL Associates, Inc*
	Contributors:	Timothy Cape, CTS-D, Principal Consultant, *Technitect* David M. Prince, Field Engineer, *Bose Corporation*
Chapter 3 Signals	**Chapter Chair:**	Jim Sinopoli, PE, RCDD, Principal, *Sinopoli and Associates*
	Contributors:	Timothy Cape, CTS-D, Principal Consultant, *Technitect* Kristen R. Kuipers, CTS, Senior Associate, *Newcomb & Boyd*
Chapter 4 Transmission	**Chapter Chair:**	Wayne Becker, Vice President of Sales & Marketing, *Communication Systems, Inc*.
	Contributors:	Doug Dillman, CTS-D, CTS-I, Sr. Integrated Systems Designer, *CIM Audio Visual* David M. Prince, Field Engineer, *Bose Corporation*
Chapter 5 Infrastructure	**Chapter Chair:**	Suzanne Hommertzheim, RCDD/NTS Specialist, Sr. Engineer–IPTV, *AT&T Services, Inc*.
	Contributors:	Mark Hurshman, RCDD/NTS/OSP, Special Project Manager, *Capital Electric* David Funston, RCDD, Senior Site Engineer, *SBC Internet Services, Inc.*
Chapter 6 Networking	**Chapter Chair:**	Daniel C. Burlingham, PE, RCDD, Senior Associate, *Burt Hill*
	Contributor:	Brian Brustad, CTS-D, AV Designer, *RTKL Associates, Inc*.

Acknowledgments, continued

Chapter 7 Electrical Principles	**Chapter Chair:**	Brent Lehmkuhl, PE, RCDD, Associate, *RTKL Associates, Inc.*
	Contributor:	Ken Michaels, Project Manager, *BellSouth Communications Systems*
Chapter 8 Grounding	**Chapter Chair:**	Brent Lehmkuhl, PE, RCDD, Associate, *RTKL Associates, Inc.*
	Contributors:	Ken Michaels, Project Manager, *BellSouth Communications Systems* Joseph Bocchiaro III, PhD, CTS-D, CTS-I, *InfoComm International* Mike Holt, President, *Mike Holt Enterprises, Inc*
Chapter 9 HVAC	**Chapter Chair:**	Paul Remke, PE, RCDD, Vice-President, *Schmidt Dell Associates, Inc.*
	Contributor:	W. Joseph Jones, PE, Mechanical Engineer, *Schmidt Dell Associates, Inc.*
Chapter 10 Structural Considerations	**Chapter Chair:**	Jim Sinopoli, PE, RCDD, Principal, *Sinopoli and Associates*
	Contributor:	Paul Remke, PE, RCDD, Vice-President, *Schmidt Dell Associates, Inc.*
Chapter 11 Acoustics	**Chapter Chair:**	Kenneth W. Graven, PE, Vice President, *Charles M. Salter Associates, Inc.*
	Contributors:	Paul Remke, PE, RCDD, Vice-President, *Schmidt Dell Associates, Inc.* Timothy Cape, CTS-D, Principal Consultant, *Technitect*
Chapter 12 Lighting	**Chapter Chair:**	Jim Yorgey, PE, Technical Applications Manager, *Lutron*
Chapter 13 Interior Design	**Chapter Chair:**	Brian Brustad, CTS-D, AV Designer, *RTKL Associates, Inc.*
	Contributor:	Timothy Cape, CTS-D, Principal Consultant, *Technitect*
Chapter 14 Audio Components	**Chapter Chair:**	Tony M. Warner, CTS-D, CSI CDT, Director of AV Design, *RTKL Associates, Inc.*
	Contributor:	David M. Prince, Field Engineer, *Bose Corporation*
Chapter 15 Video Components	**Chapter Chair:**	Tony M. Warner, CTS-D, CSI CDT, Director of AV Design, *RTKL Associates, Inc.*
	Contributors:	Alan C. Brawn CTS, ISF, AIA, *Brawn Consulting* Timothy Cape, CTS-D, Principal Consultant, *Technitect* David M. Prince, Field Engineer, *Bose Corporation*

Acknowledgments, continued

Chapter 16 Control Components

Chapter Chair: Tony M. Warner, CTS-D, CSI CDT, Director of AV Design, *RTKL Associates, Inc.*

Contributor: David Silberstein, CTS, Manager of Consultant Market Development and Technical Services, *Crestron*

Chapter 17 Systems

Chapter Co-Chairs: Tony M. Warner, CTS-D, CSI CDT, Director of AV Design, *RTKL Associates, Inc*.
Charles E. Green, Jr., RCDD, AV/VTC Sector Lead Engineer, *Northrop Grumman IT Solutions*

Contributors:

"Introduction"
Richard G. Derbyshire, Partner, *Shen Milsom & Wilke, Inc*.

"Visual Displays Systems"
Richard G. Derbyshire, Partner, *Shen Milsom & Wilke, Inc*.

"Program Audio and Speech Reinforcement Systems"
David M. Prince, Field Engineer, *Bose Corporation*

"Signal Distribution Systems"
Richard G. Derbyshire, Partner, *Shen Milsom & Wilke, Inc*.

"Audioconferencing Systems"
Craig H. Richardson, PhD, Vice-President, General Manager, *Polycom Installed Voice Business*

"Videoconferencing Systems"
H. Jim Smith, CTS, CVE, Systems Engineer, *Polycom*

"Control Systems"
Richard G. Derbyshire, Partner, *Shen Milsom & Wilke, Inc*.

"Overhead Paging"
Tony M. Warner, CTS-D, CSI CDT, Director of AV Design, *RTKL Associates, Inc*.

"Sound Masking Systems"
Jeffrey Coil, RCDD, Sales Manager, *Graybar Electric*

"Digital Signage Systems"
Richard F. Trask, Marketing Director, *Scala Inc*.

"Broadband Systems"
Jerry Budge, *Blonder Tongue Laboratories, Inc*.
Shelly Williams, Product Manager, *Blonder Tongue Laboratories, Inc.*

Acknowledgments, continued

Chapter 18 Venues

Chapter Chair: David M. Prince, Field Engineer, *Bose Corporation*

Contributors:

"Designing Primary and Secondary School Audiovisual (AV) Systems"
Martin Philip, *HP Electronics, Inc*.

"Designing College/University Audiovisual (AV) Systems"
Joseph Bocchiaro III, PhD, CTS-D, CTS-I, Senior Instructor, *InfoComm International*
Thomas Corbett, *Charles Salter Associates*

"Designing Places of Worship Audiovisual (AV) Systems"
Simon Davis, CTS-D, Director of Engineering—Boston, *HB Communications, Inc*.
Joseph Bocchiaro III, PhD, CTS-D, CTS-I, Senior Instructor, *InfoComm International*

"Designing Corporate/Boardroom/Training Room Audiovisual (AV) Systems"
Simon Davis, CTS-D, Director of Engineering—Boston, *HB Communications, Inc*.

"Designing Command and Control Audiovisual (AV) Systems"
Gregory Moquin, Senior Associate, *Shen Milsom & Wilke, Inc*.

"Designing Hospital Audiovisual (AV) Systems"
Peter O'Connor, *EQ International*

"Designing Hotels and Conference System Audiovisual (AV) Systems"
Jeff Loether, President, *Electro-Media Design Ltd.*

"Designing Stadium Audiovisual (AV) Systems"
Brad Ricks, *JBL Professional*
Jack Wrightson, Managing Principal, *Wrightson, Johnson, Haddon & Williams, Inc*.
Jim Faber, Senior Associate, *Wrightson, Johnson, Haddon & Williams, Inc.*

"Designing Airport Audiovisual (AV) Systems"
Gregory Moquin, Senior Associate, *Shen Milsom & Wilke, Inc*.
John Fish, *Advanced AV*

"Designing Retail Audiovisual (AV) Systems"
David M. Prince, Field Engineer, *Bose Corporation*

"Designing Entertainment Audiovisual (AV) Systems"
Jay Paul, *SPL Integrated Solutions*

"Designing Performing Arts Audiovisual (AV) Systems"
Randal Willis, PE, *McKay Conant Brook, Inc*.

Acknowledgments, continued

Chapter 18, continued		**"Designing Museum Audiovisual (AV) Systems"** Robert J. Haroutunian, *PPI Consulting* **"Designing Legal Audiovisual (AV) Environments"** Joseph Bocchiaro III, PhD, CTS-D, CTS-I, Senior Instructor, *InfoComm International*
Chapter 19 Project Processes	**Chapter Chair:**	Jim Sinopoli, PE, RCDD, Principal, *Sinopoli and Associates*
Technical Chapter Reviewer:		Scott Wills, CTS-D, CTS-I, Senior Staff Instructor, *InfoComm International*
Glossary	**Leads:**	Jeffrey Coil, RCDD, Sales Manager, *Graybar Electric* Tony M. Warner, CTS-D, CSI CDT, Director of AV Design, *RTKL Associates, Inc.*
	Contributors:	All AVDRM chapter chairs and chapter contributors listed in this section, and Robert Y. Faber, RCDD/NTS Specialist, *The Siemon Company*

Participants, *AVDRM* DACUM, Tampa, FL, June 24-25, 2005:

Dr. Katherine (Kitty) Manley, Facilitator (National Occupational Competency Testing Institute); Daniel C. Burlingham, PE, RCDD; Jeff Coil, RCDD; Joseph D'Angelo; Doug Dillman, CTS-D, CTS-I; Tom Kehr, CTS-D; Leo Marsh, PE, RCDD, CTS; Dan Van Meter, CTS-D; L. William Nattress III, CTS-I; Donald Walker, RCDD; Scott Walker, CTS-D; Tony M. Warner, CTS-D, CSI CDT.
BICSI/InfoComm staff attending: Patricia Boyland, CAE (BICSI), Amanda Collett, CTS (InfoComm), Colleen McIlroy, M.Ed. (BICSI), Nermina Miller (BICSI), and Melissa Taggart (InfoComm).

Participants, *AVDRM* Editorial Review, Tampa, FL, February 2-4, 2006:

Wayne Becker; Timothy Cape, CTS-D; Brian Brustad, CTS-D; Daniel C. Burlingham, PE, RCDD; Jeffrey Coil, RCDD; Doug Dillman, CTS-D, CTS-I; Richard G. Derbyshire, CTS-D, CTS-I; Suzanne Hommertzheim, RCDD/NTS Specialist; Kristen R. Kuipers, CTS; David Labuskes, RCDD/NTS/OSP Specialist, CSI; Brent Lehmkuhl, PE, RCDD; David M. Prince; Paul Remke, PE, RCDD; Jim Sinopoli, PE, RCDD; Tony M. Warner, CTS-D, CSI CDT; Jim Yorgey, PE.
BICSI/InfoComm staff attending: Patricia Boyland, CAE (BICSI), Amanda Collett, CTS (InfoComm), Clarke W. Hammersley (BICSI), Joan Hersh (BICSI), Tom Kehr, CTS-D (InfoComm), Nermina Miller (BICSI contractor), Ron Shaver, RCDD/NTS/OSP/WD Specialist (BICSI), and Melissa Taggart (InfoComm).

Acknowledgments, continued

The following BICSI Professional Development and Credentialing staff members produced this manual at BICSI World Headquarters, Tampa, FL. in cooperation with InfoComm International:

BICSI Director of Professional Development and Credentialing:	Patricia Boyland, CAE
BICSI Manager of Knowledge Architecture:	Ron Shaver, RCDD/NTS/OSP/WD Specialist, Master Instructor
BICSI *AVDRM* Project Manager/Lead Technical Editor:	Nermina Miller (under contract)
BICSI *AVDRM* Senior Technical Editor:	Clarke W. Hammersley
***AVDRM* Technical Editors:**	Joan Hersh, Karen Jacob
Design and Production:	Danielle E. Fernandez, Senior Publications Design Facilitator John Ditzel, Publications Design Facilitator Nermina Miller (under contract)
Index:	Nermina Miller (under contract)

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8610 Hidden River Parkway
Tampa, FL 33637-1000 USA
Tel.: 800.242.7405 (USA/Canada toll-free)
Tel.: +1 813.979.1991
Fax: +1 813.971.4311
E-mail: bicsi@bicsi.org
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Figure 1.1
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Chapter 1
Introduction

This chapter describes the audiovisual (AV) industry, which has a rich and eventful history. Having a proper understanding of its evolution provides the AV designer with an important foundation on which to build strong design skills.

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Overview

History of Audiovisual (AV) Industry

Looking Back on the Industry

The audiovisual (AV) industry has come a long way. Not long ago, it was known primarily as the source for overhead projectors, projection screens, and basic audio equipment. Today, the AV industry consists of designing and installing sophisticated multimedia and integrated systems built into a building's environment, as well as creating live events for sports, entertainment, and corporate presentations.

In response to a rapidly changing world of technology, the Cleveland School System hosted a conference in 1937 to help the schools identify, understand, and organize their visual classroom materials. At this meeting, the idea for a national AV organization was formed and the National Association of Visual Education Dealers (NAVED) became a reality.

With the advent of World War II, the US government trained millions of men and women for war with the help of NAVED, using hardware and software in the form of slides, projectors, and transparencies to accomplish this task.

The AV industry also made a smooth transition from the war service to the education demands of the postwar years. NAVED, revitalized with the energy and experience of post-military personnel, reemerged stronger than ever. Three years after the war, NAVED and the Non-Theatrical Film Association merged to form the National Audio-Visual Association (NAVA).

NAVA had one primary goal—to encourage increased government funding of education. This was accomplished with the passing of the *National Defense Education Act* in 1958. Billions of dollars went into America's public schools to improve educational opportunities for all citizens.

This level of funding continued through the John F. Kennedy and Lyndon B. Johnson administrations, resulting in increasingly sophisticated methods of education for the public. The demand for more information drove the development of technological advancements.

Those first decades of rapid AV development are comparable to the amazing pace of technological shifts in the last 30 years. The 1970s saw the increased use of photography, the power of movie special effects, and the advent of computers in the business world.

The 1980s wrestled with a change of focus. While still used extensively for education, AV technology expanded beyond that arena to multiple markets. It marked the introduction of computers, digital audio and video processing and effects, new videotape formats, satellite distribution, satellite news gathering, optical fiber, and high definition television (HDTV). This period of feverish development delivered products that cost less and maintained performance. For example, improvements in computer microprocessor technology saw dramatic results in the features and performance of new systems. Consequently, equipment costs dropped and demand increased.

History of Audiovisual (AV) Industry, continued

Also during the 1980s, interest in environmental concerns increased, both in the area of resource protection and the impact of the environment on learning and communication. Acoustics, lighting, and other building infrastructure have always been important in spaces where AV communications occur. With the advent of new technologies, the room environment and the physical infrastructure became even more important to AV design and integration.

In recognition of the global scope of these emerging technologies and the industry behind them, NAVA changed its name to the International Communications Industry Association (ICIA [now InfoComm International®]). The AV industry had become a world player.

With the 1990s came new display technologies, advanced microcomputers, and the Internet, with new media and business models that have produced the most profound changes since moving pictures. The presentation market has boomed. Liquid crystal display (LCD) and digital light processing (DLP) electronic projectors have become commonplace in corporate environments, higher education facilities, and other presentation venues. The installation market has become more systems-oriented, with sophisticated controls, network connections, videoconferencing, and interactive technologies. Audio has become increasingly important, driven by consumers' demand for compact disc (CD) quality sound in all application environments from classrooms to boardrooms.

Today, the industry remains committed to innovative technological enhancements, professional support services, and the appropriate integration of systems to ensure that end users have the quality they need. Looking back, the AV industry has developed and delivered the basics. Today, an improvement in the quality of the presentation is paramount.

Defining Audiovisual (AV) Industry

Stated simply, the AV industry is dedicated to producing efficiently functioning AV systems that enhance communications throughout an organization or venue. It involves the technologies, products, and systems for:

- Visual display.
- Audio reproduction.
- Video and audio recording, production and post-production AV signal control, distribution, and transmission.
- Lighting.
- Control systems.
- Interactive display and audio presentation systems.
- Collaborative conferencing (video, audio, data, and Web conferencing).
- Streaming media.
- Furniture and lecterns.
- Cabling, connectors, racks, cases, and accessories.

This industry interfaces with the information technology (IT) and information transport systems (ITS) industries to create and transport the information presented to the intended audience.

Essence of Audiovisual (AV) Design and Integration

Fundamentally, AV design and integration combines four basic but essential elements:

- The hardware or the physical electronics connected together.
- The software or programs loaded into the electronics to perform various AV tasks.
- The environment or the space and infrastructure within which the hardware and software work.
- The content, which includes video, audio, and data material created and presented using the available software and hardware.

Each of these elements has specific and unique requirements that must be addressed during project design and implementation and their ultimate interactions produce the desired solutions. Critical to successful project integration is the careful monitoring and balancing of the systems hardware, software, and environments (or infrastructure) with the nature of presentation of the content in mind. Proper integration ensures that the human aspects of AV, or the ability to clearly see and hear the presentation, are fully and successfully solved.

Segments within Audiovisual (AV) Industry

The AV industry may be viewed simply on the basis of the outlets for the actual equipment. More specifically, differentiations are based less on products and more on the relationship that evolves from the services offered, the people involved, the procurement method used, and the desired applications.

The industry serves and sustains relationships with three primary markets:

- Consumer/retail AV systems
- Residential AV systems
- Professional AV systems

Rental and staging could arguably be included as a separate category. These two processes include installation and event management of temporary setups for special or ongoing events. However, for the purposes of the professional AV system integration discussion, the two processes are mentioned but not fully explored.

Consumer/Retail Audiovisual (AV) Systems

Consumer AV primarily consists of personal electronics applications, such as digital versatile disc (DVD) players, cameras and camcorders, boom boxes, home stereos, large screen TVs, and home audio and video devices.

Consumer AV is almost always a direct relationship between the consumer and the manufacturer, with direct store or online retail as the most common procurement method.

In this industry segment, AV devices are purchased as components or prepackaged systems by the end user from a retail establishment or online outlet and personally installed in a home or office.

Segments within Audiovisual (AV) Industry, continued

Residential Audiovisual (AV) Systems

The residential market falls into the home theater or whole-house automation category. It usually involves a professional or company serving the residential electronics market. Residential sales represent a consumer relationship that most frequently goes beyond the retail establishment to a residential AV dealer that provides and installs the equipment.

Home theater is targeted almost exclusively to higher-end residential installations, although there may be some overlap in small commercial applications. On small-scale projects, the procurement is the same as consumer AV. On larger scale residential AV projects, the procurement comes as a complete system through a home theater/home automation specialist.

Professional Audiovisual (AV) Systems

Professional AV involves numerous specialists but is almost always systems-focused. While box sales (a term used to define professional AV equipment sold without dealer installation) are a large part of this industry, boxes are generally part of a larger, more sophisticated system.

This industry segment includes commercial-grade equipment with some consumer or prosumer gear (equipment intended for use in both the general consumer market and professional situations).

Professional AV applications can be found in commercial, government, education, religious, and transportation facilities and include installations in arenas, stadiums, performing arts spaces, classrooms, auditoria, boardrooms, command-and-control centers, courtrooms, museums, training rooms, multimedia presentation rooms, call centers, and many other venues.

NOTE: For detailed information on different venues, see Chapter 18: Venues.

Other than high-volume end user organizations that have direct sales arrangements, procurement of professional AV systems is generally made through a dealer/integrator. Because professional AV involves systems, it often requires the design skills of an AV design professional and the installation skills of a systems integrator to advance beyond the box connection to system requirements and installation.

Professional Audiovisual (AV) Systems Integration

By definition, professional AV integration is the process whereby professional AV systems and equipment are designed, purchased, and installed within a building project. Typical tasks include:

- Project needs analysis work.
- System design and engineering.
- Equipment specification and acquisition.
- Cabling and equipment installation.
- Interface and controls programming.
- Testing, training, and technical support.

Because the overall project success depends on the physical environment in which the system is installed, the greater integration process includes coordination with building architecture, interior design, acoustics, lighting, structural, mechanical, and electrical systems, during both the design and the construction phases.

Other low-voltage industries are peripherally related to professional AV systems, with systems that may involve AV elements. These systems include, among others:

- Security systems.
- Nurse call systems.
- Life safety systems.
- Fire alarm systems.
- Sound masking systems.
- Computer systems.
- Telecommunications systems (commonly referred to as data/telecom).

Companies that provide professional AV services also design and install these systems. However, professional AV and other low voltage industries differ; each is a discipline unto itself.

Professional AV dealers, including systems integrators and installers, are responsible for close to 70 percent of the service component of the AV market size.

Participation in Professional Organizations Related to Audiovisual (AV) Designers

Audiovisual (AV) Industry Certification

Many individuals enter the AV industry from other fields. Often, individuals with careers in music, art, theater, telecommunications, engineering, or IT become interested and involved in the AV industry. A professional education and certification program allows these individuals to learn the technical aspects of the business and to demonstrate their AV technical proficiency to colleagues and clients.

With the unique requirements of designing, installing, and operating AV systems, AV professionals require special training. InfoComm International, Inc.® offers a wide variety of education options. The training covers numerous disciplines and topics, including AV design, installation, networking, audio, video, conferencing, and other subjects.

In 1981, InfoComm recognized the need for a strong certification program that would validate the credentials of its professionals, and established the Certified Technology Specialist (CTS) program.

The CTS credential is intended for AV professionals who have demonstrated knowledge and comprehension of the science and technology used in communications including audio, video, display and systems.

The CTS-D credential is a specialized certification for AV systems design professionals. A CTS-D is an individual who has earned this specialized certification by demonstrating detailed knowledge of analyzing, selecting, and planning seamless AV communications equipment interoperation.

The CTS-I credential is the specialized certification for AV installation professionals. A CTS-I is an individual who has earned this specialized certification by demonstrating skills and knowledge through a rigorous regimen of testing in a broad array of installation practices and techniques. A CTS-I is proficient in installing all components of a professional AV system.

The Certified Audiovisual Solutions Provider (CAVSP) credential is a company certification awarded to organizations who have demonstrated their commitment to professional excellence by supporting their employees who achieve and maintain individual InfoComm certification credentials.

CAVSP companies also have agreed to comply with 10 Standards of Excellence developed in collaboration with industry experts to emphasize the best practices of AV businesses. The Standards of Excellence are a guidepost for AV companies and professionals who place the customer first and offer quality AV solutions. These standards convey the importance that AV solutions providers place on their own skills development through continuing education. They also cover the critical role that AV professionals play as partners with IT specialists, architects, telecommunications designers and installers, building managers, and professionals in other building trades.

Participation in Professional Organizations Related to Audiovisual (AV) Designers, continued

Nationally Recognized Certification

In 2005, InfoComm became the only AV association to receive national registration for its certification program. Awarded by the National Certification Commission, this recognition was given after a review process considering 20 criteria and guidelines for effective administration and presentation of certification programs. Examples of these criteria include:

- Adequacy of the program to recognize the career in an assessment of education and experience.
- Process availability and objectivity.
- Appropriateness of the designation title.
- Number of approved participants.
- Staff resources and functions.
- Advisory committee composition, qualifications, and responsibilities.
- Applicability of components, requirements, and the evaluation.

Other Credentials

Other credentials may be encountered in professional AV and related fields, including BICSI® Registered Communications Distribution Designer (RCDD®), Professional Engineer (PE), and International Organization for Standardization (ISO) 9001 certification.

The PE license is primarily used for mechanical, civil, electrical, structural, plumbing, and other essential building industry trades with life safety concerns. AV companies sometimes employ PEs in mechanical, electrical, and acoustical engineering, which may not be AV-specific. PE licensure allows companies to use the term engineer in their company names and to be listed in various engineering resources.

BICSI's RCDD designation is intended for data network and communications professionals, an essential component of AV work. Those awarded with the RCDD designation have demonstrated their knowledge in the design, implementation, and integration of telecommunications and related infrastructure in the ITS industry.

BICSI telecommunications distribution design courses serve as a career path for those seeking advanced knowledge in this area. The RCDD status conveys a(n):

- Professional designation of excellence.
- Highly regarded status recognized and mandated by many private and state organizations.
- Noted mark of design knowledge valued internationally.
- Indication of experience and knowledge known throughout the ITS industry.

The ISO 9001 certification is quality assurance credential. While not AV-specific, it is a recognized certification that acknowledges attention to management and quality control performance within a company.

References

Cape, Timothy W. and Jim Smith. 2005. *Audiovisual Best Practices: The Design and Integration Process for the AV and Construction Industries*. Fairfax, VA: InfoComm.



Chapter 2
Foundations

Many of the concepts and formulas discussed in detail throughout this manual assume a good working knowledge of certain mathematical and scientific principles. This chapter seeks to provide the audiovisual (AV) designer with an overview of the most common principles.

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Overview

The audiovisual (AV) field is grounded in mathematical, scientific, and physiological principles. It is assumed that the reader of this manual has a working knowledge of many of the topics and most common of these principles.

The foundations discussed in this chapter have been divided into three main categories:

- Mathematical and scientific fundamentals
- Properties of sound and light
- Sensory communication

Mathematical and Scientific Fundamentals

Introduction

Much of the audiovisual theory and practices discussed in this section is rooted in a variety of mathematical and scientific properties. Like most forms of science, the student of AV technology may encounter anything from basic arithmetic to advanced calculus. This section focuses on the principles most commonly found in the commercial AV industry.

Ohm's Law

Current, voltage, and resistance/impedance are related. The current in an electrical circuit is proportional to the applied voltage. An increase in voltage yields an increase in current if resistance remains constant.

Current

Current is defined as the movement of electrons through a conductor. The flow of current through a cable is affected by the conductor material (e.g., copper, aluminum, or other), type (solid or stranded), gauge or diameter, and length or distance. Current can be measured using an ammeter and calculated using the following formula:

$$I = V/R$$

Where

I = Current in amperes (A)

V = Voltage in volts (V)

R = Resistance in ohms

Ohm's Law, continued

Voltage

Voltage is defined as electrical pressure, a force that causes current to flow through a conductor. As the impedance increases with distance increase, and the current remains unchanged, a drop in voltage or loss in electrical pressure occurs. Voltage can be measured using a voltmeter and calculated using the following formula:

$$V = I \times R$$

Where

V = Voltage (V)

I = Current (A)

R = Resistance

Because current and resistance are inversely proportional, an increase in resistance produces a decrease in current if voltage remains constant.

A helpful analogy of the relationship between current and resistance in direct current (dc) is the operation of a sink with a water stopper. The water pressure in the sink basin is like voltage. It has the potential to flow down the drain. Likewise, voltage has the potential to become power. Once the stopper is removed, the amount of water that flows through the drainpipe is like current. The pipe's size represents resistance. A wider pipe would drain more water than a narrower pipe in the same amount of time.

Resistance / Impedance

Resistance is the ability of a conductor to oppose the flow of electricity through it. Resistance is expressed in ohms. One ohm of resistance allows 1 A of current to flow when 1 V of electricity is applied. This is stated mathematically in Ohm's law, as:

$$R = V/I$$

In alternating current (ac) flow, the total opposition to that flow is called impedance (Z). This is the combined effects of resistance (R), inductance (L), and capacitance (C) of the circuit. Inductance and capacitance are collectively known as reactance (X). This can be expressed using the following formula:

$$V = I \times R$$

$$Z = \sqrt{R^2 + (X_l - X_c)^2}$$

$$X_c = 1 \big/ 2\pi f C$$

$$X_l = 2\pi f L$$

Ohm's Law, continued

In practice, resistance is mostly associated with dc circuits such as dc power circuits. Impedance is associated with alternating current (ac) systems such as audio and video circuits. For example, cables have a resistance that is purely the result of the conductor's length, size, and composition. Cables, however, also have capacitance and inductance that result from the cable's construction (e.g., shielding, insulation, and conductor proximity). These elements vary with frequency and contribute to the overall impedance of the cable, which is beyond its pure resistance.

In active electronics, impedance plays an important role in how devices are interconnected.

Logarithms

A logarithm is the opposite of an exponent. The logarithm $\log_x y$ for a base x and a number y is the inverse function of x^y. Logarithm base 10 for a number x is expressed as $\log x$. For example, log 10 000 is 4 and log 0.0001 is –4. Therefore, the range from log 0.0001 to log 10 000 may be expressed as –4 to +4.

Logarithms make ratio values easier to understand. For example, the ratio between the threshold of hearing and the threshold of pain is 1 to 1 000 000. The formula for the relationship of painful to just audible sound in decibels of sound pressure level (dB SPL) is:

$$\text{dB SPL} = 20 \log (1\,000\,000/1) = 20 (6) = 120 \text{ dB SPL}$$

Decibels

A measure of analog signal strength is a bel, named after telephone pioneer Alexander Graham Bell. The term is inappropriately large for AV work, so dB (one tenth of a bel) is used. It is not an absolute value but a ratio of two signals and may be used to compare power, current, or voltage.

Amplifier gain and circuit attenuation are typically stated as decibel (dB) gain or dB loss. For example, an amplifier may have a power gain of 10 dB, or a connector in a cabling system may have a loss of 0.3 dB. Decibels express a ratio of two values, but the ratio is not linear.

The dB is a logarithmic function (as opposed to linear) that allows large variations to be shown in very small increments. As a base reference, the human ear can typically sense a 1 dB change in sound pressure level.

A loudness measurement might have to be compared to what human ears perceive as silence. In this instance, silence is 0 dB SPL. This is known as a zero reference. Any sound can be compared to silence. A conversation is louder than silence, and therefore has a positive dB measurement (+dB).

A doubling or halving of the power results in an increase or decrease of 3 dB. A doubling or halving of the voltage results in an increase or decrease of 6 dB.

Decibels, continued

Increases or decreases of 10 dB for power, and 20 dB for voltage or current, will cause an increase or decrease of 10 times the original value. This moves the decimal point one place forward or backward. For example, if the input power is equal to 1 W, a decrease of 10 dB will have a value of 0.1 W; however, an increase of 10 dB will have an output of 10 W.

The formula for computing dB for power is:

$$dB = 10 \log (P1/P2)$$

Where

P1 = Device output power

P2 = Input power

Different dB calculations may be used depending on what is being measured. When measuring sound pressure level, we use dB SPL. When measuring an audio system's power, we use decibels referenced to 1 milliwatt (mW) across an impedance of 600 ohm (dBm).

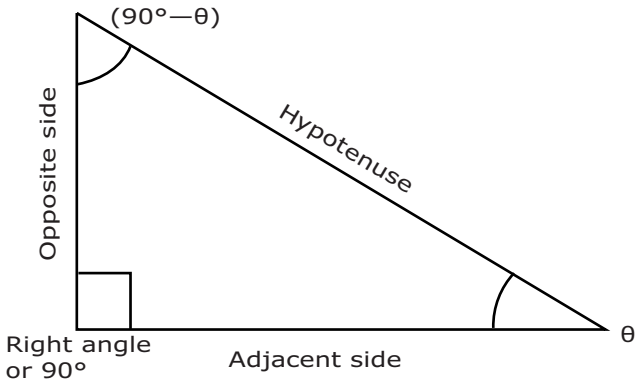
Trigonometry

The term trigonometry is a Greek compound that stands for triangle measuring. Trigonometry deals with the mathematical properties of the right triangle (see Figure 2.1). It specifically relates to the lengths of the sides and the angles of the triangle. One of the angles in the right triangle is equal to 90 degrees. A total of 180 degrees form the angles in any triangle. Thus, the remaining two acute angles in the right triangle must add up to 90 degrees.

The trigonometric relationship exists between the angles and the sides of the right triangle. This relationship consists of three basic functions: sine (sin), cosine (cos), and tangent (tan). The three functions respectively refer to the two sides opposite and adjacent to an acute angle and the hypotenuse, which is opposite the right angle. The hypotenuse side is always the longest side.

Trigonometry, continued

Figure 2.1
Right triangle



The functions are usually represented by the Greek letters theta (θ) or phi (φ). As long as one side and one angle are known, the other sides and angles can be determined using the following equations:

$\sin \theta = \text{opposite/hypotenuse} = O/H$

$\cos \theta = \text{adjacent/hypotenuse} = A/H$

$\tan \theta = \text{opposite/adjacent} = O/A$

Inverse Square Law

As a wave travels farther away from its source, the intensity of the wave dissipates over distance. That dissipation is logarithmically related to the change in distance quantified by the inverse square law. The inverse square law states that the measured energy emitted from a point source decreases to a quarter of its level for each doubling of distance from the source.

Both sound and light decrease in level according to the inverse square law when moving away from a point source in free space.

For example, in audio, this means that moving from the distance of 3 meters (m [10 feet (ft)]) from a loudspeaker to the distance of 6 m (20 ft) from a loudspeaker the sound pressure would drop by 6 dB.

For light, doubling the distance reduces the light level to a quarter of its level.

Properties of Sound and Light

Sound

Sound is a physical occurrence involving the movement of molecules. As an object vibrates, it moves the molecules around it closer together and, an instant later, it moves them further apart.

The action of molecules pressing closer together is called compression. The action of the molecules moving apart is rarefaction. The changes in pressure among these molecules create invisible sound waves.

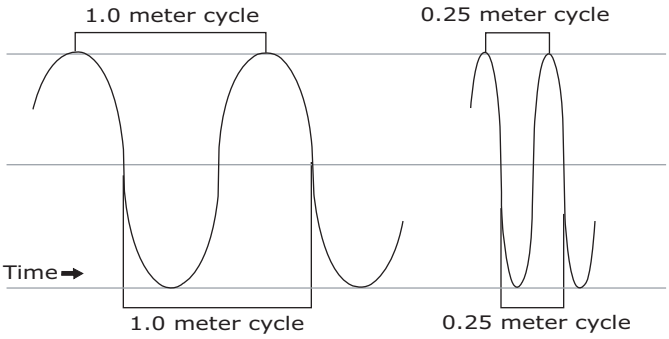
When a pebble is thrown into a pond, an expanding, rippling wave travels away from the impact point and the water level slightly rises and falls along the wave's path. Similarly, sound travels by an expanding, rippling wave causing slight variations in pressure.

Wavelength

Through the use of measurement equipment, sound waves can be depicted graphically. When the waveform is above the midline, vibrating molecules are compressing. When the waveform is below the midline, the molecules are rarefying.

Wavelength is the distance in between two corresponding points of two consecutive cycles (see Figure 2.2). Some sound wavelengths are several meters (m) while others are a few millimeters (mm) long.

Figure 2.2
Measuring wavelength



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Sound, continued

Amplitude

Amplitude is the magnitude of a signal. When represented as a wave, it represents the intensity of the wave or the distance of the wave's displacement from the midline. Figures 2.3 and 2.4 show amplitude and frequency relationships of sound waves.

Figure 2.3
Different amplitudes of equal frequency sine waves

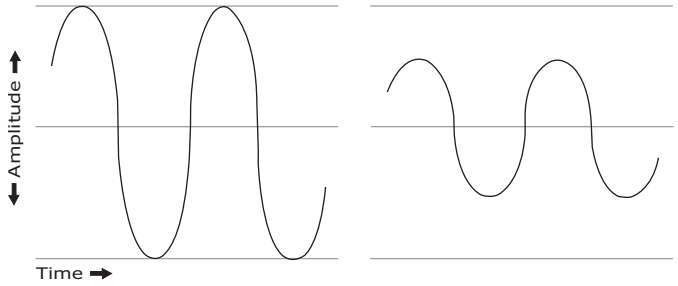
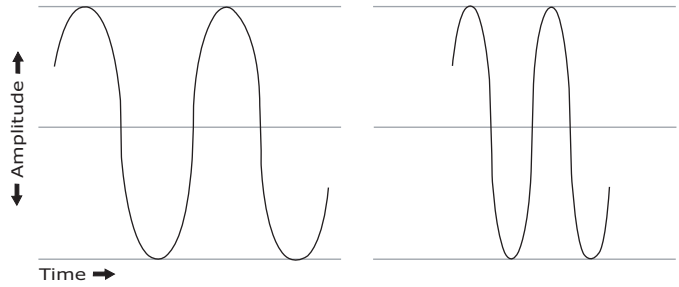


Figure 2.4
Equal amplitudes of different frequency sine waves



Sound, continued

The human ear perceives amplitude of a sound as loudness or volume. The greater the amplitude of a sound wave, the louder the sound. However, a higher frequency sound with the same amplitude as a lower frequency sound may sometimes be perceived as louder. Loudness is measured in dB SPL. The dynamic range of hearing for humans is from the threshold of hearing to the threshold of pain or 0–120 dB SPL. Table 2.1 shows levels of sound pressure reference.

Table 2.1
Sound pressure level chart

Unit	Type	Reference	Use	Note
dB PWL	Sound power	10^{-12} W	Acoustics	
dB SPL	Pressure	0.0002 µb (in air)	Sound	
dB SPL	Pressure	0.0002 dyn/cm^2	Sound	
dB SPL	Pressure	Threshold of hearing in young, undamaged ear, 1–4 kHz	Sound	
dBA (dB SPL, A weighted)	Pressure	0.0002 µb (in air)	Low sound pressure measurements	Filter: –30 dB at 50 Hz response curve
dBB(dB SPL, B weighted)	Pressure	0.0002 µb (in air)	Medium sound pressure measurements	Filter: –12 dB at 50 Hz response curve
dBC (dB SPL, C weighted)	Pressure	0.0002 µb (in air)	High sound pressure measurements	Filter: relatively flat response curve

dB = Decibel
dyn/cm^2 = Dynes per square centimeter
kHz = Kilohertz
µb = Microbar
PWL = Power watt level
SPL = Sound pressure level
W = Watt

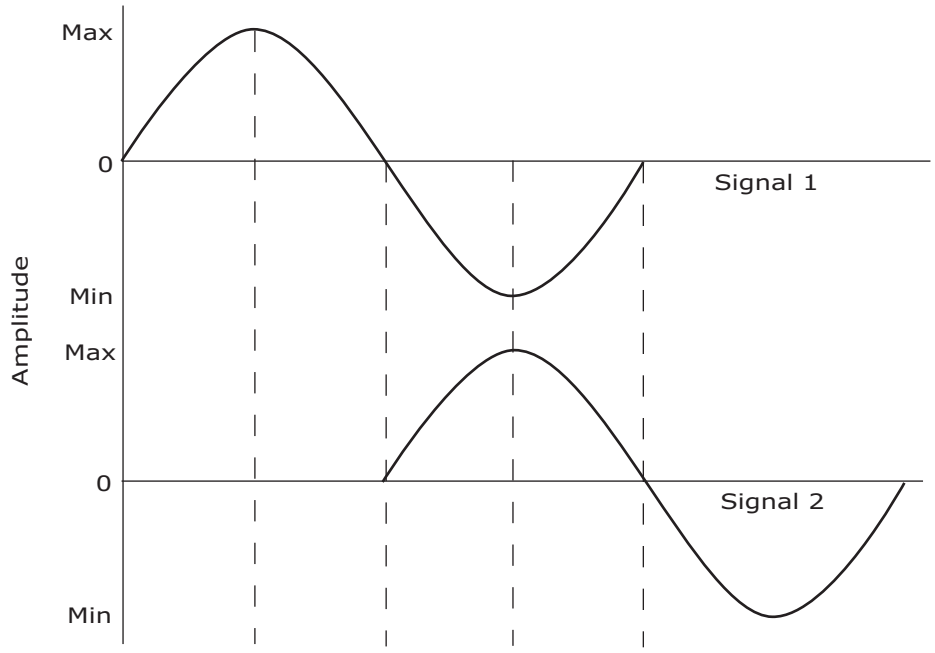
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Sound, continued

Phase

The phase of a signal is a term used to express a waveform's position in time compared to another waveform. It is expressed in degrees, with 360 degrees representing one complete cycle of the wavelength. If a signal is said to be 180 degrees out of phase with another signal, it means that one wave is at its maximum pressure point and the other is at its minimum pressure point (see Figure 2.5).

Figure 2.5
Two waves offset by 180 degrees



Max = Maximum
Min = Minimum

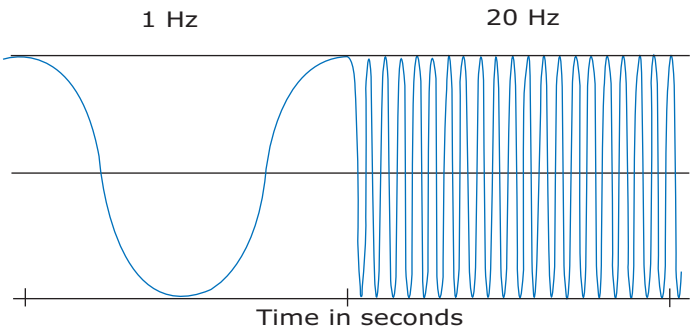
Phase represents itself in a variety of ways. In some instances, it can be beneficial, while in others it can be detrimental. A problem may occur when a sound is picked up by two close microphones at slightly different times and summed together on an audio mixer. The difference in the time of arrival at the microphones generates two signals with misaligned phases. When the signals are summed, they create unwanted frequency variations that are uncharacteristic of the original sound source. This phenomenon is referred to as comb filtering because it creates sharp peaks and dips in the waveform of the signal similar to the teeth of a comb.

Sound, continued

Frequency

Frequency is the number of cycles in a given time period (see Figure 2.6). Most often, frequency is measured in hertz (Hz) or cycles per second.

Figure 2.6
Frequency



Hz = Hertz

As wavelength increases, the frequency decreases. If a lot of little waves were hitting the beach quickly, they could be described as having short wavelength and high frequency. If only a few big waves were hitting the beach slowly, they would have long wavelength and lower frequency.

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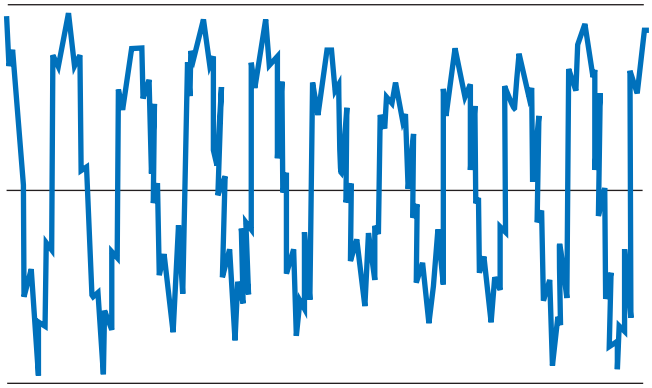
Sound, continued

Harmonics

Most sounds are far more complex than simple waves with even oscillations and amplitude. Simple single waves are typically generated by electronic devices that produce single frequencies and are heard as a pure tone or note.

A single sine wave is called a fundamental waveform, or fundamental. However, speech and music are a complex mixture of many different sound waves. A complex waveform (see Figure 2.7) is a combination of different frequencies and amplitudes and determines the sound quality.

Figure 2.7
Complex waveform

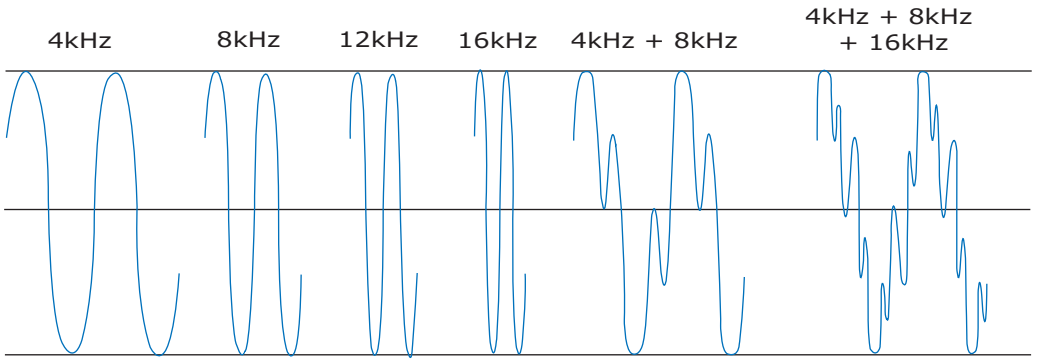


These complex waves are made up of harmonics, which are higher frequency waves blended with fundamental waveforms. For example, a piano can produce fundamental frequencies of up to 4 kHz. The vibrating part of the piano creates sound waves that are multiples of fundamental notes. These are harmonics. Harmonics create the distinctive sounds we recognize as a particular instrument or a particular person's voice.

Sound, continued

Figure 2.8 shows four fundamental frequencies, 4 kHz, 8 kHz, 12 kHz, and 16 kHz. Combining the first two fundamental frequencies creates a complex waveform. Combining three or four fundamental frequencies creates a more complex waveform.

Figure 2.8
Building complex waveforms



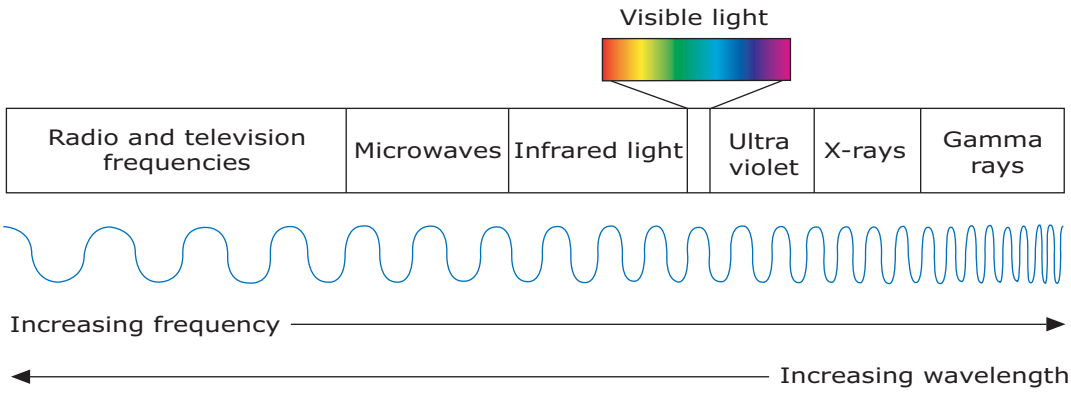
kHz = Kilohertz

Light

Two primary theories discuss the nature of light. One states that light, like sound, is made of waves of energy. Another states that light is made of small particles called photons.

Many kinds of light waves exist. These waves of energy are categorized by their wavelength. Figure 2.9 shows the range of the electromagnetic spectrum categorized by wavelength.

Figure 2.9
Electromagnetic spectrum



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Light, continued

Only a small section of the electromagnetic spectrum is visible to the human eye. This is referred to as the visible color spectrum.

Wavelength, Frequency, and Amplitude of Light

As mentioned previously with regard to sound, wavelength is the distance between two corresponding points of two consecutive cycles. In connection with light, that distance is typically measured in nanometers (nm). A nanometer is equal to one billionth of a meter (10^{-9} m).

On the edge of the electromagnetic spectrum are gamma rays with the shortest wavelengths of 10^{-6} nm. On the opposite edge are TV and radio signals with long wavelengths of 10^{8} nm.

A light wave's color is determined by the frequency. Gamma rays have the frequency of 10^{18} Hz, while radio waves have the frequency of 10^{4} Hz. Green is at the center of this spectrum. Blue light waves have a higher frequency and are difficult to see. Red light waves have a lower frequency. Visible light with the frequency of about 10^{14} Hz allows the human eye to receive about four hundred trillion light waves every second.

The amplitude of a light wave is perceived by the human eye as brightness. The greater the light wave's amplitude, the larger the wave's displacement from the midline and the light's brightness.

Measuring Light

The first quantification of visible light involved a specifically sized candle. The amount of light emitted from such a candle became the first and most fundamental unit of brightness, called 1 candlepower.

By looking at a lighted candle at the center of a darkened room, the early scientists observed that:

- The light energy radiated equally in all directions, creating a sphere of light around the flame.
- The farther they moved from the flame at the center of the light sphere, the more light energy was spread out and the less light the flame appeared to shed.

Color Temperature

While all light sources may appear to emit white light, they have different distributions of color, so each white has a different tint. Some are actually reddish white while others may be bluish white. This difference in whites is referred to as a light source's color temperature.

Color temperature is a scientific measurement for the distribution of the colors radiating from a light source, expressed on the Kelvin scale.

Light, continued

The Kelvin scale is based on the color of light emitted when a substance is heated. A substance at rest at the room temperature does not emit light. As it is heated, it emits light, beginning at red. As the substance becomes hotter, the color it emits becomes bluer. When the equal energy point is reached, it emits white light. This equal energy point, however, has several established references. These points of equal energy are the color temperatures of 3200 K, 5400 K, 6500 K, and 9300 K—all of which will look white to the eye (see Table 2.2).

Table 2.2
Color temperature ranges

Temperature in K	Use
1900 K	Candlelight
2200 K	High-pressure sodium lamp
3200–3400 K	Tungsten lamp
4200 K	Cool white fluorescent bulb
5400 K	Daylight
5500 K	Noon direct daylight, cloudless sky
6500 K	SMPTE reference white

K = Kelvin
SMPTE = Society of Motion Picture and Television Engineers

The higher the color temperature, the bluer the light. The lower the color temperature, the redder the light.

Light Wave Behaviors

Light speed changes depending on the material or medium it passes through. The behavior of light changes when the light speed changes

Refraction

Light entering one medium from another will bend due to velocity change. Refraction is the bending or changing of the direction of a light ray as it passes through material (e.g., water or glass). The extent of light refraction or the size of the angle of refraction represents the refractive index.

Dispersion

White light is made up of many frequencies and wavelengths. Frequency and wavelength are directly related to a color of light. The refractive index varies for each of the different wavelengths of light. This difference produces an effect called dispersion.

Dispersion can be seen when a white light beam passes through a triangular prism. The different wavelengths of light refract at different angles, dispersing the light into its individual components.

Light, continued

Reflection

Materials with a mirrored or glossy surface reflect light, changing its direction. The direction of the reflected light can be predicted by the angle at which the original or incident light hits the reflective surface.

Scattering

When light hits a textured surface, the incoming light waves are reflected in multiple angles because the surface is uneven.

Felt provides a good example of scattered light. When light hits felt, the waves are reflected in all directions. Looking at the light-scattering surfaces is more comfortable to the human eye than looking at other surfaces.

Absorption

To darken a room, dark materials should be used. Light is absorbed by the colors close to black in value. Many outdoor athletes spread black streaks under their eyes because they absorb sunlight, reducing its effect on the eyes.

Sensory Communication

Aural Perception

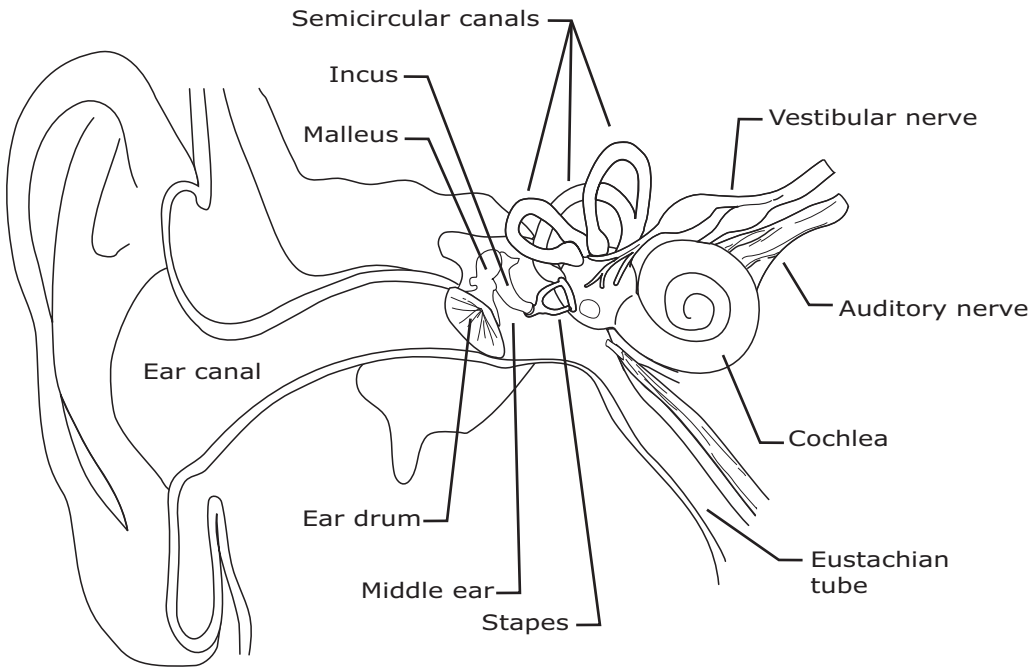
Physiology and Operation of the Ear

The human ear consists of three parts that are critical for sound perception. The area from the eardrum to the external parts of the ear is called the outer ear. The area behind the eardrum, which contains three small bones, is called the middle ear. The inner ear includes a spiral organ filled with fluid, called the cochlea (see Figure 2.10).

The human ear perceives sound in the following way:

- The pressure variations from the sound wave cause the eardrum to vibrate.
- The vibration of the eardrum moves the three middle ear bones, which form a system of levers.
- As the levers move, they strike the cochlea, creating waves in the inner ear fluid.

Figure 2.10
Parts of human ear



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Aural Perception, continued

Specialized cells within the cochlea then convert the vibration of the fluid to electrical signals, a process called transduction. Cells in the cochlea respond to the differences in sound pitch. These electrical signals are then transmitted to the brain by the auditory nerve.

A normally functioning ear is sensitive to very small changes in air pressure. It has the ability to respond to a wide dynamic range of pressures, a wide range of differences in pitch or frequencies of sound, and has the ability to resolve separate frequency variations that are similar in pitch.

The size, shape, and mechanics of the ear cause hearing perception to favor some frequencies over others. These characteristics are different from person to person and, therefore, the ability to hear different pressures and frequencies differs.

The two ears send the received information to the brain, which then localizes the position of the sound source by distinguishing the difference in intensity and the difference in time it takes to arrive at each ear.

The purpose of an audio system varies with application but, typically, audio systems perform the same function as the human ear: they convert vibrations in the air into electrical signals, amplify them, and then convert them back into vibrations. The same vibrations stimulate the eardrum, auditory nerves, and brain, allowing hearing to occur.

Psychoacoustics

While the ear acts as a transducer and receives airborne sound waves, it is the brain that interprets these waves and allows hearing to occur. The study of how the brain perceives sounds is called psychoacoustics.

Examples of psychoacoustic phenomenon are the human perception of:

- Pitch and tone.
- Delayed signals.
- Loudness.

Aural Perception, continued

Pitch and Tone

The eardrum, a very sensitive piece of skin separating the outer ear and the middle ear, responds to the precise formation of sound waves. High frequency sounds move the drum more rapidly.

The frequency of a sound wave determines the pitch or tone heard by the human ear. High frequency sounds have high pitch; low frequency sounds have low pitch. A child's ear is generally sensitive to frequencies from 20 Hz to 20 000 Hz. As people age, their ability to hear high frequencies diminishes.

A sound wave at a frequency of 1 kilohertz (kHz) is called a "1k tone." Because the sound wave is a steady frequency, it is considered a pure tone or a fundamental frequency and scientifically referred to as a sine wave.

Pitch is a very accurate definition of frequency, though it can be based on one of several intonation schemes. The two most common schemes are intonation and equal temperament. The scope of these definitions is beyond the purpose of this manual; however, at its base, pitch directly correlates to frequency when qualified by the reference.

Tone is the definition given to the overall sound of a particular note produced by an instrument or acoustic transducer. This includes the fundamental frequency of the note (the pure tone) as well as all of the harmonics produced. The sum of these elements can be defined as the tone of an instrument and explains why the same note produced on one instrument has a completely different tone than the same note produced on another instrument. The same can be said of two different loudspeakers producing the same fundamental frequency. While based on a fundamental frequency, tone is the sum of all frequencies produced as a result of the fundamental frequency.

Tone should not be confused with loudness or sound pressure. For example, a harder clapping of hands may produce a more forceful sound, but the tone remains the same.

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Aural Perception, continued

Acoustic and Electronic Delay

Listening to someone speak in a room under typical circumstances, the listener hears the speaker more than once. The listener first hears the sound directly from the speaker's mouth through the air over the line of sight (LoS), which constitutes the shortest path of the sound. The speaker's sound also bounces off of the walls, floor, and ceiling surface at least once before reaching the listener's ears. This path between the speaker and the listener is longer than the direct path and, therefore, called a delayed sound.

Because in most small-size rooms the path difference is relatively short, the listener does not hear the additional reflected sound as an echo. In fact, these early reflections enhance the listener's perception of the sound. The brain melds the sounds together to make them sound like a single sound source.

However, if the reflected path between the speaker and the listener is much longer than the direct path, the later sound is not melded into the direct sound, and the listener hears it as an echo separately from the direct sound.

This transition between helpful reflections and echo happens in the range of 50 to 70 milliseconds (ms) of delay. Distinct reflections that arrive less than 50 ms after the direct sound are merged together with the direct sound and heard as one. Distinct reflections arriving later than about 70 ms relative to the direct sound are heard as a distinct echo.

Delayed sound can be introduced both acoustically (in a large room, stadium, or outdoors) due to long reflection paths, but delay can also be introduced electronically by use of a sound system. Latencies introduced in processing, particularly with digital signal processing (DSP) devices, can be detrimental to both speech reinforcement and audio playback applications.

Aural Perception, continued

Loudness

Table 2.3 indicates the actual levels of some typical sounds along with their relative loudness.

NOTE: Sound pressure is not a measure of loudness, although certain ranges can be associated with a subjective degree of loudness.

Table 2.3
Sounds and sound pressure levels

Thresholds / Noise Sources	Sound Level (dB)	Subjective Evaluation
Jet takeoff	140	Deafening
Human threshold of pain	120	Deafening
Noisy motorcycle	100	Very loud
Pneumatic drill at 15.2 m (50 ft)	80	Loud
Conversation at 1 m (3 ft)	60	Moderate
Library, quiet home	40	Faint
Slight rustling of leaves	20	Very faint
Threshold of human hearing	0	Very faint

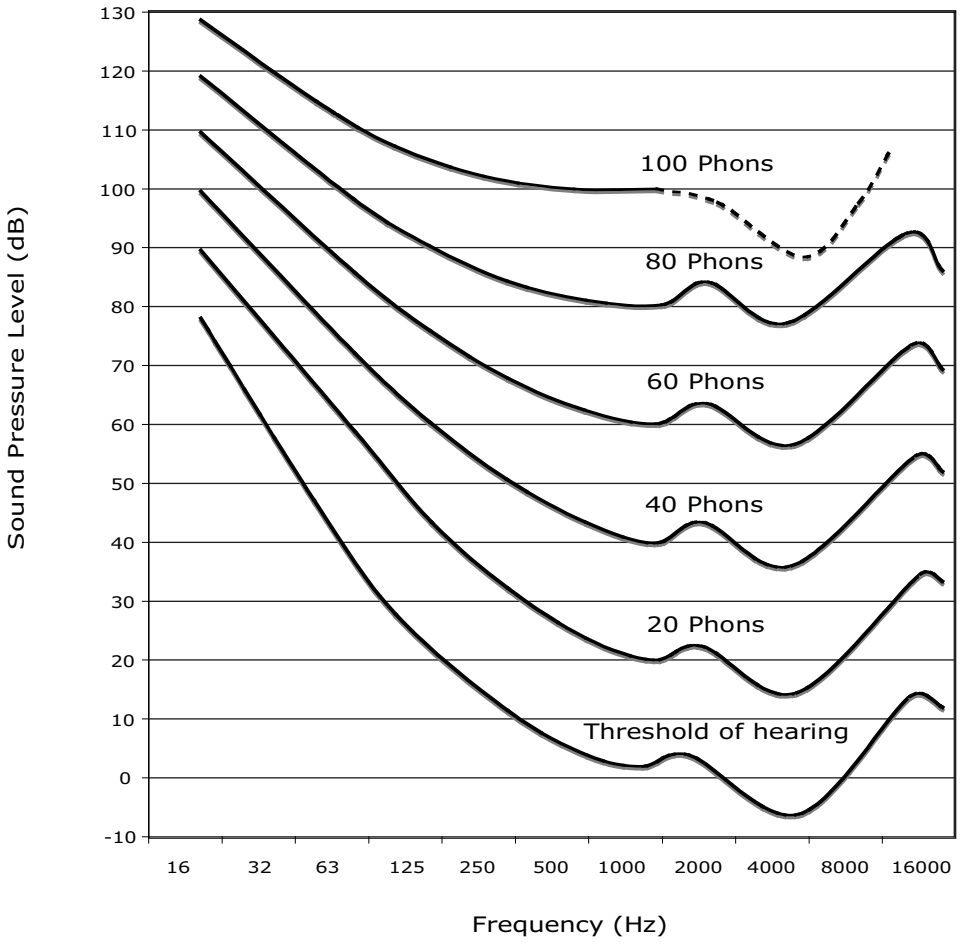
Perception of loudness varies with frequency. Humans are commonly more sensitive to sounds in the mid-frequencies and less sensitive to higher and lower frequencies. Harvey Fletcher and W. A. Munson conducted a study analyzing this phenomenon in the early 1930s. The study resulted in a set of equal loudness curves, which depict a set of sound pressure levels appearing to the human ear as the same loudness.

NOTE: These curves have since been recreated and revised by various research teams.

Aural Perception, continued

Ultimately, the International Standards Organization (ISO) standard 226, *Acoustics—Normal Equal-Loudness–Level Contours*, was developed and establishes standard equal loudness curves. These are illustrated in Figure 2.11. Each curve represents the dB SPL at each frequency that corresponds to a perceived equal loudness along that curve. The loudness associated with each curve is noted in phons (units of perceived loudness). The dashed line represents estimated data.

Figure 2.11
Equal loudness curves



dB = Decibels
Hz = Hertz

Aural Perception, continued

Another important aspect of hearing is how relative changes in the overall SPL correspond to perceived changes in loudness. Table 2.4 lists some of these relationships.

Table 2.4
Characteristics of loudness

dB Change	Example	Example Explained
Original sound	20 dB SPL	Whisper
± 1 dB	21 dB SPL	No perceivable difference
± 3 dB	23 dB SPL	Perceived slightly louder than whisper
± 6 dB	26 dB SPL	Moving closer to the listener and cutting the distance in half, the sound intensity increases 6 dB.
± 10 dB	30 dB SPL	Perceived twice as loud as whisper
± 20 dB	40 dB SPL	Perceived four times louder than whisper

dB = Decibel
SPL = Sound pressure level

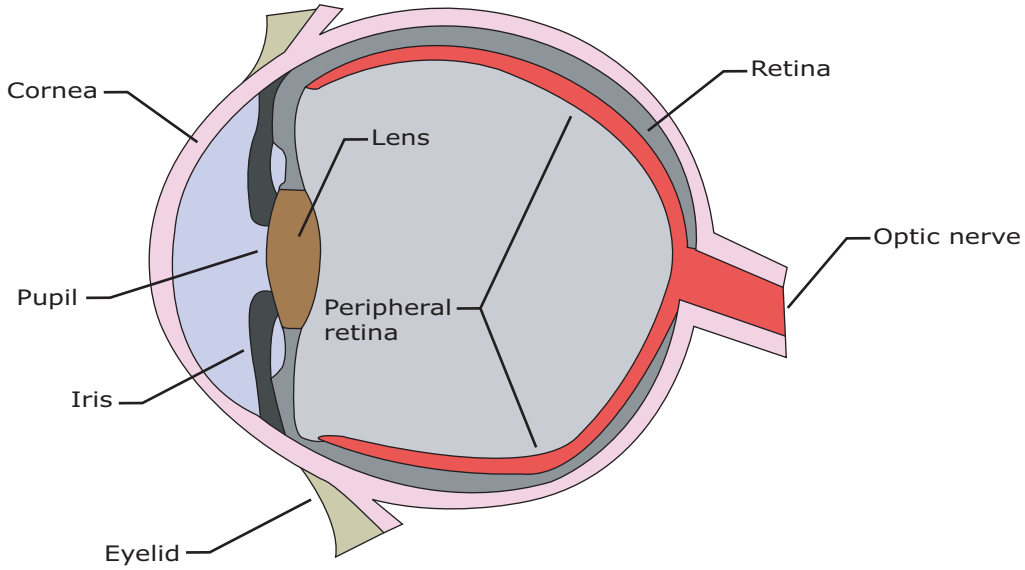
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Visual Perception

Physiology and Operation of the Eye

The eye is the human optical system (see Figure 2.12). The eye detects variations in light.

Figure 2.12
Parts of human eye



The light first passes through the cornea, a clear covering in front of the eye. Behind the cornea are the lens, the iris (the colored part of the eye), and the pupil in the center.

The pupil is an opening through which light passes. The iris causes the diameter of the pupil to change. The diameter becomes larger as the intensity of the light decreases to allow more light through.

The lens focuses the light at the back of the eye, called the retina. Two types of light receptors cover the surface of the retina:

- Cones
- Rods

Cones are the receptors used for seeing under bright light. They are sited densely at the center of the retina. Cones provide the ability to sense color and resolve fine detail in the observed objects.

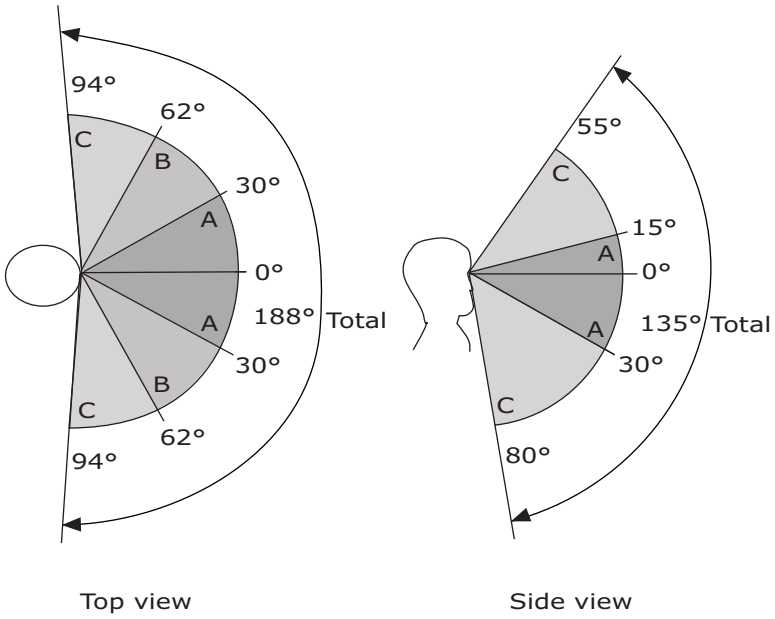
Visual Perception, continued

Rods are extremely sensitive to low levels of light and do not distinguish color. They facilitate sight at dusk and night. The majority of rods are located on the perimeter of the retina, which makes peripheral vision dim and blurry.

Behind the cones and rods is the optical nerve, which transmits the visual data to the brain.

The size of each eye's visual field (monocular vision) is impressive: 135 degrees high and approximately 120 degrees wide. Using both eyes (binocular vision), the horizontal field of view extends to 188 degrees (see Figure 2.13).

Figure 2.13
Fields of view



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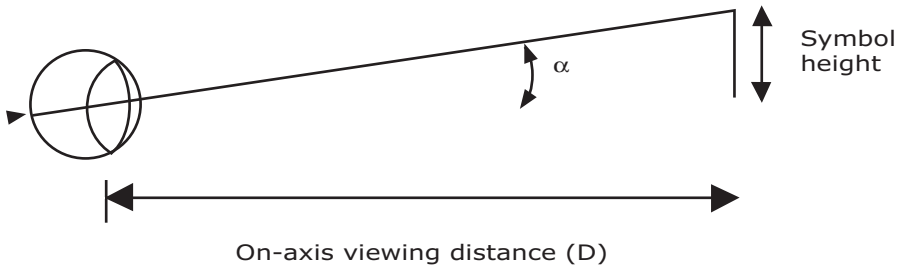
Visual Perception, continued

Visual Acuity

Research has determined that the human eye is capable of discerning a minimum of 10 arc minutes for symbol height, 16 arc minutes for clear legibility, and 30 arc minutes for public viewing. Arc minute is a unit of angular measurement, equal to one sixtieth of one degree.

Symbol height should extend at least 10 arc minutes opposite the minimum height angle (α) in the relationship shown in Figure 2.14.

Figure 2.14
Minimum height (α)



Visual Perception, continued

The formula for determining the viewing angle (W) in arc minutes for on-axis viewing is:

$$W = 3438 \times H/D$$

Where

H = Symbol height (Figure 2.15)

D = Viewing distance.

Figure 2.15
Symbol height



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Chapter 3
Signals

This chapter describes a multitude of signal types that characterize the audiovisual (AV) field. Understanding the fundamental differences between the various types is a tenet of AV design.

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Overview

This chapter provides an overview of the many different types of communications signals utilized in audio and visual systems. Signaling methods are influenced by market acceptance, government regulations, standards development, and technological evolution.

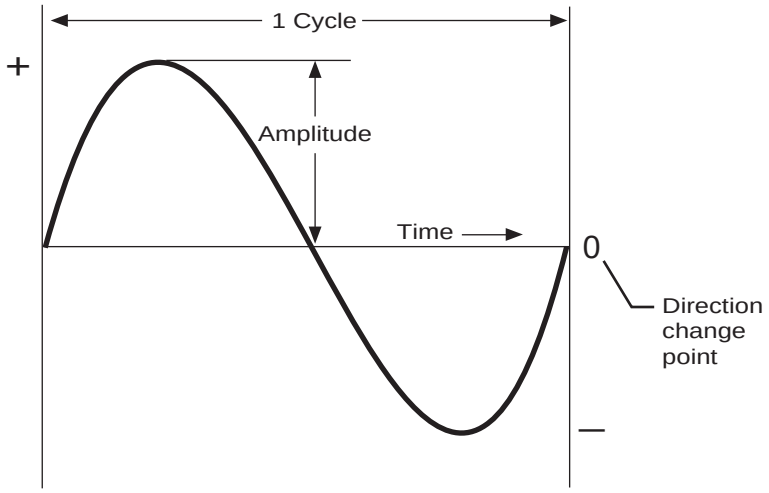
In many ways, communications signaling involving audiovisual (AV) systems is more complicated than those involving voice and data networks or building automation and security systems. There is a myriad of communications signals in AV systems, some of which are legacy methods and some are still emerging. Understanding the different types of signals is critical to the design and performance of AV systems.

Types of Signals

Introduction

Analog is derived from the term analogous, which means "similar to." Analog transmission uses continuously varying electrical signals that directly follow or are similar to the changes in loudness (amplitude) and frequency (tone) of the input signal (e.g., the human voice). For example, the transmitter of a telephone converts sound waves to an analog electrical signal that varies in amplitude (signal strength) directly with the loudness of the voice and varies in frequency directly with the tone of the voice (see Figure 3.1).

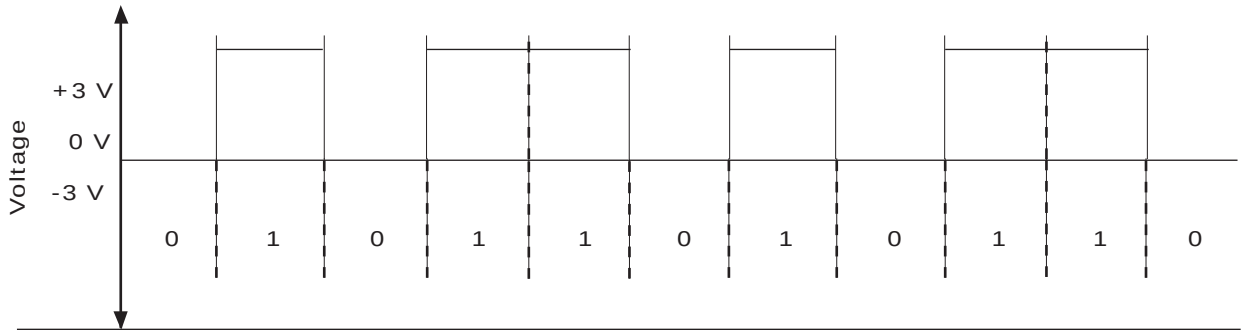
Figure 3.1
Analog signal



Introduction, continued

A digital signal (see Figure 3.2) is a discontinuous signal that changes from one state to another in a number of discrete (single) steps within fixed bit-framing time slots. In its basic form, there are two states, or signal levels, on and off, where the on translates to a digit 1 and off is seen as a zero level corresponding to the digit 0. Other means can be used to represent the two states (e.g., a positive and a negative voltage).

Figure 3.2
Digital signal



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Comparing Analog and Digital Signals

Historically, audio and video signals have been analog. Digital audio and video signals are now predominant, and the two signal types are fundamentally different. This section describes those differences.

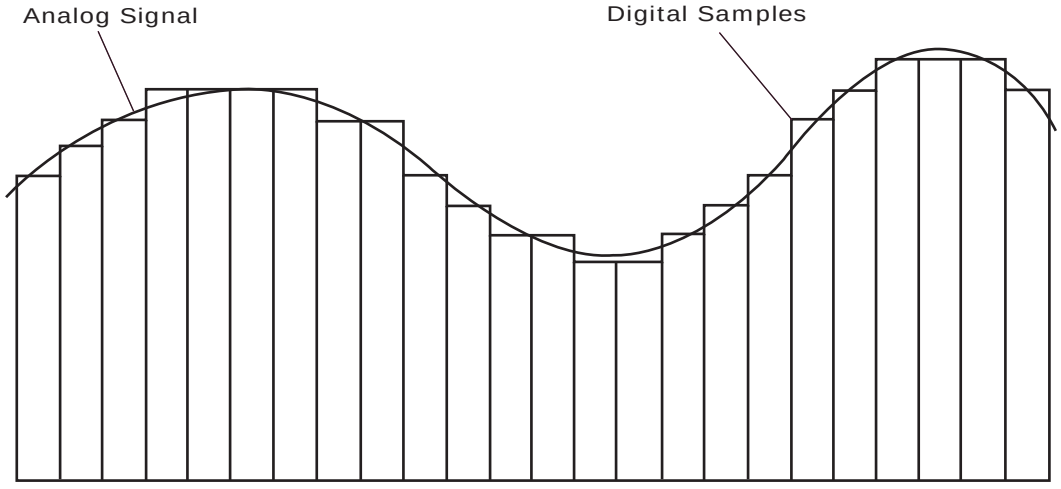
The analog signal represents reality well because it accommodates all gradations—in sound like a voice or in color like an image. The digital signal must break down information into pieces; the smaller the piece, the closer it is to reality because of the increasing level of detail.

Table 3.1 and Figure 3.3 show analog and digital signal comparison.

Table 3.1
Comparing analog and digital signals

Analog Signals	Digital Signals
Continuously varying signals	Data of 0s and 1s
Found in nature	Representation of nature
Degrades during transporting or storing	Resilient to transport and storage operations
No error correction	Error correction

Figure 3.3
Analog versus digital signal

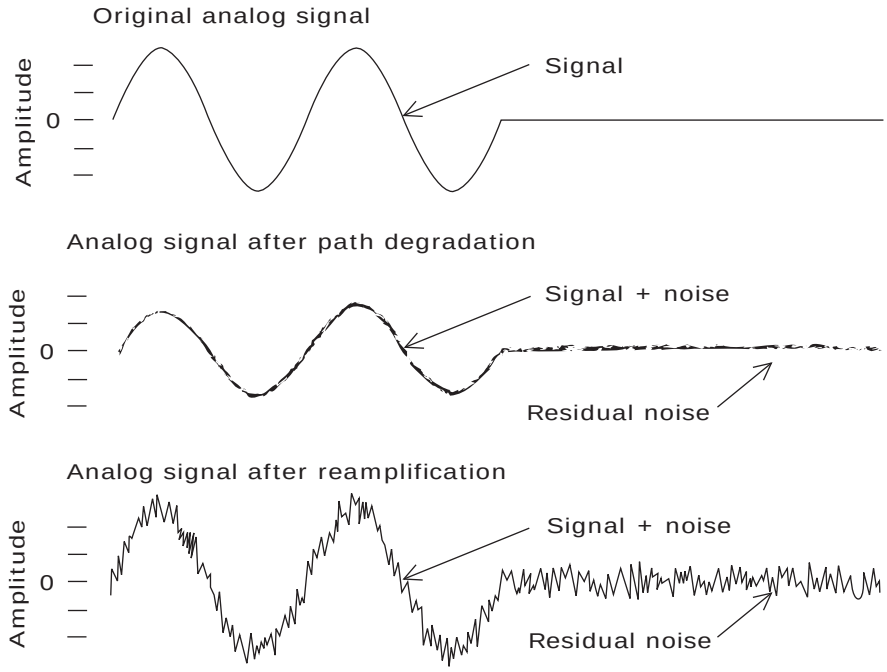


Comparing Analog and Digital Signals, continued

Signal Transmission

Analog signals are challenging to transport from one place to another. To carry the audio signal corresponding to a human voice, the signal may have to be re-amplified (with repeater amplifiers) many times to overcome the losses found in cable and other devices. With every re-amplification, noise also is amplified (see Figure 3.4). After many generations of re-amplification, the noise overcomes the signal. For a medium to rely on a continuous signal, degradation is inevitable.

Figure 3.4
Analog signal transmission

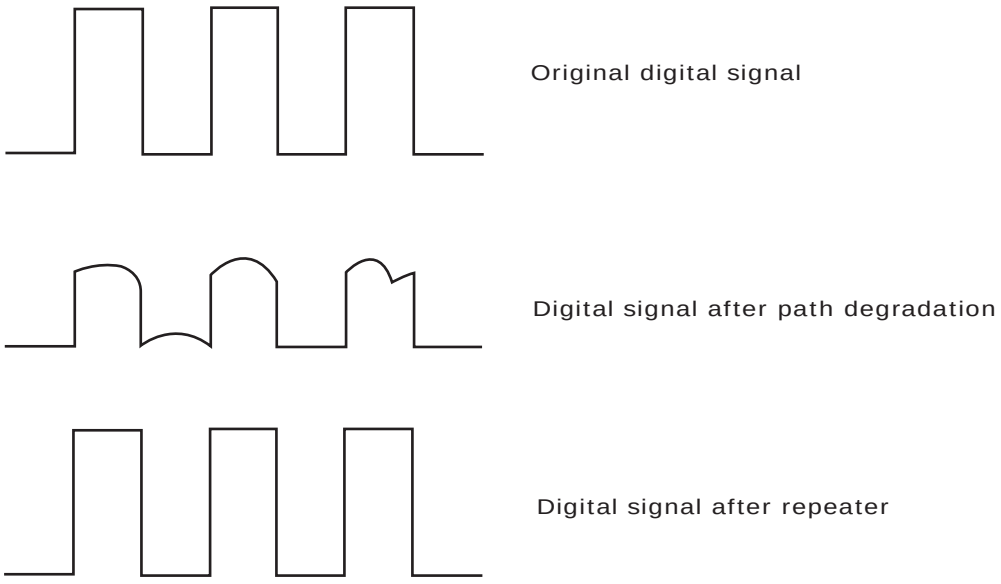


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Comparing Analog and Digital Signals, continued

Digital signals, on the other hand, can be restored (see Figure 3.5). As noise is introduced to a signal, the discerning circuitry can determine if the signal is intended to be high or low and then retransmit a solid high or low without the imposed noise.

Figure 3.5
Digital signal transmission



Storage

Analog signals are subject to noise introduced by the recording or playing device. Also, if the analog medium undergoes changes (e.g., warping over time, wear and tear), the true signal remains infinitely variable, but it does not exactly resemble the original recording. Digital signals remain intact during every playback.

Recording

The noise introduced when copying an analog signal during replication becomes progressively worse with each iteration. However, copying a digital signal is essentially the replication of a list of numbers, which remain the same.

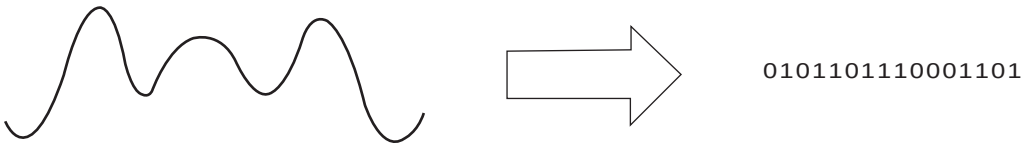
Comparing Analog and Digital Signals, continued

Analog-to-Digital (A/D) Signal Conversion

The number of possible states for a given bit depth can be calculated by raising 2 to the number of bits power. Thus, a bit depth of 4 has 2^4 or 16 possible states. Each additional bit doubles the number of possible states. A bit depth of 5, therefore, has 2^5 or 32 possible states. Equipment with 24-bit processing has 2^{24} or 16 777 216 available levels of audio. (See Bit Depth of a Digital Audio Signal in this chapter for more information.)

Analog signals are converted to digital signals using sampling rates and bit depth. This is commonly called analog-to-digital (A/D) or AD signal conversion (see Figure 3.6).

Figure 3.6
Example of analog-to-digital signal conversion

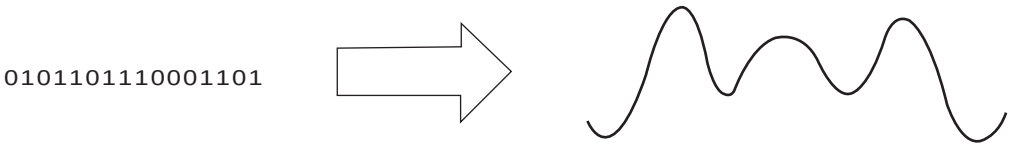


Digital-to-Analog (D/A) Signal Conversion

Digital-to-analog (D/A) conversion is the opposite of A/D conversion (see Figure 3.7). Digital signals appear as long strings of 1s and 0s, corresponding to high and low voltage amplitudes. When a D/A converter is used to decode the binary digital signals, the meaningful output appears as continuously varying voltage amplitude. The original signal is then reproduced before being converted to a digital signal. The reproduced signal is not an exact but a very close replica of the original signal with sufficient bit depth and sampling rate.

In many instances, the intelligibility or fidelity of the original signal can be improved or deliberately modified before it is converted to analog. This is called digital signal processing.

Figure 3.7
Example of digital-to-analog signal conversion



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Audio Signals

Introduction

Speaking into a microphone produces an analog sound received by the microphone. Listening to a sound from speakers connected to an AV system, the person hears an analog sound. True human audio is analog. Humans speak and hear using analog communications. To be precise, humans naturally hear or produce the slight variations in air pressure, called sound, in an analog fashion. The pressure variations are continuously changing, much like ocean waves.

Digital signals are estimations of the true analog communications signal.

Analog Audio Signals

The only real restriction to modern audio technology is the human ear. The range of audio frequencies that a human can hear is generally between 20 hertz (Hz) and 20 kilohertz (kHz). Most audio equipment operates in an audio range larger than that of the human ear, typically 10 Hz to 30 kHz. Even though AV equipment is predominantly digital, AV systems will typically involve the use of analog audio signals. Such components may include microphones, speakers, mixers, and analog signal amplifiers.

The three audio level categories are:

- Microphone.
- Line.
- Speaker.

Microphone levels are typically in the range of –60 to –20 decibels referenced to 0.775 volt (V) root mean square (rms) [dBu]. Line levels are typically –20 to +25 dBu. Speaker levels are typically greater than +25 dBu and normally measured as voltage level. See Table 3.2 for typical audio signal measurement units.

Line levels used are typically two types:

- Professional level (+4 dBu)
- Consumer (–10 dB referenced to 1 V [dBV])

Analog Audio Signals, continued

Table 3.2
Typical audio signal units of measurement

Unit	Type	Reference	Use	Note
dBm	Power	mW	Audio systems	600 ohm
dBu	Voltage	0.775 V	Audio systems	
dBv	Voltage	0.775 V	Television	
dBV	Voltage	1 V	Consumer devices	Standardized by the International Electrotechnical Commission (IEC)
dBmV	Power	13.33 nW	Cable television (US) of power, defined as 1 mV rms across 75 ohm	
dBW	Power	1 W	Audio systems (power amplifiers)	Used in place of dBm when calculating high level outputs like power amps

dBm = Decibels referenced to 1 milliwatt (mW) across an impedance of 600 ohms
dBmV = Decibel millivolt
dBu = Decibels referenced to 0.775 volts (V) root mean square (rms) across any impedance
dBv = Decibels referenced to 0.775 volts (V) root mean square (rms) across any impedance
dBV = Decibels referenced to 1 volt (V) root mean square (rms) across any impedance
dBW = Decibels referenced to 1 watt (W)
mW = Milliwatt
mV = Millivolt
nW = Nanowatt
rms = Root mean square
V = Volt
W = Watt

Headroom and Total Harmonic Distortion

An AV designer may be required to document the operating condition of a completed sound system. Two common criteria to measure the quality of an installation are:

- System headroom.
- Total harmonic distortion plus noise (THD+N).

System headroom is the difference between the level of a typical audio system operation and the maximum level attainable by a system. If a sound system usually operates at +1 dBv but could operate as high as +20 dBv, it is said to have 19 dB of headroom. Having enough headroom to handle momentary increases of intensity is critical.

Any change to the original signal is referred to as distortion. System resonances, both electronic and acoustic, can produce harmonics of the original signal and additional artifacts (spurious signals produced artificially). Additional artifacts not related to the original signal are referred to as noise. The sum of the two entities is known as THD+N. The level of distortion describes the state of being a particular dB value below the original source signal. The more common method of documenting THD+N is as percentage of the original signal. The lower the THD+N, the better the system. A total system THD+N of less than 1 percent is considered acceptable.

Analog Audio Signals, continued

Signal-to-Noise Ratio (SNR)

Signal-to-noise ratio (SNR) is a term that describes the power ratio between a signal and the background noise. The following is the formula expressing that ratio:

$$SNR = \frac{P_{signal}}{P_{noise}}$$

SNRs are usually expressed in terms of the logarithmic dB scale. SNR is 10 times the logarithm of the power ratio or 20 times the base 10 logarithm of the amplitude ratio in dB, as shown in the following formula:

$$SNR\ (dB) = 10 \log_{10}\left(\frac{P_{signal}}{P_{noise}}\right) = 20 \log_{10}\left(\frac{A_{signal}}{A_{noise}}\right)$$

Where

P = Average power

A = RMS amplitude.

Both signal and noise power are measured within the system bandwidth.

SNR is closely related to the concept of dynamic range. Dynamic range measures the ratio between noise and the greatest undistorted signal on a channel. SNR measures the ratio between noise and an arbitrary signal on the channel, which may not be the most powerful signal. Therefore, measuring SNRs requires selecting a representative or reference signal. In audio engineering, this reference signal is 1.228 V rms, obtained when 4 dBm is taken as the standard calibration level, which is equal to zero on a volume unit (VU) meter. The following equation shows that relationship:

0 VU = +4 dBm = 1.228 V rms.

Analog Audio Signals, continued

Balanced and Unbalanced Circuits

Balanced audio circuits offer three connection points:

- Conductor carrying the signal just as it originated (+)
- Conductor carrying the same signal with opposite polarity (–)
- Electrical ground (usually the shield)

The two signal conductors have the same impedance relative to ground, which makes the circuit balanced. The conductors are equally exposed to the induced noise. Noise is canceled at the input stage by the inversion of the (–) signal and its summation with the (+) signal. This provides for a higher quality signal with less noise over long-distance cable runs.

Balanced circuits may be expensive to manufacture and time-consuming to terminate; however, if the signal's purity is important, balanced circuits should be the AV designer's choice. The selection between balanced and unbalanced cables is based on which approach provides the desired SNR. Microphone level signals should always be balanced because their extremely low level requires the best possible protection. Phantom-powered microphones also require a balanced connection to supply power to the microphone.

NOTE: It is the circuit, and not the cable or connector, that may be balanced or unbalanced.

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Digital Audio Signals

The process of converting analog signal to digital requires sampling. Sampling rate is the number of times a sample is taken per second. Samples of an analog signal are made at certain time intervals (e.g., every second, tenth of a second, microsecond [ìs]). Therefore, a sample represents the digital level of an analog signal in a particular point in time.

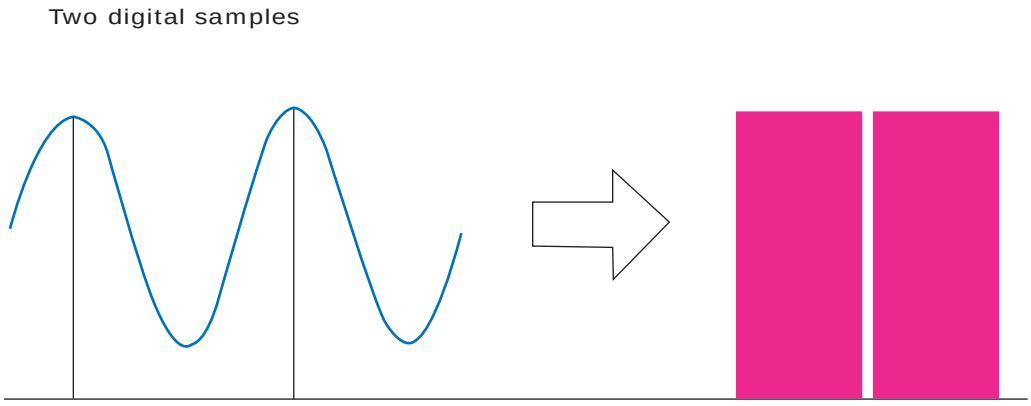
Sampling Rate of a Digital Audio Signal

Samples are recorded and stored for later use in replication or playback. Determining an acceptable sampling rate is crucial to obtaining a digital representation that resembles the original signal.

The Nyquist theorem states that the sampling rate must be at least twice the highest frequency of the analog signal being sampled. The Nyquist frequency represents the highest frequency of the analog signal being recorded and is equal to half of the sampling rate. In other words, if the audio falls within a 20 kHz bandwidth (i.e., all audio signals are below 20 kHz), the sampling rate should be at least 40 kHz.

In Figure 3.8, the sampling rate is equal to the frequency of the signal being sampled. The sample is taken at each peak of the wave, so the digital signal only captures the analog signal's maximum values.

Figure 3.8
Sample rate the size of the signal frequency

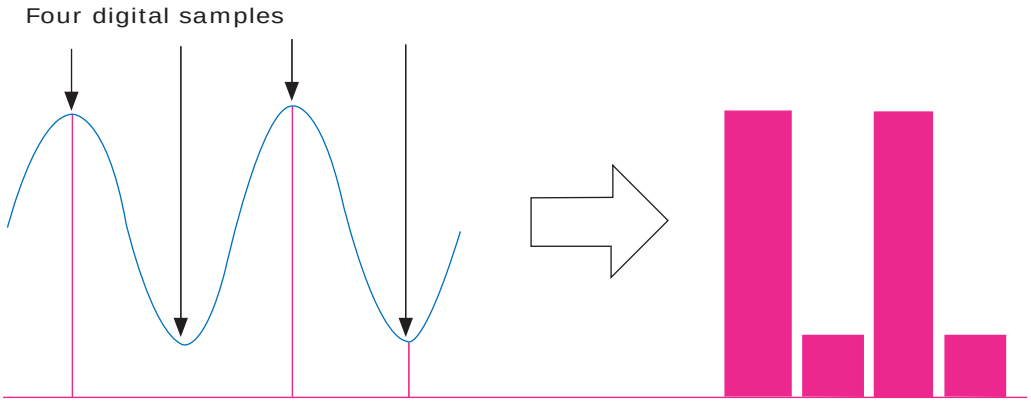


Digital Audio Signals, continued

Such recording does not indicate that the signal is an oscillating wave. As a result, the signal reproduced from the samples has only one value. This is a poor representation of the original signal.

The sampling rate in Figure 3.9 is at least twice the frequency of the analog signal. The resultant digital representation of the analog signal resembles the original. Higher sampling rates would produce an even better representation.

Figure 3.9
Sample rate double the size of signal frequency



Bit Depth of a Digital Audio Signal

The sampling rate and bit depth of a digital signal are factors of accuracy and precision in the representation of original signals. Bit depth is defined as the number of bits that describe a signal value.

One bit, with the value of either 0 or 1, can only describe a signal as being on or off. Two bits have four possible states (00, 01, 10, and 11) to describe a signal. A bit depth of three bits will have eight possible states.

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Digital Audio Signals, continued

Digital Audio Distortion

Resolution

The resolution of a digital audio signal is the range of numbers that can be assigned to each sample. Compact disc (CD) audio uses 16 bits, which provides 2^{16} possible values to represent each sample with values ranging from 0 to 65 535. Having more bits to represent the signal level increases the resolution and reduces the error between the actual signal value and the digitized value. This error is known as quantization noise.

An A/D converter is typically configured to sample a specific range of an analog signal voltage represented in dBV. For instance, if a range of ±1 V is sampled with a 16 bit A/D converter, each sample has a granularity of 30.5 µV (2 V/2^16). However, if a signal has a voltage of ±10 V, each sample has a granularity of 305 µV (20 V/2^{16}).

If an A/D converter is set up to support a ±10 V signal, using a signal of only ±1 V wastes approximately 3 bits of information. Conversely, using a ±10 V range signal with an A/D set up to support signals from ±1 V causes a clipping distortion since loud signals cannot be represented.

The sample resolution determines the optimal signal to error (S/E) ratio in dB. With some assumption based on the signal statistics, the S/E ratio is modeled according to the following equation:

$$\text{S/E (dB)} = 6.02\,n + 1.76 \text{ dB}$$

Where

n = Bit resolution

Digital Audio Signals, continued

Table 3.3 shows resolutions for some of the commonly used audio and video devices.

Table 3.3
Common bit resolutions

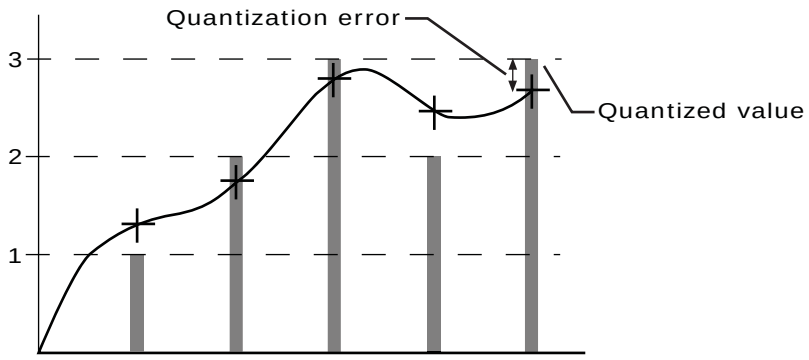
Bit Resolution	Calculated S/E	Usable S/E	Example Device
8	49.92	48 dB	Internet voice
12	74	72 dB	Digital video camcorders
16	98.08	96 dB	Audio compact disc
24	146.24	144 dB	Audio digital versatile disc (DVD)

S/E = Signal to error
dB = Decibel

Quantization

Quantization is the process of selecting whole numbers to represent the voltage level of each sample. The A/D converter must select a whole number closest to the level of the signal at the moment it is sampled. This produces small rounding errors that cause distortion in the representation of the original analog signal (see Figure 3.10).

Figure 3.10
Quantization errors



Dithering

Dithering is a process designed to introduce random noise into the signal to mask the effects of quantization distortion within the A/D converter.

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Digital Audio Signals, continued

Clipping

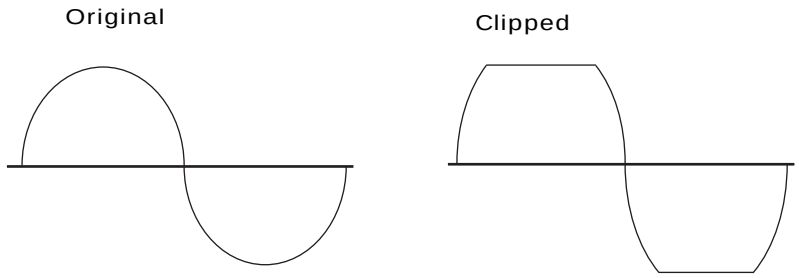
Both analog and digital media have an upper limit beyond which they can no longer accurately represent the amplitude (level) of an audio signal.

Analog clipping varies in quality depending on the recording medium and the portion and type of the electronic circuit that is clipping and causing the distortion. Occasionally, analog distortion may be desirable (e.g., the overdrive in an electric guitar amplifier).

Unlike an analog audio signal, which can convey usable information when pushed beyond its headroom limits into distortion, a digital audio signal has a specific bit resolution dedicated to conveying the amplitude level.

Exceeding the sampling resolution causes digital clipping (see Figure 3.11). Once an amplitude value of 1111111111111111 or approximately 90 dB above the zero reference is reached in a 16 bit resolution sample, all of the amplitude information above 90 dB is disregarded and truncated.

Figure 3.11
Digital clipping



The result is not a smooth and rounded waveform flattening as in analog clipping, but a truncated waveform. If the A/D converter exceeds the headroom allowed by the sampling resolution, no useable information from the remainder of the sample is captured.

Digital Audio Signal Protocols

Digital audio is becoming more prominent in AV system designs. The AV designer should understand digital audio sample rates and bit depths and their effect on component interconnection, particularly in the digital domain. Other issues include setting gain structure within a digital system.

Several digital audio protocols are available in the marketplace. Some standards-based (e.g., American Engineering Society/European Broadcasting Union [AES/EBU]) and some are proprietary (Sony/Phillips digital interface [S/PDIF]).

Video Signals

Introduction

Both analog and digital methods are used to capture, process, and display video in AV systems. Video signals affect the quality and resolution of the video. In addition, analog signals typically must be part of, or complement, video signals to present to the viewer both sound and video.

Analog Video Signals

The three primary analog video standards are:

- National Television System Committee (NTSC).
- Phase alternation line (PAL).
- Séquentiel couleur avec mémoire (sequential color and memory [SECAM]).

Each of the three standards is incompatible with the other two. Also, the video equipment used in a system, from the video camera to the display device, must be formatted for that signal. A PAL videotape cannot be played back on an NTSC videocassette recorder (VCR) and monitor.

This section discusses the creation, quality, and composition of video signals and the importance of video standards.

Video Camera

Video process, equipment, and application in the areas of AV involve capture of video signals. Just as a movie is created by multiple still images on film, video is a series of still images. A video camera uses a lens, like an eye, to focus on an image. Like an eye, the camera needs light to “see,” and what it captures is turned into a video signal.

A video camera does not record an image like a film camera does. The video camera’s function resembles that of a language translator. Video “speaks” the languages of light and electronics. The camera “reads” the language of light and “translates” it into the language of electronics.

A video signal may be formed in many ways, and one type builds upon the next.

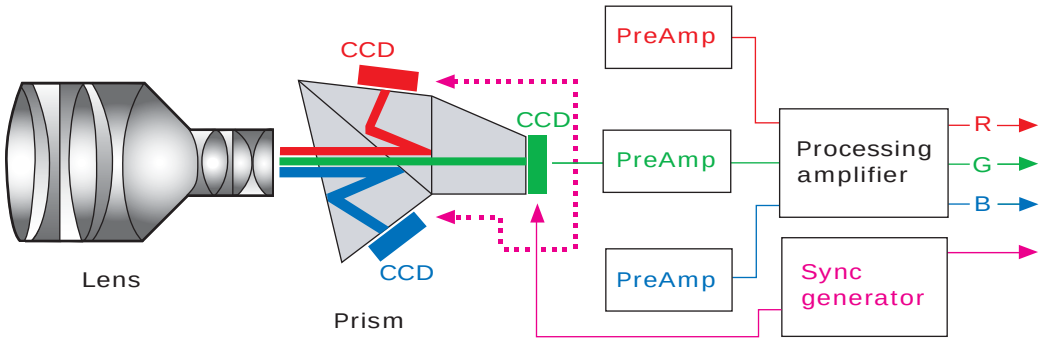
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Analog Video Signals, continued

Video Signal Building Blocks

The electronic signal for a single still image is made up of several signal components. Part of the signal indicates color. All light can be broken down into three primary colors: red, green, and blue (RGB). These colors are the only color signals needed to create every hue in an image; all other colors of light are mixtures of RGB. The light focused on the imager is, therefore, separated into RGB signals (see Figure 3.12).

Figure 3.12
Video signal building blocks



B = Blue
CCD = Charge coupled device
G = Green
R = Red

Working with color signals requires coordinating the signal information with respect to time, a process called synchronization (sync). Sync keeps the time relationship between video frames and correctly positions the image horizontally and vertically. This information is called horizontal (H) sync and vertical (V) sync. RGB, along with H and V sync, make up the information needed for a complete video image.

Analog Video Signals, continued

Horizontal and Vertical Signals

Video signals were originally intended for cathode ray tube (CRT) displays, which use raster scanning. Nearly all electronic devices display images generated by some variation of scanning.

Scanning refers to the process in a CRT where an electron beam moves in a sequenced and ordered manner, charging phosphors. The path is controlled by the H and V sync pulses, which are part of the original signal sent to the CRT. These pulses are sent to the deflection coils, which guide the beam with precision.

The electron beam charges the phosphors in a line from left to right. The beam then drops down and scans another line. At the end of each line, the H sync pulse communicates to the beam to turn itself off, which constitutes a process called horizontal blanking. The beam then returns to the beginning of the next line, a process called retrace. This process continues from the top to the bottom of the display, where the V sync pulse prompts the beam to turn itself off while it goes back up to the top to start over. This process is called vertical blanking.

Scan Rates

H and V sync signals direct the electron beam of a CRT, which traces the image. The speed of this process is referred to as the scan rate. The horizontal scan rate is the rate at which the electron beam scans each line from left to right and back again. Of the two fields in the image frame, the first field consists of the odd-numbered lines, the second field the even-numbered lines. The vertical scan rate is the rate at which the electron beam completes its cycles of vertical motion, from top to bottom, which is one field.

The number of horizontal scan lines in an image depends on the video standard. NTSC has 525 individual scan lines in a frame or 262.5 per interlaced field. PAL and SECAM frames contain 625 lines or 312.5 lines per field.

Because many horizontal scans are completed in a single vertical scan, the frequency of the horizontal scan is faster than the frequency of the vertical scan. The horizontal scan rate (frequency) is the number of horizontal lines drawn by the display device each second and measured in kHz. The NTSC standard has the horizontal frequency of 15.75 kHz, which equals 60 fields per second (i.e., 15 750 Hz/262.5 scan lines). PAL and SECAM have the horizontal frequency of 15.625 kHz, which equals 50 fields per second (i.e., 15 625 Hz/312.5 scan lines).

The vertical scan rate describes the number of fields drawn by the display device per second. This may also be called the frame rate, V sync rate, or refresh rate. The vertical scan rate is measured in Hz or cycles per second. The NTSC standard has the vertical frequency of 59.94 Hz, which is compatible with the alternating current (ac) electrical supply found in NTSC countries. The PAL and SECAM standards have the vertical frequency of 50 Hz, compatible with the ac electrical supply found in the corresponding regions.

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Analog Video Signals, continued

Blanking Interval and Retrace Time

The scanning of each line is regulated by the H sync pulse. H sync pulses communicate to the beam when they reach the end of one line and should go back and start the next. The scanning beam is shut off or blanked so it can be moved into the position to begin the next scan line. The time during which the beam is turned off is called the horizontal blanking interval and is usually very brief, varying from 5 to 15 µs.

At the end of a frame or field, a V sync pulse is produced to initiate a similar process for vertical blanking. The scanning beam is shut off while it returns to the top of the raster, and starts the next frame. Blanking is also called refresh.

The time it takes the electron beam to turn off, travel to its next starting point, and turn back on to begin scanning again is called retrace time.

Different video standards have various blanking and retrace times.

Signal Quality

The goal of a signal is to move from a camera to a display device. The method for this process depends on the required image quality.

High-quality images require high-quality signals. High-quality signals require a lot of room. This requirement calls for a sufficient quantity of high-quality cable, as well as the video equipment that can manipulate high-quality signals.

Signal quality is assessed in terms of bandwidth. Bandwidth measures the capacity to carry information. High-quality signals contain sizeable amounts of information that travels very quickly, requiring a lot of room or bandwidth. The highest-quality analog video signals are called full bandwidth signals. Lower-quality signals are bandwidth-limited signals and require slightly less room.

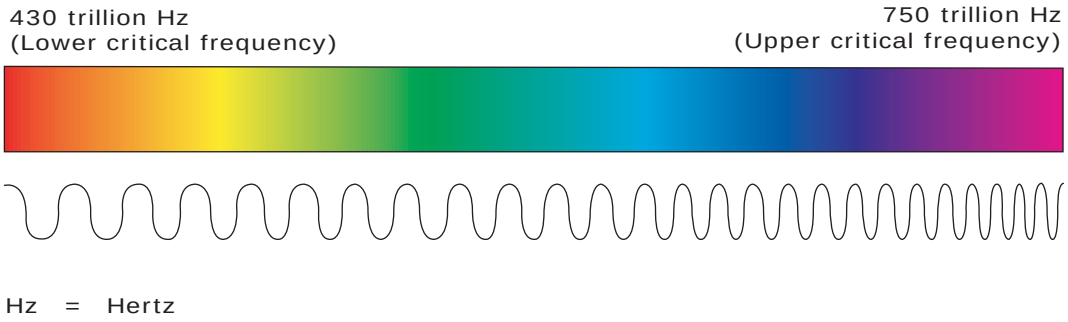
Analog Video Signals, continued

Video Signal Bandwidth

High-quality video contains very fine detail. More detail requires more information, which, in turn, requires more bandwidth.

Bandwidth is the range of frequencies that can pass through a medium. Light travels at varying frequencies, some of which can be seen by the human eye. The bandwidth of human vision, from the lowest to the highest observable frequency of light, is 430 to 750 trillion Hz (see Figure 3.13).

Figure 3.13
Video signal bandwidth



In electronics, bandwidth is assessed in terms of the frequency of voltage rather than of light. Such bandwidth is the range of frequencies that can pass though a circuit.

Every electronic circuit can detect frequencies in a specific range. The difference between the fastest and the slowest frequencies a circuit can detect and process is considered the circuit's bandwidth.

When electronic frequencies fall out of the circuit's bandwidth, the frequencies can no longer be detected.

Each video signal component occurs at a different frequency. V sync occurs the least often and thus has the lowest frequency. H sync operates in the kHz range. Video picture information operates in the megahertz (MHz) range.

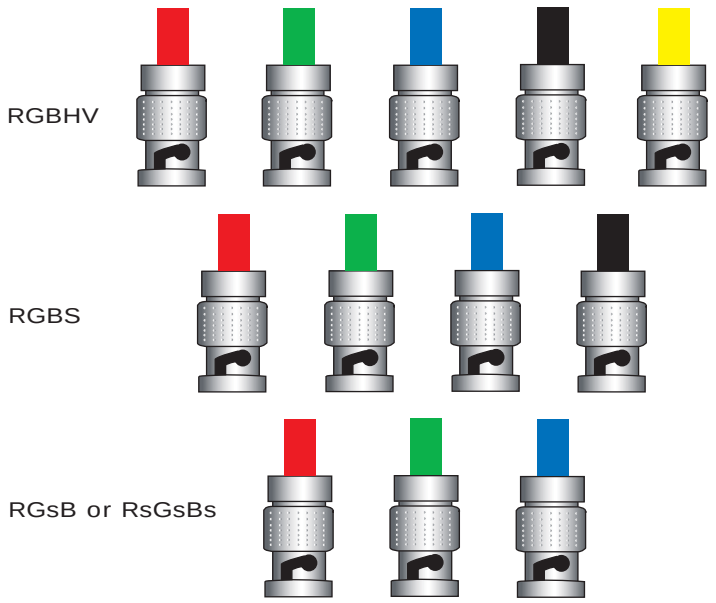
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Analog Video Signals, continued

Full-Bandwidth Signals

A combination of the three RGB signals and sync or timing signals makes up all of the information contained in the image converted by the camera's sensors. This combination is referred to as a full-bandwidth RGB signal or unencoded signal (see Figure 3.14).

Figure 3.14
Full-bandwidth signal transmission



B = Blue
G = Green
R = Red
S = Composite sync
s = Composite sync added to a channel

Analog Video Signals, continued

Signals of this level of quality are:

- RGB, H sync, and V sync (RGBHV):
  - Referred to as full bandwidth RGB with separate sync
  - Highest signal quality and stability
  - Requires five cables to carry the signal, one for each component
- RGB and composite sync (a combination of H and V sync [RGBS]):
  - Referred to as full bandwidth RGB with composite sync
  - Requires four cables to carry the signal, one for each component
- RGB and composite sync added to the green channel (RGsB):
  - Referred to as full bandwidth RGB with sync on green
  - Requires three cables to carry the signal: one for red, one for green and sync, and one for blue
- RGB and composite sync added to each color channel (RsGsBs):
  - Referred to as RGB sync on all three
  - Requires three cables to carry the signal

Composite sync reduces the signal stability. However, none of the full-bandwidth signals involve bandwidth limiting or encoding, thus the overall image quality is not compromised.

Bandwidth Limiting

All full-bandwidth signals are too robust to be readily handled by most processing equipment. Fitting a color video signal into a black-and-white signal space requires bandwidth limiting. Bandwidth limiting is achieved by encoding the signal's color channels.

While an encoded signal takes up less bandwidth, the process of encoding and subsequent decoding adds small disturbances that affect the signal quality, such as noise and artifacts.

The signal encoding occurs in the video camera's circuitry. A video camera may have any of the following bandwidth-limited signal outputs:

- Component video
- S-video
- Composite video

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Analog Video Signals, continued

Luminance

A method of creating bandwidth-limited signals that combines the sync information with the signals for brightness is called luminance or luma (Y).

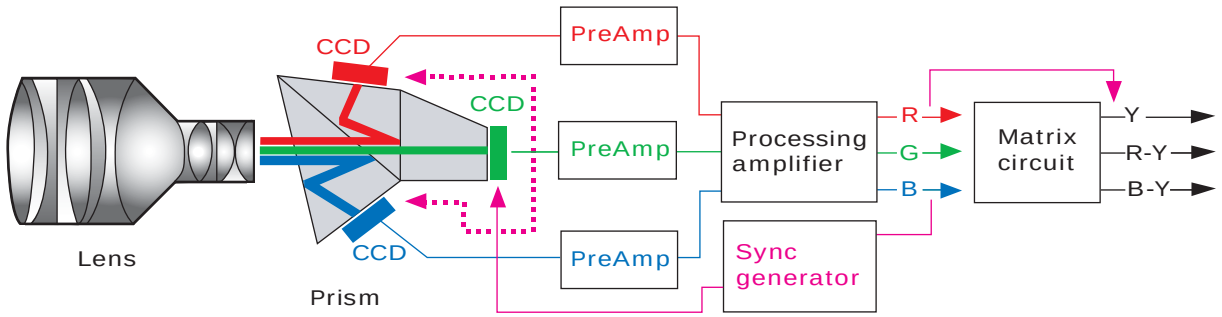
Human perception of light is most sensitive to the yellow/green spectrum of light, less sensitive to red, and least sensitive to the blue spectrum. The Y signal is derived using the following formula:

$$Y = 0.30R + 0.59G + 0.11B$$

The first of several limiting events is the processing performed by the color encoder or matrix. The matrix (see Figure 3.15) strips the brightness information from the RGB signals and adds it up to make Y. That leaves red minus luminance (R-Y), green minus luminance (G-Y), and blue minus luminance (B-Y).

If three pieces of information are known, one missing piece can be easily determined. To save bandwidth, one of the pieces, G-Y, is removed. The R-Y and B-Y signals are called color difference signals.

Figure 3.15
Signals Y, R-Y, and B-Y



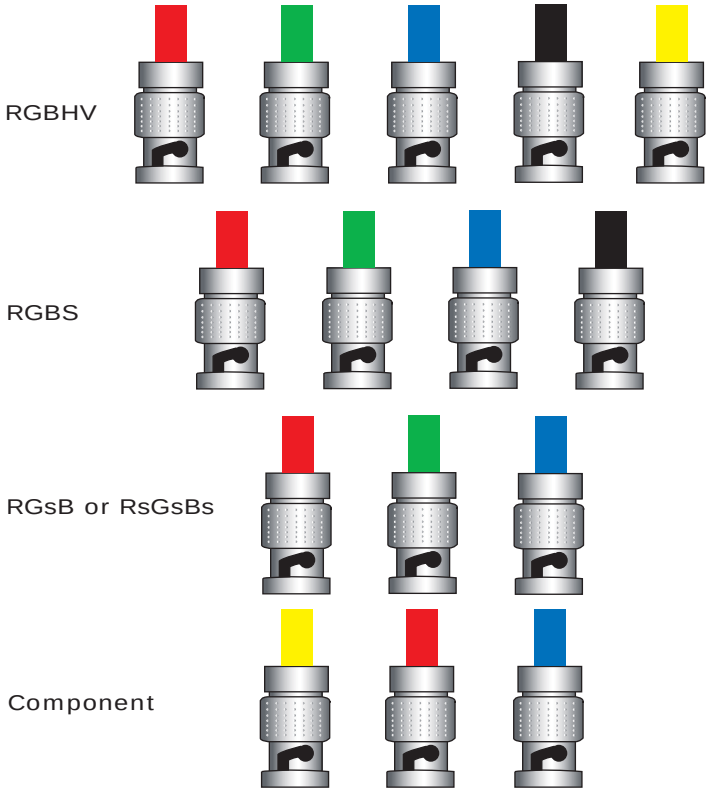
B = Blue
B-Y = Blue minus luminance
CCD = Charge coupled device
G = Green
R = Red
R-Y = Red minus luminance
Y = Luminance

Analog Video Signals, continued

The Y signal and the color difference signals R-Y and B-Y together are referred to as component video (see Figure 3.16), which:

- Requires three cables to carry the signal, one each for Y, R-Y, and B-Y.
- Is used extensively in the production environment due to its quality and lack of artifacts.

Figure 3.16
Component video transmission



B = Blue
G = Green
R = Red
S = Composite sync
s = Composite sync added to a channel

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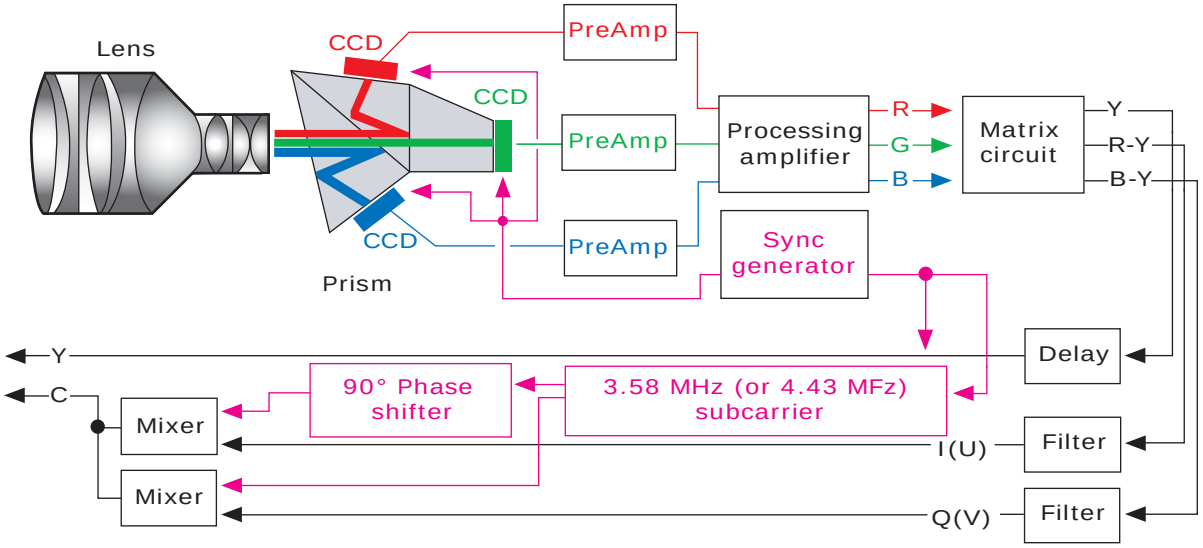
Analog Video Signals, continued

Separate Video (S-Video)

Encoding an S-video signal begins with the component signal. The R-Y signal, compacted through filtering to 1.5 MHz of bandwidth, is called in-phase (I). The B-Y signal, compacted through filtering to 0.6 MHz of bandwidth, is called quadrature (Q). I is allowed more room because eyes are more sensitive to red than blue. I and Q are added together to form chrominance or chroma (C) signal. While the C signal is mixed, the Y signal is sent to a delay (see Figure 3.17).

NOTE: I and Q are used for the NTSC standard. For PAL, they are called U and V.

Figure 3.17
S-video signal



B = Blue
B-Y = Blue minus luminance
C = Chrominance
CCD = Charge coupled device
G = Green
I = In-phase
Q = Quadrature
R = Red
R-Y = Red minus luminance
Y = Luminance

Analog Video Signals, continued

A color-burst signal is added to the signal before transmission so the color information can be decoded later. The color-burst signal serves as the decoder for unlocking the color information for each video line.

The color-burst signal is a sine wave with a specific frequency and amplitude. A modulator (circuit) puts the color burst on a sub-carrier frequency. The sub-carrier frequency for NTSC is 3.58 MHz and for PAL it is 4.43 MHz.

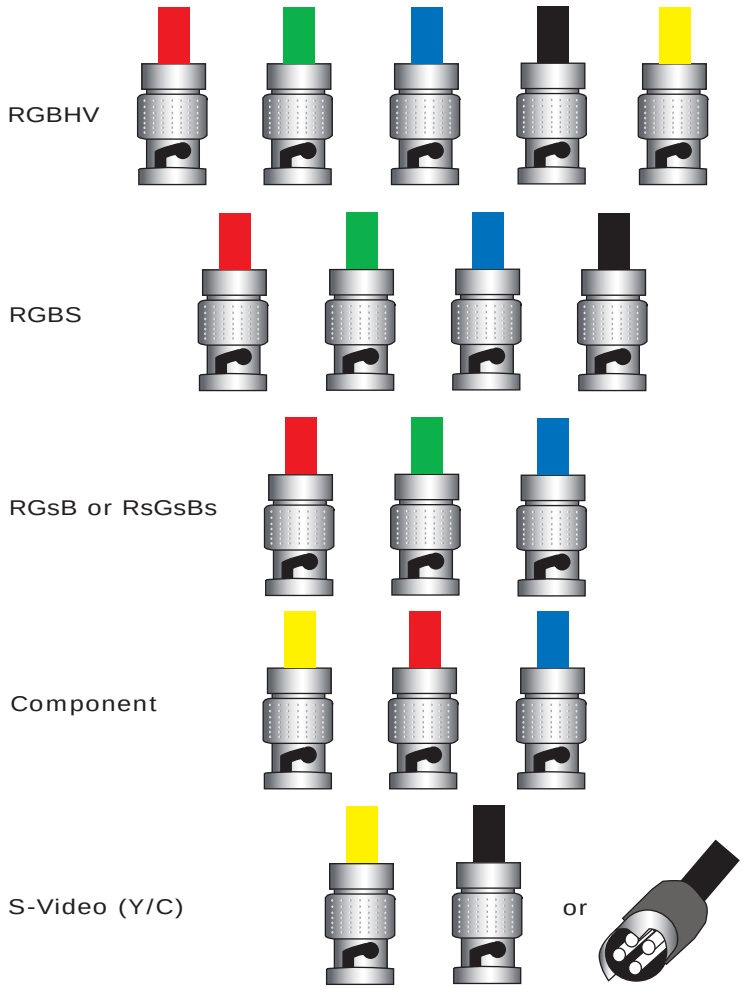
To separate the color difference signals, the color-burst sine wave for the I component is twisted 90 degrees to make it out of phase with the Q signal.

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Analog Video Signals, continued

The luminance with sync/chrominance (Y/C) signal, referred to as S-video signal, requires two cables, one for Y and one for C (see Figure 3.18).

Figure 3.18
S-video transmission



B = Blue
G = Green
R = Red
S = Composite sync
s = Composite sync added to a channel
Y/C = Luminance with sync/chrominance

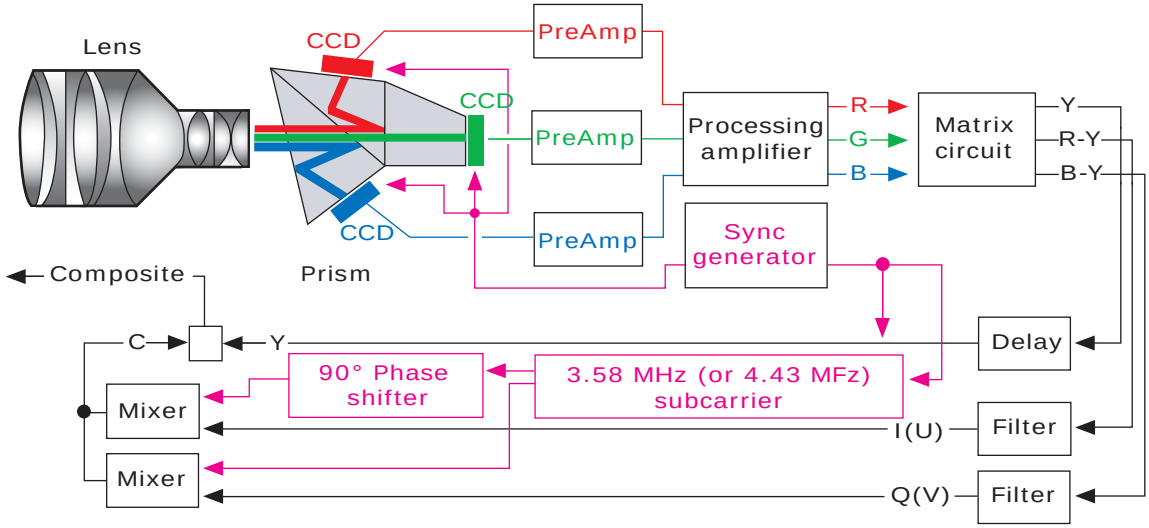
Analog Video Signals, continued

Recording with a Y/C recorder requires that all of the signal-processing equipment be capable of maintaining the Y/C signal.

Composite Video

The C signal is added to the Y signal to form a composite signal, also called baseband video (Figure 3.19).

Figure 3.19
Composite video signal



B = Blue
B-Y = Blue minus luminance
C = Chrominance
CCD = Charge coupled device
G = Green
I = In-phase
Q = Quadrature
R = Red
R-Y = Red minus luminance
Y = Luminance

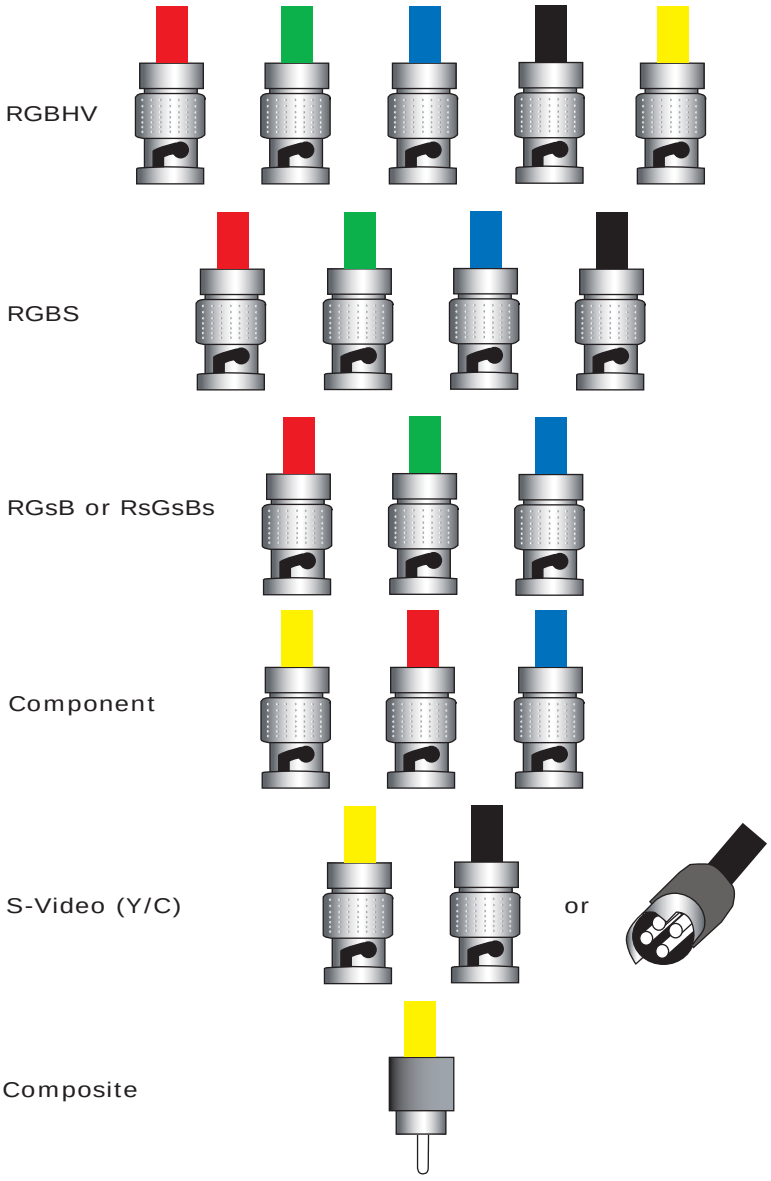
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Analog Video Signals, continued

The composite video:

- Requires one cable to carry the signal (see Figure 3.20). One difficulty with this method is that some of the information cannot be separated cleanly, leaving artifacts, small disturbances in the image that affect the quality of the signal.
- Is the most common combination of video signals, both in the professional AV and in the home VCR.

Figure 3.20
Composite video transmission



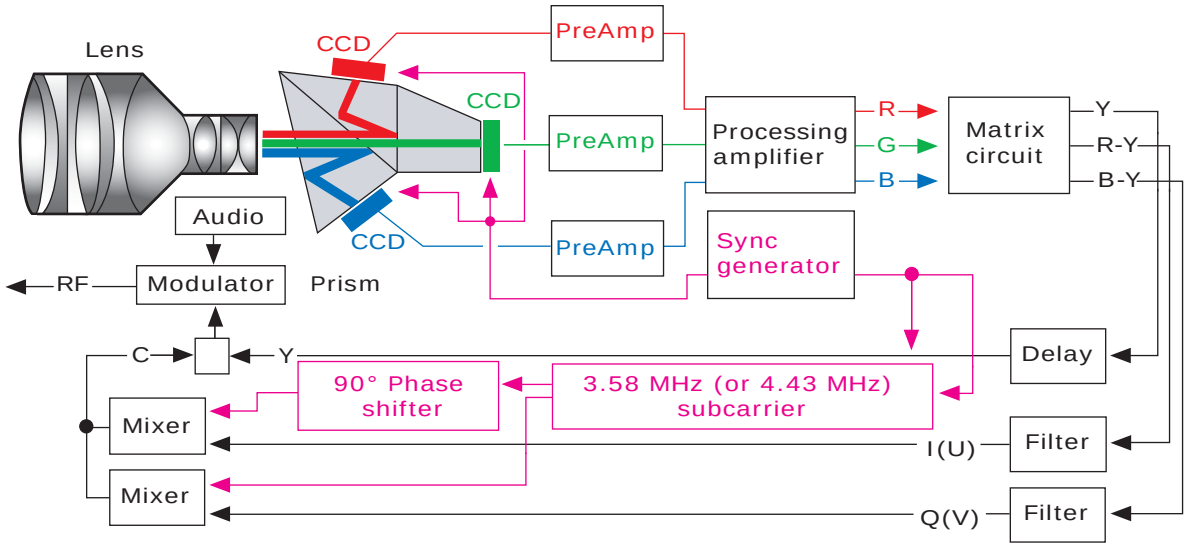
Analog Video Signals, continued

Radio Frequency (RF) Signal

Cable television (TV) service typically uses radio frequencies (RFs). In community antenna television (CATV) systems, video signals from multiple antennas or inputs are processed at the headend.

Video signals are modulated at different RFs and combined into a single large or broadband signal, which is distributed and fed to subscribers (see Figure 3.21). When subscribers change channels, they are basically changing the RF of the input to the TV. RF signals have the lowest video quality. RF video is composite video with two audio channels.

Figure 3.21
Radio frequency signal



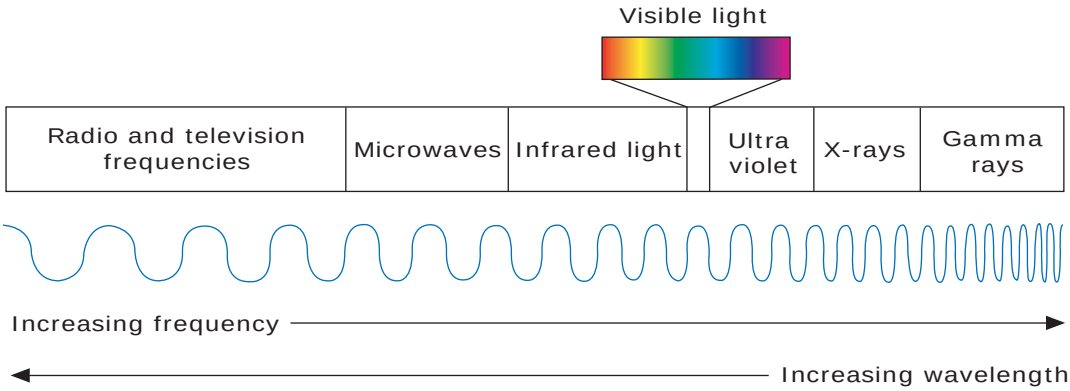
B = Blue
B-Y = Blue minus luminance
C = Chrominance
CCD = Charge coupled device
G = Green
I = In-phase
MHz = Megahertz
Q = Quadrature
R = Red
RF = Radio frequency
R-Y = Red minus luminance
Y = Luminance

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Analog Video Signals, continued

The RF signal frequency falls into the radio and TV band on the frequency spectrum (as shown in Figure 3.22).

Figure 3.22
Radio frequency on the frequency spectrum

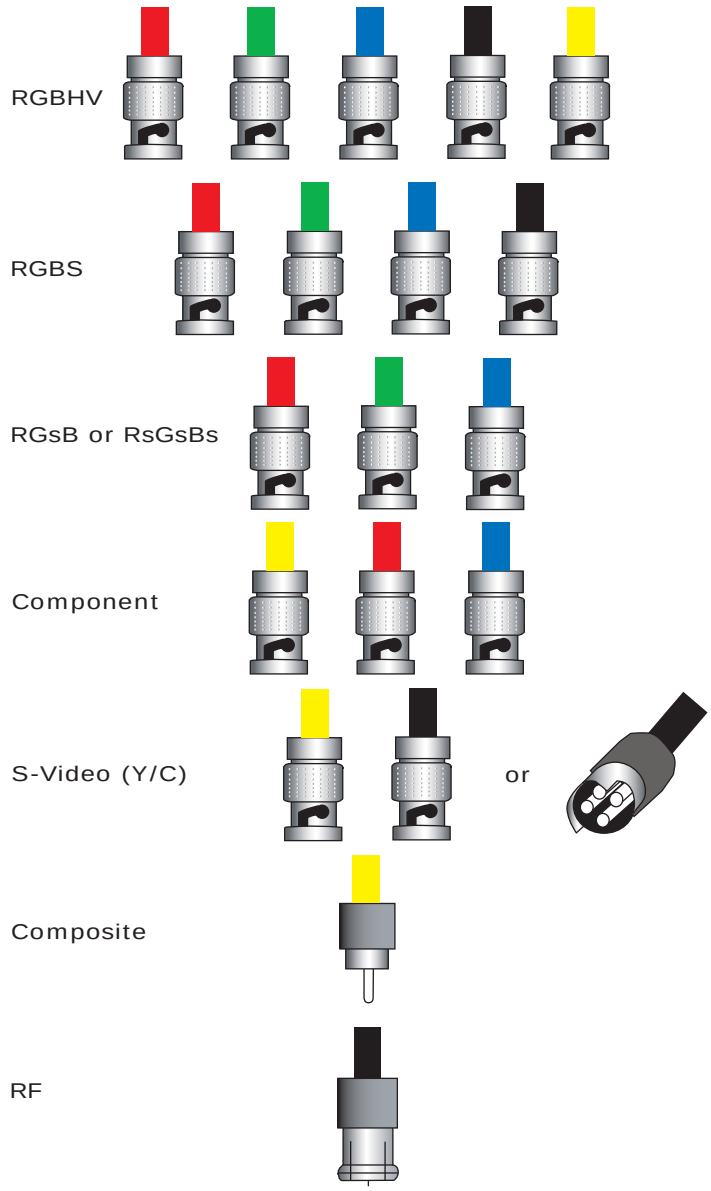


The composite video and audio signals are sent to a modulator, a circuit that combines the signals and centers them on a carrier frequency. The signal is thus modulated for transmission (i.e., given very specific timing and measurements). To get picture information, the TV essentially deletes the carrier frequency from the signal.

Analog Video Signals, continued

RF signals are carried by coaxial cable, in many instances terminated with an F connector (Figure 3.23).

Figure 3.23
Radio frequency transmission



B = Blue
G = Green
R = Red
RF = Radio frequency
S = Composite sync
s = Composite sync added to a channel
Y/C = Luminance with sync/chrominance

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Analog Video Signals, continued

Signal Separator

Once bandwidth-limited (encoded) signals reach a display, they must be decoded. Decoding signals is the reverse of the operation of encoding.

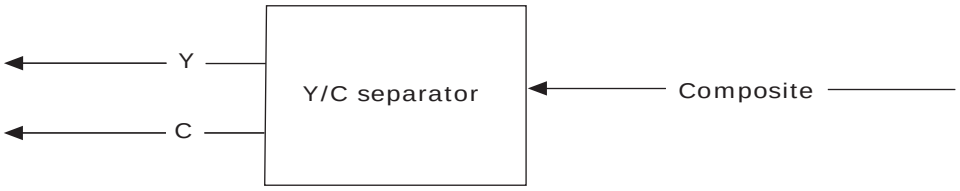
In decoding, some of the information is stripped away, so the resultant picture is only as good as the remaining information.

Working backwards, the RF or composite video information is decoded first. To form these signals, the chrominance information was combined with the luminance and sync information. Sync is stripped off the signal and supplied to the sync circuitry. However, separating Y and C signals is a significant challenge and is performed satisfactorily by only a small number of manufacturers' devices.

Filters

One of the issues related to the picture quality produced by the display device is the quality of the Y/C separator (see Figure 3.24). Its ability is not only to separate the two signals, but also to deal with the artifacts generated by the separation determines the picture clarity and detail.

Figure 3.24
Y/C separator



Y/C = Luminance with sync/chrominance

Three techniques can be used to separate Y and C signals. Each is a different kind of filter. They are, in order of least to best quality:

- Low-pass filter.
- Notch filter.
- Comb (transversal) filter.

Analog Video Signals, continued

Low-Pass Filter

The low-pass filter is very effective at separating the two signals. However, it passes all of the information only up to a certain point. The finer detail information contained in the higher frequency information is, therefore, lost with the use of a low-pass filter.

Notch Filter

Notch filters are used in low-cost display devices. The filter notches out a specific frequency or band of frequencies. The inherent problem with this method is that the notch filter removes not only the sub-carrier information, but also the luminance information at the sub-carrier frequency of 3.58 MHz.

Comb (Transversal) Filter

The comb filter is used in the mid- to high-range display devices due to its ability to separate the luminance from the chrominance and eliminate the majority of the cross-color and cross-luminance artifacts. The filter combs out a specific set of frequencies and is very effective at separating the interleaved chrominance and luminance sidebands of the NTSC video signal.

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Analog Video Signals, continued

Decoders (Demodulators)

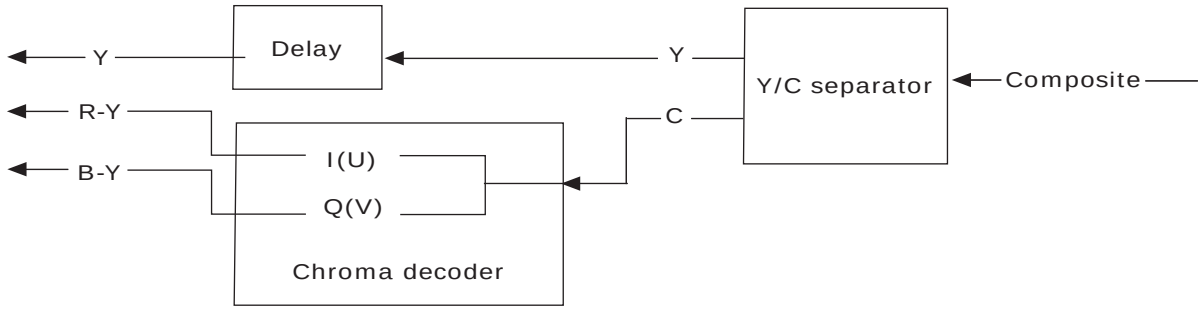
Following the filtering, the composite signal is decoded to an S-video signal. Two types of decoders are:

- Chroma decoder.
- Matrix decoder.

Chroma Decoder

Chroma decoders separate the C signal into the color difference signals R-Y and B-Y. While this process is occurring, the luminance signal is fed to a delay line (see Figure 3.25). This keeps the luminance signal and the color difference signal in time with each other. The chroma decoder determines which colors are reproduced.

Figure 3.25
Chroma decoder



B-Y = Blue minus luminance
I = In-phase
Q = Quadrature
R-Y = Red minus luminance
Y = Luminance
Y/C = Luminance with sync chrominance

During the encoding process, the I and Q signals are 90 degrees out of phase. To accurately decode the signals, this particular phase relationship must be maintained by a 90 degree IQ decoder.

Some consumer decoders employ a different decoder angle. Such a design attempts to expand the decoding process and emphasize all flesh tones. However, accurate reproduction of all other colors is jeopardized.

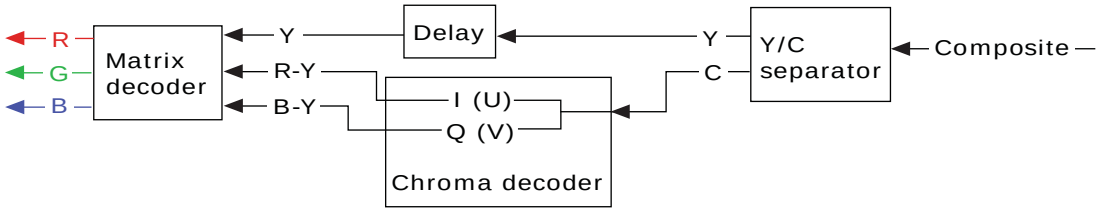
The chroma decoder takes phase-encoded color information and recovers the component signals. It does not adjust the amplitude, but reacts and recreates the appropriate color signals according to the input signal.

Analog Video Signals, continued

Matrix Decoder

The matrix decoder takes the color difference signals output by the chroma decoder and the luminance signal output by the delay circuit and matrixes them together to produce RGB signals (see Figure 3.26).

Figure 3.26
Matrix decoder



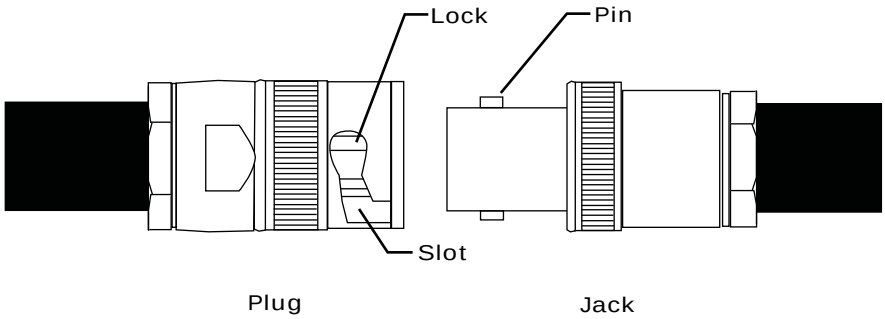
B-Y = Blue minus luminance
I = In-phase
Q = Quadrature
R-Y = Red minus luminance
Y = Luminance
Y/C = Luminance with sync chrominance

This set of signals resembles the original signals but contains less information due to the bandwidth limiting employed in the conversion from RGBHV to composite video.

Sending Video Signals

Full bandwidth signals and component video use coaxial cable with Bayonet Neill-Concelman (BNC) connectors (see Figure 3.27).

Figure 3.27
Bayonet Neill-Concelman connector

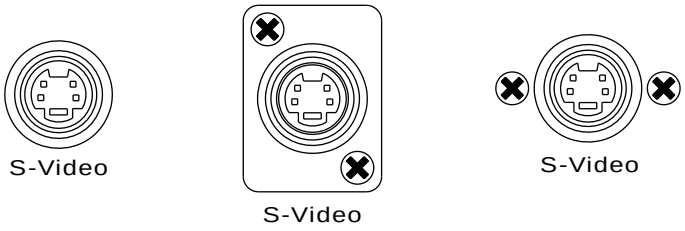


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Analog Video Signals, continued

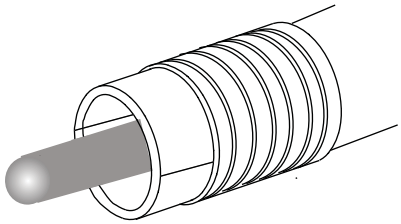
S-video uses coaxial cable with two BNC connectors or a single Deutsches Institut für Normung (DIN) connector (see Figure 3.28).

Figure 3.28
Deutsches Institut für Normung connector for S-video



Component video uses coaxial cable and BNC connectors or phono (Radio Corporation of America [RCA]) connectors (see Figure 3.29). BNC connectors lock in place with a quarter twist, while phono connectors push in without locking. While BNC connectors are used in professional AV environments, phono connectors are used with consumer VCRs or camcorders. Phono connectors are increasingly being used in professional AV design to conduct a variety of video and audio signals.

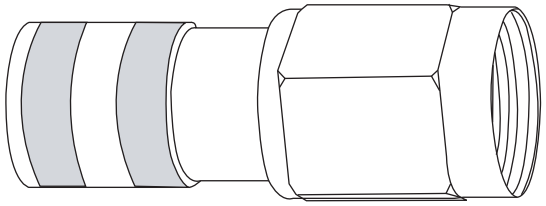
Figure 3.29
Phono connector



Analog Video Signals, continued

RF signals use a coaxial cable and an F connector (see Figure 3.30).

Figure 3.30
F connector



Three options are available for RF signal transmission. The RF signal can:

- Be sent from a transmission antenna, which emits RF waves into the air. The RF waves are detected by receiver antennas. (This is the original method of TV signal reception).
- Travel by cable.
- Travel by satellite.

Analog Video Standards

The three primary video standards, NTSC, PAL, and SECAM, determine:

- How the signal is derived.
- H and V scan rates.
- Blanking periods.
- How the color information is handled.
- Where the sub-carrier signals are located.
- Where the sound information is carried.

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Analog Video Signals, continued

National Television System Committee (NTSC) Standard

In 1954, the United States implemented the NTSC standard, which was compatible with its existing broadcasting system. NTSC color video can be demodulated on a color or on a black-and-white TV.

NTSC is used in North America, parts of South America, and some countries in the Pacific Rim, including Japan, and the Philippines.

The NTSC system specifies 525 individual horizontal scan lines for each image. The scanning beam scans every other horizontal line, from the top of the image to the bottom, which equals one field. The beam completes one line at 15 734.27 Hz. This is the horizontal scan rate.

The beam shuts off at the end of the first field. Back at the top, the beam fills in the even-numbered lines. Two fields are scanned for every frame. The two fields are displayed in immediate succession, creating the appearance of a single 525-line frame. The beam scans all the lines in a frame at 59.94 Hz. This is the vertical scan rate, which is compatible with the ac electricity supply of 60 cycles per second.

Color for NTSC video is carried at 3.58 MHz. Sound for NTSC video is carried at 4.5 MHz. NTSC 4.43 is a common variant on the NTSC standard, and is a combination of the NTSC and PAL video signals. The horizontal and vertical timing is the same as NTSC, while the color encoding standard uses the PAL color sub-carrier frequency and modulation. This standard is used in Japan and other parts of Asia.

Phase Alternate Line (PAL) Standard

Video professionals in England and Germany delayed developing a standard to review options complementing their broadcasting system, which was slightly different from that of North America. In 1967 they started broadcasting with the PAL standard.

PAL is used in Australia, China, Western Europe, and some of South America and Africa.

The PAL system specifies 625 individual horizontal scan lines. The beam completes one line at 15 625 Hz. This is the horizontal scan rate.

PAL has a field rate of 50 fields per second. The two fields are displayed in immediate succession, creating the appearance of a single 625-line frame. PAL can complete 25 frames per second (fps) or 50 fields per second, which is compatible with the European electrical supply frequency (e.g., 50 Hz).

Color for PAL video is carried at 4.43 MHz. Sound for PAL video varies with the version used.

Analog Video Signals, continued

Other characteristics of PAL are that:

- Although the PAL frame contains 625 lines, only 576 are used for display; the others are reserved for teletext (data). Teletext is only visible with a special decoder and does not interfere with regular image transmission.
- It generally has a better depth of field and contrast ratio than NTSC.
- There may be a slightly yellowish tint to the picture due to a slower scan rate.
- There are several variations of the PAL signal referred to as PAL B, D, G, H, I, and N. These standards vary in video channel bandwidth and audio frequency.

The color process for PAL is less subject to color distortion and hue shifts than NTSC. The PAL system uses a line-by-line reversal of the phase of one of the color components. The phase of each chrominance signal is inverted during the alternate line periods to compare and contrast alternating lines. PAL has a greater reliability in determining the correct color.

Séquential Couleur avec Mémoire (Sequential Color with Memory [SECAM])

Developed in France in 1967, SECAM is operationally one of the world's simplest TV systems. It is used in France, Russia, the former Soviet Union, Asia, and Africa.

Like PAL, SECAM has 625 scan lines and is based on 50 Hz. SECAM uses two color difference signals and modulates them onto alternate lines. Through a built-in delay both signals are available at the same time, which eliminates phasing. With frequency modulation (FM) transmission and good color recovery, saturation was unnecessary.

While NTSC and PAL transmit the Y and C signals simultaneously, SECAM transmits the Y signal continuously and generates only one of the two chrominance signals on any given line. The frame rate is 25 fps, which is compatible with the European electrical 50 Hz supply frequency. The horizontal rate is 15 625 kHz.

SECAM's disadvantage is the visibility of sub-carrier signals, particularly in the mid-gray and white signals. This visibility detracts from its black-and-white compatibility.

SECAM is not compatible with PAL or NTSC.

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Digital Video Signals

Digital video signals are an alternative to analog video signals. Several different standards for digital video are currently used. Some of the standards also include audio and control built into the same cable. These new digital video signal standards require the AV designer to address a range of issues including latency, delay, compression, and audio sync issues.

NTSC, PAL, and SECAM are the standards for traditional, analog video encoding and transmission. Today, however, digital video signal transmission is emerging with digital television (DTV). Different standards apply for digital signal transmission, and like their analog predecessors digital video standards vary by region.

DTV is a TV signal transmitted digitally. When DTV is discussed, the Motion Pictures Expert Group (MPEG) format must be mentioned. MPEG is a collection of video compression tools. It is named after the international group that established it to standardize compressed video and audio. The version typically used for TV is MPEG-2. It provides a set of tools designed to cover a wide range of video and audio quality requirements.

Serial digital interface (SDI) is a digital video standard used in broadcast, production, and post-production systems. SDI can be carried over a single coaxial cable for up to 305 meters (m [1000 feet (ft)]).

High-definition SDI is a standard that transmits audio and video at 1.5 gigabits per second (Gb/s) over a single coaxial cable.

Other digital video devices and signals that a systems designer may have to support within a system include:

- Apple® FireWire® (i.LINK™) serial bus.
- Universal serial bus (USB) and USB2.
- Transmission-minimized differential signaling (TMDS).
- High-definition serial digital interface (HD-SDI).

A number of digital standards are used, including:

- Institute of Electrical and Electronics Engineers, Inc.® (IEEE®) 1394, *Standard for High Performance Serial Bus Bridges* (FireWire).
- Internet protocol (IP).
- Digital video interface (DVI).
- High-definition multimedia interface (HDMI).

Digital Video Signals, continued

Conversion is usually necessary when digital video components or transport are involved. Conversion capability is often built into equipment, supporting both legacy and contemporary standards.

The standards identified above originate from computer video manufacturers but may bridge the gap to high definition television (HDTV) standards. Many displays accept these standards as an option through a plug-in board.

The AV designer should determine the possibility of building a system with all of the electronics in the digital domain, which would eliminate the need for A/D and D/A converters. The designer may decide to convert all signals to a common format, such as RGBHV, and use that as the standard for the components within the system.

Digital Television (DTV) Standards

Broadcast DTV is known as digital terrestrial television broadcasting (DTTB) or terrestrial DTV. As in the case of traditional TV, groups of standards dictate DTV transmission in a given region. The primary standards are:

- Integrated services digital broadcasting (ISDB), used in Japan.
- Digital video broadcasting (DVB), used in Europe, Australia, and Asia.
- Advanced Television Systems Committee (ATSC) standard, used in North America.

Each of these standards broadcasts multiple versions of DTV. DTV includes a variety of formats, some of which offer higher resolution than the traditional NTSC, PAL, and SECAM broadcast standards. DTV formats include standard definition television (SDTV) and HDTV.

Standard Definition Television (SDTV) and High Definition Television (HDTV)

DTV encompasses both standard serial digital signals and high definition serial digital signals in broadcast environments. SDTV programs are typically digital versions of the programming on traditional TV. Usually, SDTV programs are in a 4:3 aspect ratio, similar to traditional TV.

HDTV has a higher resolution, resulting in greater detail and clarity than in SDTV. This is achieved by increasing the number of transmitted scan lines. HDTV video may have either 720 progressive scan lines or 1080 interlaced scan lines. The HDTV aspect ratio is 16:9 or one third wider, and is closer to movie theater aspect ratios than SDTV.

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Digital Television (DTV) Standards, continued

HDTV is superior to analog TV in picture detail and realism, and can be transmitted in the same size channel (6 MHz) as analog broadcasts. This is accomplished by compressing the digital video and audio before broadcast. Compression allows broadcasters to transmit several SDTV programs at the same time on a single DTV channel.

SDTV and HDTV are available in two resolution formats:

- Interlaced scanning (i.e., traditional TV systems)
- Progressive scanning (i.e., computer images)

Table 3.4
Standard definition television versus high definition television

SDTV	HDTV
480p – 480 progressive scan lines	720p – 720 progressive scan lines
480i – 480 interlaced scan lines	1080i – 1080 interlaced scan lines

HDTV = High definition television
SDTV = Standard definition television

Control Signals

Introduction

AV communications signals are controlled by a variety of control protocols. These protocols have different data rates, physical connectors, and applications in AV systems. This section covers the characteristics of the most common control protocols for AV systems.

RS-232 Serial Communications

This is a form of data communications where information is sent sequentially, one piece at a time, down a cable. The most common version of serial communication is classified as RS-232.

RS-232 was named after the Telecommunications Industry Association (TIA) standard TIA-232-F, *Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange*. Part of the standard is bidirectional communications. However, not all devices utilize the feedback feature.

RS-232 is found on many existing AV components and has the following characteristics:

- Bidirectional, providing 1-way or 2-way communication between the device and the control system.
- Protocol is device dependent and similar to many computer languages. It includes embedded error checking to ensure the quality of the data stream and traffic control elements, including stop bits and request to send/clear to send (RTS/CTS).
- Speed of communication (baud rate) is rated in bits per second (b/s).
- Transmitted data quantity is rated according to the number of data bits.

Examples of the data that can be transmitted via the RS-232 protocol include:

- Binary (e.g., 11010001).
- American standard code for information interchange (ASCII [e.g., PLAY]).
- Hexadecimal (e.g., 5A).

Most video projectors have an RS-232 control port. The following RS-232 port settings may need to be adjusted to maintain control:

- Speed of data transfer (baud rate)
- Error checking or parity
- Number of data bits
- Number of stop bits

Devices would not be controllable if their settings were incorrect, even if only one piece of data were wrong.

RS-232 Serial Communications, continued

A common setting for serial communications is 9600/N/8/1, where:

- 9600 is the baud rate.
- N stands for no error checking.
- 8 is the number of data bits.
- 1 is the number of stop bits.

The controlled device and the control port programming must match before communications occurs.

The RS-232 connectors can vary widely. The protocol requires a minimum of two wires for one-way communication and a minimum of three wires for bidirectional. Since it is an unbalanced circuit, RS-232 is limited to 15 m (50 ft). While the most common connector is the 9-pin D-shell (DE-9), just about any type has been used. DIN, captive, and tip-ring-sleeve (TRS) mini have all been used for RS-232.

RS-422 Serial Communications

A serial digital data interface standard similar to, but more robust than, RS-232 is RS-422. It is based on the TIA standard 422-B, *Electrical Characteristics of Balanced Voltage Digital Interface Circuits*, and describes signal voltages.

RS-422 is balanced, so lines can be run longer distances than RS-232 lines, typically 609 m (2000 ft) to 1829 m (6000 ft) with links between equipment normally limited to 1275 m (4183 ft) depending on data rate. It was initially used with DE-9 and 37-pin D-shell (DC-37) connectors, but now is also used with 25-pin (DB-25) connectors. Since it utilizes balanced circuitry for data transmission in each direction, RS-422 requires a minimum of five conductors. It offers balanced lines and its maximum data rate is 10 Mb/s.

NOTE: Some major control system manufacturers include both RS-232 and RS-422 on the same DE-9 connector. This makes the pin-out on the control system's serial control port nonstandard. Connecting a standard pin-out cable to these connectors may cause communication errors. The control manufacturer's manual should be consulted for exact connecting instructions.

RS-485 Serial Communications

RS-485 is based on the TIA standard 485-A, *Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems*. It is a balanced communication protocol similar to RS-422. The advantage of RS-485 over RS-422 is that its signal can support multiple devices on the same line.

Transmission Control Protocol / Internet Protocol (TCP / IP)

Using transmission control protocol/Internet protocol (TCP/IP) as part of the control system, devices can be connected directly to a local area network/wide area network (LAN/WAN) within a facility and access the control built in by the product manufacturer. A projector could permit on and off powering, changing inputs, and checking the lamp condition.

TCP/IP is the protocol used for computer networking technologies, and over the Internet. Within a TCP/IP network, each device is given an IP address that allows it to be controlled over either a closed network or the Internet.

Infrared (IR) Serial Control

Infrared (IR) serial control uses IR light to transmit and receive serial data. IR light's wavelength is longer than that of visible red light but shorter than that of microwaves. IR control signals are produced by sending an electronic signal along a conductor to a light emitting diode (LED), which in turn produces light pulses that can be received by an IR controllable device (e.g., a digital versatile disc [DVD] player). These pulses of light represent bits of data that make up a serial data string that controls the equipment.

IR controls are one-way; commands can be sent to a device but, under typical circumstances, no information can be retrieved back from the device as with RS-232 connections.

If handheld controllers are used, an unobstructed line of sight (LoS) is normally required between the handheld controller and the controlled device. IR signals cannot pass through walls as RF signals can. A distance limitation of about 7.6 m (25 ft) is usually imposed between the controller and the controlled equipment unless repeaters or high-output IR emitters are used.

Handheld IR controls are used in many consumer AV devices. In the professional AV industry, IR serial control is used in both handheld and fixed control devices. In an integrated professional AV system, an IR equipped device is often controlled from a fixed control system. In these cases, a copper cable with an IR LED is attached near the IR receiver to control the device. The commands for that device are programmed into the control system.

Some AV devices (e.g., assistive listening devices) use IR light to transport audio signals to receivers. Though using the same technology, these devices are part of the audio signal flow and are not control system devices.

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Variable Voltage

Variable voltage control can be used when adjustable voltages are required for quality control testing, electronic equipment burn-in, life-tests, and improved system performance. Adjustment of output voltage can be accomplished manually or dynamically. Variable voltage controls are frequently used to adjust temperature, control lighting, and line voltage to amplifiers. Examples of applications include testing of equipment at high and low voltages and reducing level input voltages to amplifiers for sound enhancement

Contact Closure

Contact closures communicate or control through changes in current or voltage. A contact closure between two equipment components or systems notify, activate, or communicate to one system when the state of the other system changes. Contact closures can be monitored, assigned identifiers, and, depending on the system management, displayed.

IEEE® 1394 Standard

A single IEEE 1394 port can connect up to 63 external devices. Data transfer rates are up to 400 Mb/s by the IEEE 1394a standard amendment and up to 800 Mb/s by the IEEE 1394b standard amendment. IEEE 1394 requires that devices be within 4.5 m (15 ft) of the connection or bus socket on a computer or other device.

IEEE 1394 supports asynchronous and isochronous modes. The isochronous mode, which delivers data at a guaranteed rate, reducing the need for buffering, is ideal for applications such as real-time video. IEEE 1394 supports plug-and-play applications and can provide power to peripheral devices. IEEE 1394 is expected to replace RS-232, parallel, and small computer system interfaces (SCSI).

Initial products with IEEE 1394 included DVD and digital video tape players and recorders, digital cameras, and digital camcorders.

Universal Serial Bus (USB)

USB is a bidirectional serial hardware interface protocol for attaching computer peripheral devices.

USB connectivity is used in AV systems for connecting devices to control systems. USB is also used to input content from digital AV devices (e.g., digital recorders and cameras).

Characteristics of USB interfaces are as follows:

- USB 1.0 and 1.1 have a maximum bandwidth of 12 Mb/s.
- USB 2.0 (or high speed USB) has a maximum bandwidth of 480 Mb/s.
- Up to 127 peripheral devices can be attached to a bus.

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Chapter 4
Transmission

A signal can be transmitted from one point to another in many ways, ranging from traditional copper cable to wireless transmission. The design of the transmission system can significantly affect the performance of the end system. This chapter provides the audiovisual (AV) designer with the information necessary to carefully consider the benefits and limitations of each approach.

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Overview

The transmission of signals to, from, and within audiovisual (AV) systems is a critical part of an AV system design process. How a signal is generated and moves throughout the system to its end point impacts signal quality and integrity.

This chapter discusses transmission schemes and components, their use, and the best practices that assist in AV system design. Among transmission topics are wired and wireless transmission schemes; conductor types, uses, and limitations; and their impact on the system and connection types.

A key to understanding analog audio signals is impedance or the amount of resistance in an alternating-current (ac) circuit. Professional audio systems with long cable runs may have lower signal levels than consumer audio systems, and therefore require low-impedance balanced signals.

A balanced system involves signal conductors that have equal, non-zero impedance to ground. Such a system uses balanced cable with two signal conductors and a shield. Typical connectors include X series, latch, rubber (XLR) and 1/4 inch (in) tip-ring-sleeve (TRS) telephone plugs.

Consumer AV equipment, with substantially shorter cable runs, has higher impedance and uses unbalanced cable connectors. Typical unbalanced connectors include the tip-sleeve (TS) and phono (formerly Radio Corporation of America [RCA]), each of which consists of two conductors.

Wire and Cable

Wire and cable are system components (not accessories). Wire and cable installation is usually the most labor-intensive portion of any system installation. In an AV system with professional equipment, the signal should not be placed on a cable highly susceptible to interference and noise.

Wire and cable have essentially one function—to transmit a signal from point A to point B without degradation.

The terms wire and cable are often interchanged, but each has a distinct composition. Wire contains only one conductor, and that conductor may be either solid or consist of strands. Cable contains any number of insulated wires with or without a shield and protected in a jacket. Cable is the result of combining two or more wires in a manner that conforms to specific standards.

Conductor Design

Solid and Stranded Cable

A solid conductor wire uses a single conductor and is less expensive than a stranded conductor. Although relatively inflexible, this cable can be easily formed during installation to any shape desired within the bend radius limitations. Solid conductors are typically reserved for fixed connections in a permanent installation.

Conductors that combine several strands of material, called filaments, into a single conductor are referred to as stranded conductors. The finer the strands, the more flexible the conductor, which enables easier handling and installation. Stranded conductors are flexible and easy to handle, but typically more expensive. They are used when flexibility is required (e.g., a wire running to a camera pan-and-tilt head). The more strands in a stranded conductor, the greater the cost and the greater the flex life (i.e., how long a wire will last until it breaks). Stranded conductors offer slightly lower resistance than solid conductors when comparable gauges are considered.

Applications of Solid and Stranded Cable

Solid conductors within a cable are typically used for high-current applications (larger conductors) and telephony, data, and control circuits in low-current applications. Solid conductors in a cable provide the least amount of resistance and provide for a good mechanical connection to punch-blocks and special wire-pinching connection schemes.

Stranded conductors within a cable are typically used for low-voltage installations, where flexibility is a prime concern. Typical uses for this type of cable are microphone, line level, serial control data, and loudspeaker circuits. Stranded cables are typically terminated with a connector at the intended device end. Stranded cable conductors can also be tinned with solder for connection to terminals.

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Conductor Gauge

Conductors may have various sizes and are measured in size or diameter. Numerous wire gauge specifications are used around the world. In North America, the most popular is the American wire gauge (AWG) system. Conductors are sized with a wire gauge.

Aught is a term used for standard conductor gauges larger than 0 AWG. Numbers greater than 1 are smaller in gauge. Numbers expressed over zero, such as 3/0, are larger than 1 aught (Table 4.1).

Table 4.1
American wire gauge

AWG Size	Diameter mm (in)	Comparison
3/0	14.73 (0.58)	Broom handle
1	7.4 (0.29)	Little finger
12	2.1 (0.08)	Spaghetti
20	0.81 (0.03)	Diameter of a pin

AWG = American wire gauge
in = Inch
mm = Millimeter

NOTE: The AV industry uses wire in the range of 6 AWG [4.1 mm (0.16 in)] to 26 AWG [0.41 mm (0.016 in)].

Plenum and Non-Plenum Ratings

According to the Telecommunications Industry Association (TIA), plenum is a compartment or chamber to which one or more air ducts are connected and that forms part of the air distribution system. In the AV industry, plenum is short for return-air plenum. This area is used as the return source for a building's air ventilation.

Cable jackets are rated by North American and international standards for flammability, smoke generation, smoke density, and amount of toxic gases generated under flame. In AV applications, the primary distinction in this regard is made between plenum- and nonplenum-rated cable.

Plenum-rated cable meets the flammability and smoke requirements for fire and life safety. It is fire retardant and does not emit harmful or deadly fumes while it burns. Any cable with a rubber jacket and some cable with a polyvinyl chloride (PVC) jacket is nonplenum and cannot be used in a return-air plenum space.

The application and environment determines the cable selection. The selection rules may be found in the local electrical codes. Some local requirements may require all cable to be placed in conduits.

NOTE: In all cases, adherence to the strictest applicable electrical code is critical.

Cable Types

Four primary types of cable are used in AV installation:

- Coaxial cable—Commonly used for video
- Twisted-pair cable
  - Shielded twisted-pair (STP) cable—Commonly used for audio and low-speed communication data such as RS-232, RS-422, and RS-485 serial communication (see Chapter 3: Signals, for more information about serial communication.)
  - Unshielded twisted-pair (UTP) cable—Commonly used for high speed data transmission, data control, and loudspeakers
- Multiconductor and hybrid cable
- Optical fiber—Commonly used for longer-distance transmission of audio, video, or data

These cable applications may cross over and be combined (e.g., audio and video can be run on UTP cable as data; audio can be run on a coaxial cable).

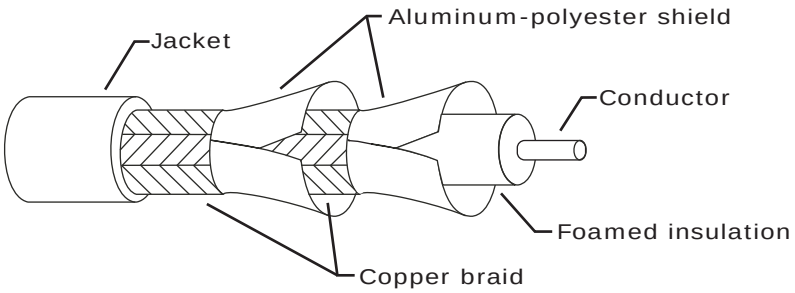
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Copper Cable

Coaxial Cable

Coaxial cable, where two conductors are located on the same axis, contains a single center conductor, a dielectric, one or two types of shields, and a jacket (Figure 4.1).

Figure 4.1
Coaxial cable



Coaxial cable is an appropriate choice for high-frequency signals. It is most commonly used for unbalanced circuits in analog video. It can be run long distances, carry high bandwidth signals, and provide good electromagnetic interference (EMI) and radio frequency interference (RFI) protection.

A high-quality coaxial cable keeps the shield at a consistent distance from the center conductor throughout the full length of its run. This ensures that the cable impedance is consistent throughout. Changes in distance can cause impedance variations, which is why the specified bend limitations and pulling tensions should be carefully observed before installing coaxial cable.

The most important distinction among various coaxial cables is impedance. Coaxial cables used in the AV industry may have one of two impedance values:

- 75 ohm impedance, the most common and used for video information
- 50 ohm impedance, used for radio frequency (RF) broadcast, computers and local area networks (LANs), and audio or antenna feeds

Impedance matching is important. Electronic devices have specific output and input impedance. Using the wrong cable causes loss of signal information, resulting in ghosting and reflections on the visual display. Cable impedance should be checked by comparing the cable's model number to the catalog reference.

The 75 ohm video cable is available in different sizes. The smaller the cable, the greater the loss over the same distance.

Coaxial Cable, continued

Signal loss is generally specified in dB per 30.5 meters (m [100 feet (ft)]). If a 20 dB (100 milliwatt [mW]) signal is applied to 30.5 m (100 ft) of cable rated at 4 dB per 30.5 m (100 ft), 16 dB (roughly 50 mW) will be measured at the other end. Also, as the frequency of the signal increases, the loss in the cable increases. For example, the loss of signal in Series 58 is 4.2 dB per 30.5 m (100 ft) for 100 megahertz (MHz) but 14 dB per 30.5 m (100 ft) for a 900 MHz signal.

Series Classification

Besides classification for impedance, coaxial cable has a Series classification. Series 59 is a common video coaxial cable.

Table 4.2 shows a few common cables and their purposes.

Table 4.2
Series classification

Series	Impedance	Common Use
8	50 ohm	Antenna leads
58	50 ohm	Antenna leads (more loss than Series 8)
6	75 ohm	General purpose video
59	75 ohm	General purpose video (more loss than Series 6)
179	75 ohm	Red, green, blue (RGB), horizontal sync, and vertical sync (RGBHV) video (more loss than Series 59; also called mini coaxial)

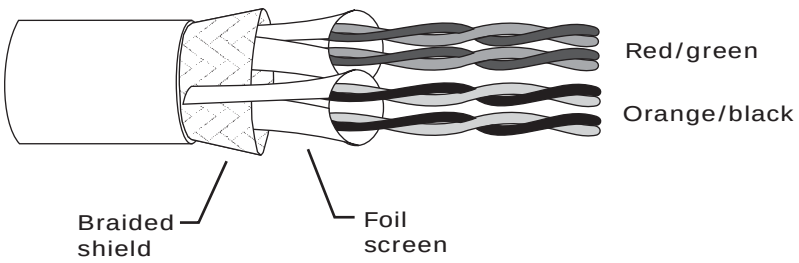
NOTE: Often, multiple video cables are bundled together in one jacket. These are generally referred to as RGB cables and can be made of three, four, and five separate video cables in one outer jacket. They are color coded for identification.

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Twisted-Pair Cable

Twisted-pair is the most widely used variety of cable in AV. Twisted-pair cable consists of at least one pair of wires twisted together to form a single run (Figure 4.2). Each wire is isolated from the other by insulation and twisted inside an outer jacket. Twisting the cables, rather than running them side by side, reduces crosstalk and reflection.

Figure 4.2
Twisted-pair cable



Twisting the wires helps ensure each is subjected to the same outside interference, so that the resulting noise is easily canceled out in the input circuit. This provides significant EMI protection at low frequencies.

Twisted pair is laid in specific lengths and has a specific number of twists per 25 mm (1 in) depending on the cable type and purpose. The more twists, the higher the manufacturing cost. The closer and more exact the spacing between the conductors, the more balanced the pair and the greater the noise reduction.

Shielded Twisted-Pair (STP) Cable

STP is two insulated wires twisted with a shield wrapped around them. The shield decreases outside noises from EMI and RFI. There are two designs for shielding twisted-pair cable: braided shield and foil shield with drain wire.

Braided Shield

Braided shield cable consists of small gauge wires braided together and encompassing the twisted pair. At termination, part of the shield is unbraided, twisted, and connected to ground. A foil shield is sometimes used in addition to a braided shield. Braided-shield cables are generally more flexible than foil shield.

Shields are rated for their effective coverage. For example, a braided shield may provide 95 percent coverage against interference.

The typical portable microphone cable consists of a braided shield around a single pair of wires. It is also common to have multiple microphone cables within one jacket, commonly termed a snake cable.

Twisted-Pair Cable, continued

Foil Shield with Drain Wire

In this type of shield configuration, an uninsulated (drain) wire is wrapped with the foil shield around the twisted pair. At termination, the drain wire is connected to ground while the foil is trimmed away. This type of cable is less expensive than braided shield. It is also less flexible than braided and intended for permanent installs.

Unshielded Twisted-Pair (UTP) Cable

UTP is lighter weight, more flexible, and less expensive than STP. It is generally easy to install and common for computer network applications. This cable is ideal for simple system installations, as long as the cable capability is not exceeded.

While coaxial cable more effectively carries high frequencies (e.g., high-resolution video and graphics) and maintains signal quality for long cable runs, the cost savings and ease of installation of UTP in these applications are widely considered more important than the loss of quality.

Ethernet and telephone cables are UTP. These communication cables are organized into different categories. Each category is given a number that relates to the speed at which the cable may transfer data. The lower the number, the slower the speed. The cable categories are governed by TIA standard 568-B, *Commercial Building Telecommunications Cabling Standard*. The standard addresses all aspects of cabling and hardware for voice and data communications in a commercial building for a computer network.

The categories of UTP cable have the following characteristics:

- Category 3 cabling is a UTP cable that has a bandwidth of 16 MHz. It is 24 AWG [0.51 mm (0.020 in)] wire in twisted pairs, with a typical impedance of 100 ohm, useful for data transmission.
- Category 5e is a UTP cable with requirements specified up to 100 MHz. It is either 22 AWG [0.64 mm (0.025 in)] or 24 AWG [0.51 mm (0.020 in)] with 100 ohm impedance. It has 4 pairs within the cable jacket.
- Category 6 offers speeds up to 250 MHz.

In addition to lower voltage signal applications, UTP is also used at larger gauges for loudspeaker cabling.

Multiconductor and Hybrid Cable

Multiconductor and hybrid cable is used when several conductors are required to carry varying signals between devices. Multiconductor and hybrid cable contain a mixture of solid and stranded conductors, which may be shielded and unshielded. Multiconductor and hybrid cable is typically constructed to carry electronic signals capable of cohabitating within the same jacket without introducing noise or crosstalk interference. Many wire manufacturers recognize this importance and typically provide a document on recommended uses of the cable. The cable manufacturer and the component manufacturer should be consulted in case of any doubt about the appropriate use of multiconductor and hybrid cable.

Limitations

The physical makeup of any conductor—type, size, length, purity, and jacket—has certain limitations. Manufacturers routinely publish specifications that indicate the limitations of their cables.

Local authorities publish requirements for cables used with specific system types and applications. An example of a limited cable is a power-limited cable.

Performance Issues

The quality of cable can dramatically affect the transmitted signal quality and the overall system functionality. Poor cabling has often been the reason why systems do not perform to specifications. The following are factors commonly affecting cable performance.

Loss versus Frequency

As with all cable, the size, conductor, dielectric, length, insulator and jacket all have a profound impact on the signal passing through it. Most information on the impact of the cable can be found in the manufacturer's specifications. However, not all manufacturers list the effect of signal loss or bandwidth reduction in their specifications. In these cases, the designer and installer should contact the manufacturer for detailed information or use a cable from a manufacturer that provides such data.

Table 4.3 shows a typical cable loss factor sheet.

Table 4.3
Typical Series 6 cable nominal attenuation

MHz	dB/100 ft	dB/100 m
1	0.24	0.78
10	0.52	1.71
50	1.18	3.85
100	1.83	6.02
200	2.73	8.95
400	3.95	12.97
700	5.38	17.65
1000	6.45	21.15

dB = Decibel
ft = Foot
m = Meter
MHz = Megahertz

Performance Issues, continued

Spectrum Issues

Bandwidth is an important element of the transmission system. It can be expressed as the amount of data that can be transmitted in a fixed amount of time. For digital devices, the bandwidth is usually expressed in bits per second (b/s) or bytes per second (B/s). For analog devices, the bandwidth is expressed in cycles per second or hertz (Hz).

In electronic communication, bandwidth is the width of the range (or band) of frequencies that an electronic signal uses on a given transmission medium. In this usage, bandwidth is expressed in terms of the difference between the highest-frequency signal component and the lowest-frequency signal component.

Although humans can hear portions of the frequencies from 20 Hz to 20 000 Hz, speech transmitted by analog telephone systems carries voice signals between 300 Hz and 3400 Hz (bandwidth of 3100 Hz), which reflects the majority of what we actually hear and recognize as speech.

A typical voice signal has a bandwidth of approximately 3 kilohertz (kHz) and an analog television (TV) broadcast video signal has a bandwidth of 6 MHz.

Voltage Drop

Electrical conductors have resistance, and power is consumed due to this resistance. This consumption of power can result in voltage drop. Calculating the voltage drop is important when determining the conductor sizing for a circuit. Voltage drop can be calculated if certain factors are known. These factors are:

R = Resistance per foot of the conductor (ohms/ft)

I = Current in the conductor (amperes)

L = One-way length of circuit (footage)

D = Cross section area of conductor (circular mils)

K = Specific resistance

NOTE: K equals the specific resistance of the conductor material that is 0.3 m (1 ft) long with a diameter of one mil (one inch divided by 1000 [1 mil = 0.001 in]).

When these factors are known, the following formulas may be used to determine the voltage drop (V_d):

For two-conductor single-phase and three-wire single-phase circuits—

$$V_d = \frac{2K \times L \times I}{D}$$

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Performance Issues, continued

For three-conductor three-phase circuits—

$$V_d = \frac{2K \times L \times I}{D} \times 0.866$$

Signal Separation and Cable Installation Parameters

Signal separation refers to providing physical distance among cables carrying various signal levels. This protects weaker, low-voltage, signals from noise and interference. Signal separation principles apply to cable routing and installation.

When grouping cables together in a bundle, all cables should be intended for only one signal type. Generally, cables should be grouped according to the following categories:

- Microphone
- Line
- Control, data, and communication
- Loudspeaker
- Alternating current (ac) technical power
- Direct current (dc) technical power
- Video
- Radio frequency (RF)

When pulling cable, different signal levels should be kept in separate conduits. In general:

- Signal cables should be routed in a completely alternate path from power cables.
- Metallic conduit should be used for signal cables.
- Microphone cables and speaker cables should not be placed in the same bundle or conduit.
- Audio cables should be separate from data cables to avoid spikes and data clicks in audio.
- If a control cable contains digital information, it must be kept separate from other signal cables.
- If there is only one conduit, high-level and microphone level signals should not be mixed.

IMPORTANT: When planning a cable route, adequate separation should be included between signal cables and the following sources of electrical noise: fluorescent lights, transformers, motors, elevator relays, radio transmitters for burglar alarms, and similar sources of noise.

Signal Separation and Cable Installation Parameters, continued

Best Practice

Signal crossing is an important planning consideration. When planning placement for conduits that will carry critical signals, conduits should cross other conduits at 90 degrees. This is an important design consideration because cables that contain critical signals can otherwise pick up crosstalk.

Crosstalk is caused by inductance. Electromagnetic waves radiate out in circular fields, and when cables are placed in parallel, the cable carrying the lower-power signal picks up interference from the cable carrying the higher power signal. However, when wires cross at right angles, the fields do not interfere with each other.

Termination

All AV system electronic components require physical interconnection. The professional AV industry typically does not use pre-packaged cables sold with the equipment. Rather, installation technicians select the appropriate cable, cut it to a custom length, and terminate it with application-specific connectors.

Poor terminations cause distortion or disruption in the flow of electricity. Poor termination is the single most prevalent problem in electronic systems. These problems are difficult to troubleshoot because they can be intermittent.

Connectors

Termination is the technique of connecting cable to a connector. Cable is terminated either by soldering, crimping, or compressing the wire.

Connectors are used to mate wire to equipment jacks. Jacks are the input connectors on equipment. Connectors mate to jacks in a number of different ways:

- Twisting
- Twisting and locking
- Threading
- Screw or snap-down locking
- Contact pressuring

A connector on a piece of equipment is called a socket. The connector on the end of a wire is called a plug.

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Connectors, continued

Common connectors used in AV systems are:

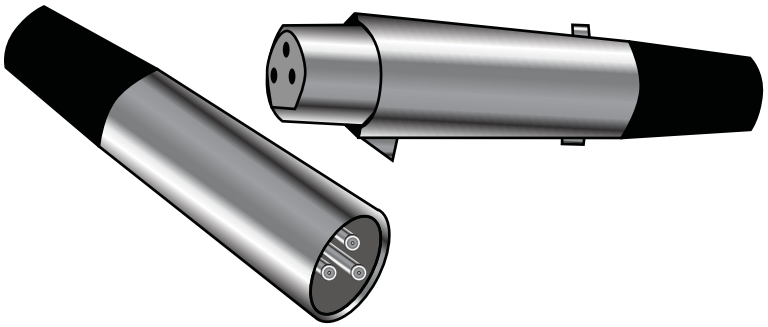
- X series, latch, rubber (XLR) connectors.
- Phono connectors.
- Telephone plugs.
- Bantam connectors.
- 3.5 mm (1/8 in) mini connectors.
- Deutsches Institut für Normung (DIN) connectors.
- D-subminiature connectors.
- Null modem adapter and gender changer.
- Bayonet-Neill Concelman (BNC) connectors.
- Digital visual interface (DVI) connectors.
- High-definition multimedia interface (HDMI).
- F connectors.
- Captive-screw connectors.
- Insulation displacement connector (IDC) blocks.
- Modular connectors.

X Series, Latch, Rubber (XLR) Connectors

The XLR connector (see Figure 4.3) is commonly used for carrying audio signals.

An XLR connector may take on different forms ranging from a rectangular chassis mount jack to a right angle plug. Most common are the straight connectors intended to terminate on the end of a cable. These have a large area to grip as the connectors are mated.

Figure 4.3
Male and female X series, latch, rubber connectors



Connectors, continued

XLR connectors are most commonly used for:

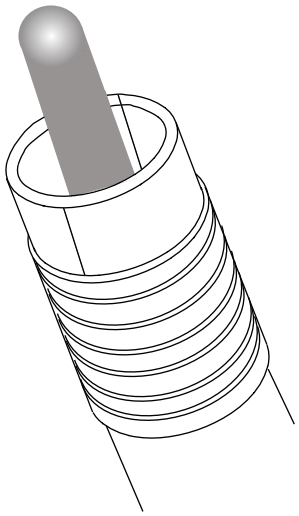
- Audio.
- Control.
- Power.

The microphone is the most common piece of equipment that uses an XLR connector.

Phono Connectors

The phono connector (see Figure 4.4) is used for carrying video or unbalanced audio line-level signals in consumer products. They are also used for data and power connections.

Figure 4.4
Phono connector



A phono is the simplest firm-fitting connector. It has a solid center pin and an outside sleeve. The phono sleeve is a push-on, pressure-fit, type. It is inexpensive and easy to disconnect, but provides only a fair electrical connection.

Phono connectors are designed to be connected and disconnected. The contact has a wiping action to clean the plug; however, a pressure connector should never remain unplugged.

Phono connectors are typically used for:

- Audio.
- Video.
- Control.
- Power.

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Connectors, continued

Telephone Plugs

Telephone plugs are also called quarter-inch plugs.

Plug type connectors come in several different sizes. Telephone plugs are used for audio signals, and are common musical instrument and equipment connectors. These connectors are found on both microphone- and line-level signals. They are also used as headphone and microphone connectors.

Telephone plugs come in two configurations:

- Three conductors, TRS, for balanced circuits and unbalanced stereo circuits (see Figure 4.5)
- Two conductors, TS, for unbalanced circuits (see Figure 4.6)

Figure 4.5
Tip-ring-sleeve connector

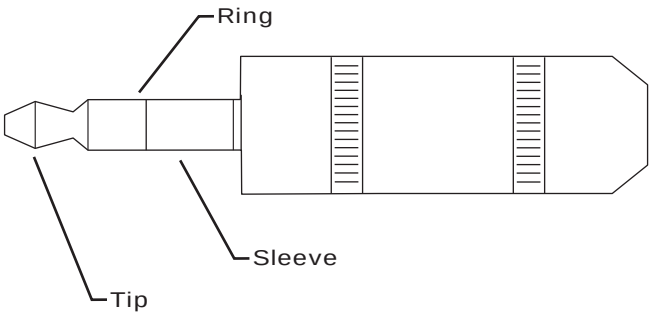
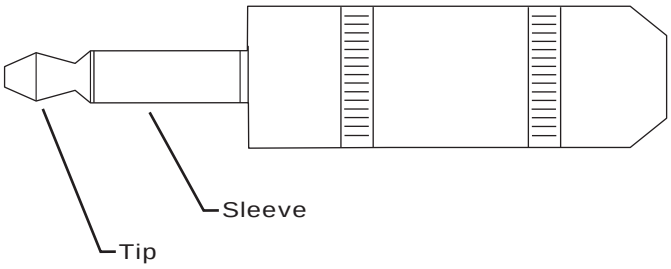


Figure 4.6
Tip, sleeve connector



Connectors, continued

A telephone connector and a phono connector are terminated similarly.

A TRS is typically wired for balanced connections as follows:

- Tip connected to the positive
- Ring connected to the negative
- Sleeve connected to the ground (shield)

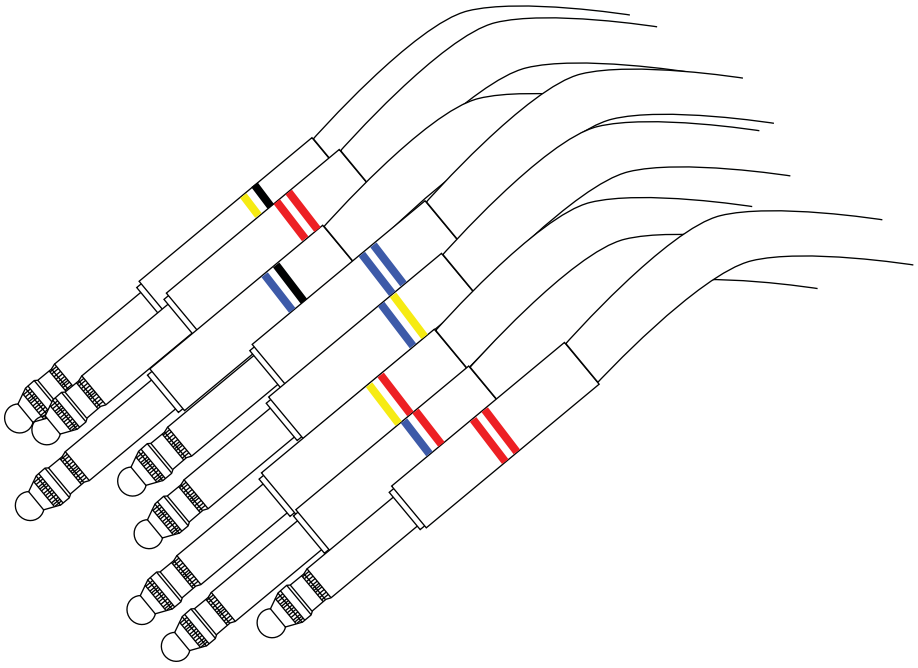
A TS is typically wired for unbalanced connections as follows:

- Tip connected to the positive (hot)
- Sleeve connected to the ground

Bantam Connectors

Bantam connectors (see Figure 4.7) are used most often in modern professional patch bays. A patch bay is a junction panel of connector jacks (patch points) for making system connections. It consists of two rows of connector jacks wired with various signals from rear equipment panels.

Figure 4.7
Bantam connectors



Bantam connectors are smaller than 6.3 mm (1/4 in) telephone plugs and are larger than 3.5 mm (1/8 in) miniatures. Bantam connectors also have a TRS design and can be wired the same as the full size 6.33 mm (1/4 in) for either balanced or unbalanced lines. They are most commonly used for audio.

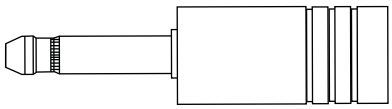
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Connectors, continued

3.5 mm (1/8 in) Miniature Connectors

Smaller versions of the telephone jack are referred to as miniature and subminiature plugs. Their design is similar to the telephone plug, except in size, because they have 3.5 mm (1/8 in) as shown in Figure 4.8 and 3.5 mm (1/8 in) diameter. They may be wired the same as the full-size telephone plug for either balanced or unbalanced lines.

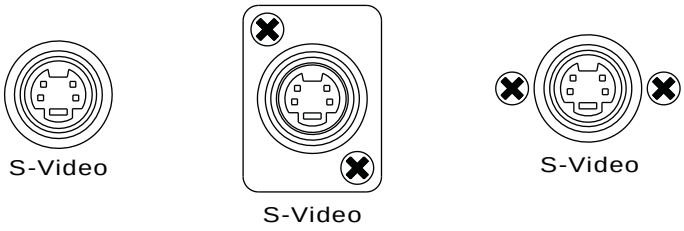
Figure 4.8
3.5 mm (1/8 in) miniature connector



Deutsches Institut für Normung (DIN) Connectors

Like many other connectors, DINs are available in different configurations. Termination procedure depends on the design of the connector, and the connector design is determined by the application. Their most common application is carrying S-video signals, calling for a DIN in a 4-pin configuration (see Figure 4.9). S-video also can use two BNCs.

Figure 4.9
Deutsches Institut für Normung connectors



Connectors, continued

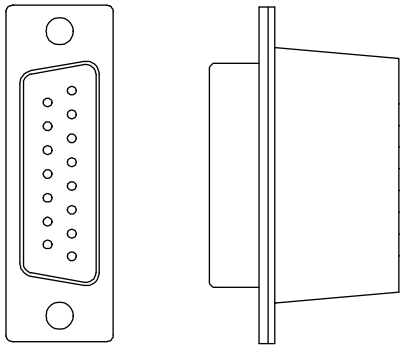
D-Subminiature Connectors

A D-subminiature connector (see Figure 4.10), a generic name for D-shaped connectors, is a multi-pin connector used in data communications. D-subminiature connectors are categorized by metal shield size and their specific pin configurations as follows:

- DA15
- DA15 HD
- DB25
- DC37
- DD50
- DE9

The letter following D indicates the shell size, and the digits indicate the number of pins in the connector. Also, connectors may be regular and high-density (HD) connectors. An HD D-subminiature connector has more pins in the same size shell than a regular density connector.

Figure 4.10
D-subminiature connectors



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Connectors, continued

The D-subminiature connector was first used in the computer industry and has since been employed in other devices. In the AV industry, this connector type is common on video projectors, computer video output devices, switchers, and processing and control equipment.

D-subminiature pin-out varies among the manufacturers.

Null Modem Adapter

A null modem adapter can help determine the proper wiring scheme. It has a male and female connector on it so it can be inserted inline. Null modem adapters are available for different types of D-subminiature connectors.

For a DE9, a null modem adapter has input pin 2 connected to output pin 3 and input pin 3 connected to output pin 2. The adapter is put in the line, reversing the pin 2-3 configuration. Once the adapter is in place, the communication is tested. When the appropriate wiring scheme is determined, adapters are removed and wiring is corrected permanently.

NOTE: Null modem adapters should not be used as a permanent solution. The wiring should be corrected and the adapter removed.

Gender Changer

Gender changer is another type of adapter, which may have male-to-male or female-to-female configurations and is available for many connectors (e.g., D-subminiature and BNC). While a standard serial cable has a male connector on one end and a female on the other, a male-to-male cable may be required. A gender changer could be temporarily added to complete the connection.

NOTE: Gender changer adapters should not be used as a permanent solution. The wiring should be corrected and the adapter removed.

Bayonet-Neill Concelman (BNC) Connectors

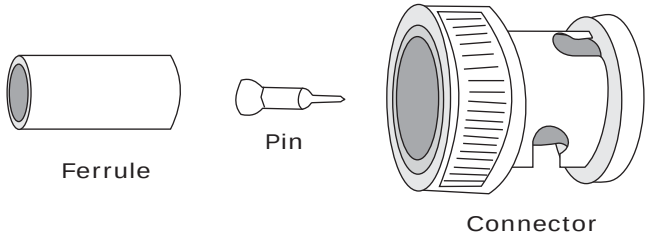
BNC connectors are the most common and most professional coaxial cable connector because of its reliability and ruggedness. BNCs are connected with a slight push and then a twist to lock them into place.

Connectors, continued

A typical BNC connector (see Figure 4.11) has three elements:

- Ferrule
- Connector body
- Silver or gold plated center pin

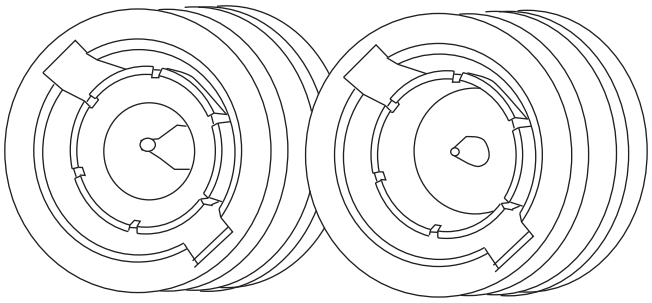
Figure 4.11
Bayonet Neill-Concelman connector components



Two categories of BNC connectors—50 ohm and 75 ohm—are intended for two distinct purposes. They slightly differ in appearance and electrical termination impedance. If the wrong connector is used, the signal can be distorted and attenuated.

The 50 ohm connectors are intended only for use with 50 ohm cable and are most often used in the AV industry as a connector for RF antenna signals. They are identified by a white insulator surrounding the center pin. The 75 ohm connector is most common and is used for video signals, which are 75 ohm (see Figure 4.12).

Figure 4.12
50 ohm and 75 ohm Bayonet Neill-Concelman connectors



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Connectors, continued

Termination with BNC connectors should be approached with caution. Not all BNC connectors fit every available cable. Hundreds of different BNC connector models are manufactured to fit varying cable size specifications and other specific applications.

With few exceptions, equipment manufacturers install female gender BNC connectors on their equipment, and cables are terminated with male connectors.

Digital Visual Interface (DVI) Connectors

DVI connectors are a newer standard that provides for a direct digital connection of a source to a display. These types of connections are limited to short transmission distances of about 5 m (16 ft) (e.g., between a personal computer [PC] and a monitor) and support the full standard National Television System Committee (NTSC) resolution.

Two types of DVI connectors are:

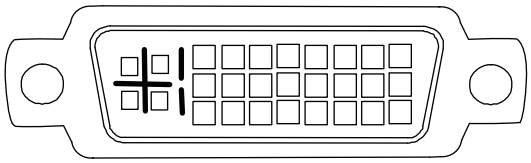
- A 24-pin connector, which supports digital signals only.
- A 29-pin connector, which supports both digital and analog signals.

The DVI standard uses three common multi-pin connectors to terminate cables carrying DVI signals:

- DVI-D, which carries only the digital RGBHV signal
- DVI-I, which carries analog RGBHV information as well as digital RGBHV
- DVI-A, which carries only analog video

The DVI-I connector has both digital and analog signals. For an example of 29-pin DVI-I female connection, which carries both digital and analog signals, see Figure 4.13.

Figure 4.13
Digital video interface I connector



Connectors, continued

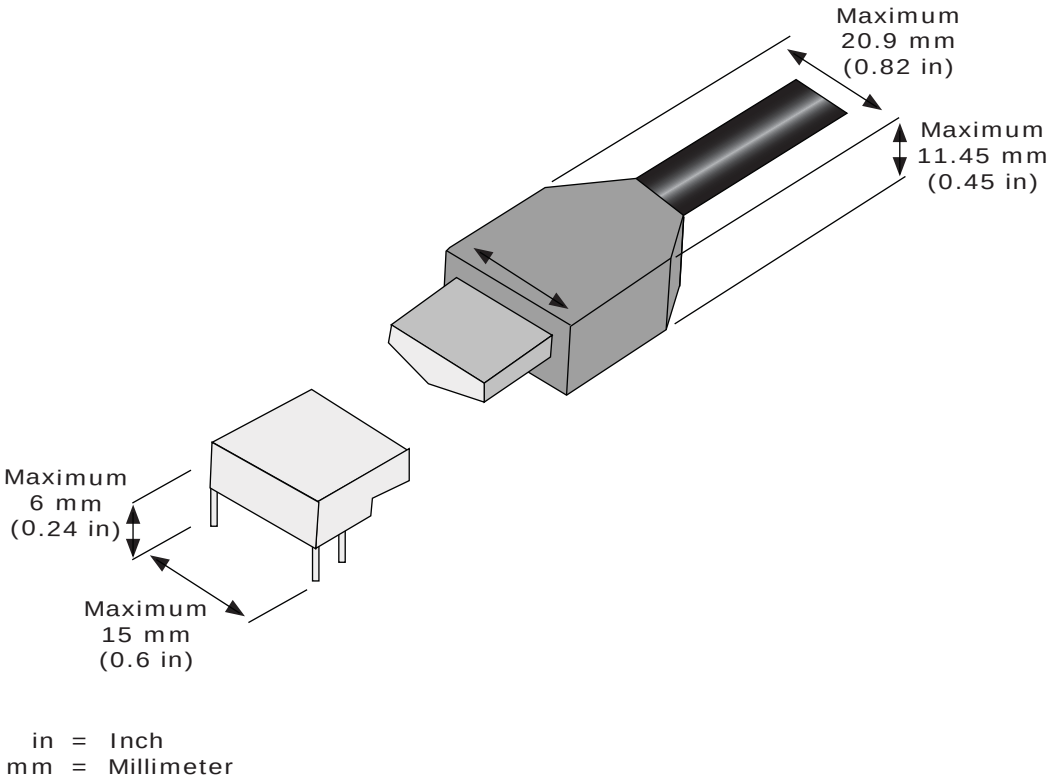
The DVI-D variety is digital-only and does not have the four separate pins.

NOTE: Using DVI interconnections in an AV system often requires other components, such as signal boosters or buffers. The DVI standards that carry analog video present the designer with the same cabling issues as standard analog video systems.

High-Definition Multimedia Interface (HDMI)

HDMI is becoming the standard for high quality all-digital audio and video in the consumer marketplace (see Figure 4.14).

Figure 4.14
High definition multimedia interface



HDMI signals include audio, control, and digital asset rights management information. It is a plug-and-play standard that is fully compatible with DVI.

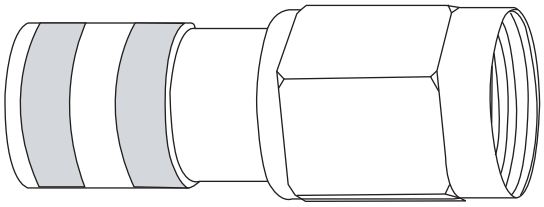
However, HDMI is not a professional standard. It is primarily intended as a point-to-point (PTP) connection between video devices. Incorporating these types of connections within a video system may create a range of issues for the AV designer to consider, including distance limitations, problems with recognizing several devices, gain peaking and timing issues, and cable delay that can prevent signals from locking during communication between devices.

Connectors, continued

F Connectors

An F connector (see Figure 4.15) is a threaded or push-on connector used in transmission applications such as cable TV. It is inexpensive because the cable‘s center conductor also serves as the connector‘s center pin.

Figure 4.15
F connector



An F connector is used for:

- RF-modulated audio and video.
- Video.

F connectors are threaded like nuts and bolts. Some F connectors twist into place and others push together.

One- and two-piece versions of F connectors are available. The one-piece connector, although more expensive, is used in community antenna television (CATV) because it has less RF leakage and is generally more reliable. The two-piece version has a separate ferrule that must be slid on over the cable before assembly. F connectors may have inconsistent impedance even when properly terminated.

Captive-Screw Connectors

Captive-screw connectors may be 3.5 or 5 mm large and provide connections for balanced or unbalanced line-level stereo audio and communications signals. The 3.5 mm captive-screw connectors are available in three pole, five pole, and 10 pole sizes. The 5 mm version provides six poles.

Connectors, continued

Insulation Displacement Connector (IDC) Blocks

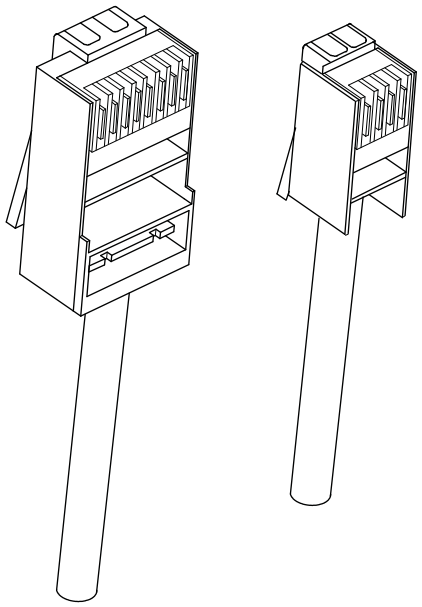
Different block types are available, the most popular of which are 66 block and 110 block. These types of IDC terminations are used for some audio patch bay connections and other types of connections.

Modular Connector

Modular connectors are 4-, 6-, and 8-position telephone-type connectors (see Figure 4.16). They click into place to connect. They are commonly used for data and voice and are available in various sizes and configurations.

NOTE: Registered jack (RJ) is incorrectly used as a term to refer to modular connectors.

Figure 4.16
8- and 4-position modular plugs



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Optical Fiber Cable

Types of Optical Fiber Cable

Optical fiber cable is commonly used to transfer information by means of photons (light) rather than electrons. Its information-carrying material is glass. The source signal is originally made up of electrons, but is converted to light through the use of an optical encoder. The light source generates a beam of light that is turned on and off very quickly to create the pulses of a digital signal. The transparent glass allows light to be guided from one end to the other with minimal loss (light pipe).

Optical fiber cable is available as:

- Singlemode, which has a smaller core and allows only one light pulse to travel at a time.
- Multimode, which has a larger core and allows many light pulses to travel simultaneously.

Optical fiber cable offers high bandwidth and maintains total electrical isolation. It is able to maintain signal integrity in noisy environments, experiencing little signal degradation over long distances. Optical fiber cable is also immune to EMI and RFI. It does not burn and withstands aging and corrosion. Optical fiber lines are also popular for security reasons. It is more difficult to covertly capture data from an optical fiber line than by copper wires or radio waves.

While the use of optical fiber cable in AV systems is more prevalent than in the past, an AV installer does not typically install the cable. Specifications and bids for AV projects increasingly call for the installation of optical fiber cable along with traditional cable. An AV installer may be responsible for connecting the terminated ends of the cable where applicable.

Optical fiber cables are used for transmitting signals consisting of impulses of light. Optical fiber cables are available in the following configurations:

- Simplex (single strand) and duplex (double strand), used for short runs between system components
- Breakout optical fiber cable consisting of multiple individually jacketed fibers in single jacket, used for longer signal transmission runs
- Loose-tube optical fiber cables utilizing fibers that reside loosely inside tubes

WARNING: Never look into the end of an optical fiber cable. Most optical fiber transmission light is invisible but can burn the retina of the eye before the AV installer realizes that the light is present. Light sources for test equipment may be just as hazardous as the regular system light source.

Singlemode Optical Fiber Cable

A singlemode optical fiber cable is a single strand of glass fiber with a diameter of about 8 to 10 micrometers (μm). Through this relatively narrow diameter, a single mode of light propagates at 1310 or 1550 nanometers (nm). Although it carries a higher bandwidth than multimode optical fiber, singlemode optical fiber requires a light source with a narrow spectral width. Other terms that are used for this cable are monomode optical fiber and unimode fiber.

Singlemode fiber provides a higher transmission rate and up to 50 times more distance than multimode, but it also is more expensive. Singlemode fiber has a much smaller core than multimode. The small core and single light wave virtually eliminate any distortion that could result from overlapping light pulses, providing the least signal attenuation and the highest transmission speeds of any optical fiber cable type.

Multimode Optical Fiber Cable

Multimode cable is made of glass fibers with a common diameter in the 50 to 100 μm range for the light carrying component, with the most common size being 62.5 μm. Multimode fiber provides high bandwidth at high speeds over medium distances. Light waves are dispersed into numerous paths or modes as they travel through the cable core of typically 850 or 1300 nm.

In long cable runs greater than 914 m (3000 ft), multiple paths of light can cause signal distortion at the receiving end, resulting in an unclear and incomplete data transmission.

Transmission Principles of Optical Fiber

The two key elements of an optical fiber are its core and cladding. The core is the innermost part of the fiber through which light pulses are guided. The cladding surrounds the core to keep the light in the center of the fiber.

The core's refractive index is higher than the cladding. Light traveling down the core that strikes the cladding at a glancing angle is confined in the core by total internal reflection. In other words, the cladding acts like a mirror to reflect light that normally escapes through the sides of the optical fiber strand back into the center of the fiber.

To reinforce and strengthen the strand, an acrylate coating is applied to the cladding. This increases the original 125 μm diameter of the cladding to 250 μm.

Limitations of Optical Fiber

Two primary factors must be considered in optical fiber selection and system design:

- Maximum supportable distance
- Maximum channel insertion loss

The first factor is maximum supportable distance based on bandwidth, transmitter and receiver specifications, propagation delay, jitter, and numerous other factors. This maximum supportable distance is established by the application standards.

Limitations of Optical Fiber, continued

The second factor is maximum channel insertion loss. The maximum channel insertion loss is established by the difference between the minimum transmitter output power coupled into the optical fiber and the receiver sensitivity, less any power penalties established. The channel insertion loss can be affected by the system design (i.e., number of connections and/or splices, the length, the wavelength of operation, and loss values of components).

Equations allow users to determine whether the system design will remain within the maximum channel insertion loss. For existing systems, the channel insertion loss should be measured. For new installations, the system design can be verified using the equations below based on the minimum component specifications:

- Channel insertion loss < Maximum channel insertion loss
- Channel insertion loss = Cable insertion loss + connector insertion loss + splice insertion loss
- Channel insertion loss = [Cable insertion loss coefficient (dB/km) x length (km)] + [# connector pairs x 0.75 dB] + [# of splices x 0.3 dB]

Therefore, to determine maximum length for a particular system design, the resulting equation is:

$$\text{Maximum length (km/mi)} = \frac{\left[\text{Max chan. ins. loss} - \left(\#\ \text{connector pairs} \times 0.75\ \text{dB}\right) - \left(\#\ \text{splices} \times 0.3\ \text{dB}\right)\right]}{\text{Cable insertion loss coefficient}}$$

Connectors

Optical fiber connectors perform the same function as copper connectors but use a different medium (light impulses through optical fiber as opposed to electrical signals through a wire).

Unlike electrons, which are forgiving when it comes to connector alignment as long as a good electrical contact is made, optical fiber connectors must be precisely aligned to allow maximum signal transfer between the connectors. Many optical fiber connectors require an adapter to precisely align the two connectors tip to tip. The adapters are sometimes referred to as couplers or sleeves.

The most commonly used connectors in backbone optical fiber systems are the straight tip (ST) and subscriber connector (SC). See Figure 4.17 for illustrations of these connectors.

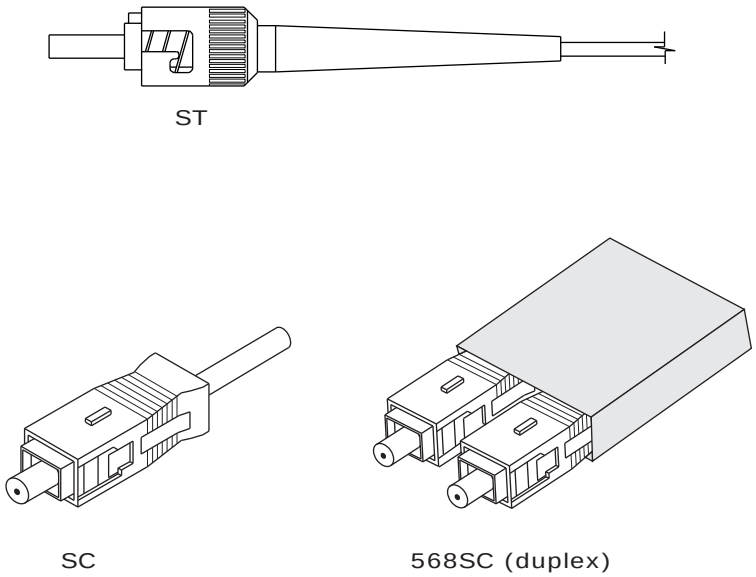
The ST-type connectors feature a bayonet-type coupling that employs a quick release mechanism. The ST connector is keyed to prevent the ferrule from twisting during insertion, while the main connector housing requires only a quarter turn to engage or to disengage. In multimode and singlemode operation, the ST-type connector is used for:

- Premises cabling.
- Networking.
- Test equipment.

Limitations of Optical Fiber, continued

The 568SC general-purpose connector for premises cabling and network applications uses a push-pull mechanism for mating. The plugs mate in a connector housing that aligns the ferrules. An advantage is that two plugs can be joined together to form a 568SC duplex connector. Multifiber capabilities allow for building duplex (two-position) connectors. One fiber core is used to transmit, while the other fiber core is used to receive.

Figure 4.17
Optical fiber connectors



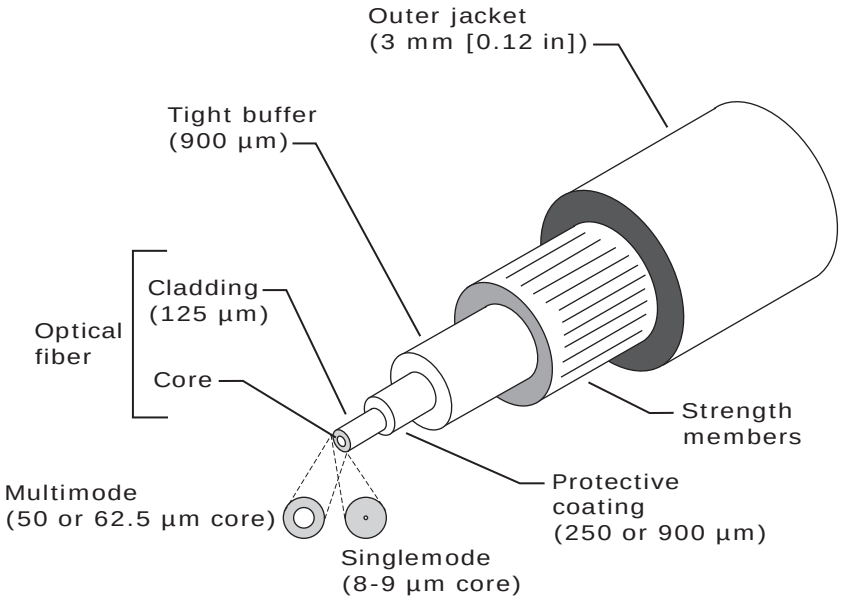
SC = Subscriber connector
ST = Straight tip

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Construction of Optical Fiber Cable

Optical fiber is composed of several elements. The construction of an optical fiber cable consists of a core, cladding, coating buffer, strength member, and outer jacket (see Figure 4.18).

Figure 4.18
Optical fiber cable construction



in = Inch
µm = Micrometer

The optical core is the light-carrying element usually made up of a combination of silica and germania. The cladding surrounding the core is made of pure silica. The cladding has a slightly lower index of refraction than the core. The lower refractive index causes the light in the core to reflect off the cladding and stay within the core.

Index of refraction is the ratio of the velocity of light in a vacuum to the velocity of light in a material. The speed of light in a vacuum is equal to 300 000 000 meters per second (m/s) or 3×10^8 m/s. The higher the index of refraction, the slower the speed of light through the material. The following is the formula for refractive index:

$$n = \frac{c}{v}$$

Where

n = Refractive index

c = Speed of light in a vacuum

v = Speed of light in the given material

Construction of Optical Fiber Cable, continued

Therefore, to find the refractive index of air:

$$c = 300\,000\,000 \text{ m/s}$$

$$n = \frac{300\,000\,000 \text{ m/s}}{300\,000\,000 \text{ m/s}} = 1$$

To find the refractive index of glass:

$$c = 200\,000\,000 \text{ m/s}$$

$$n = \frac{300\,000\,000 \text{ m/s}}{200\,000\,000 \text{ m/s}} = 1.5$$

Code Regulations for Optical Fiber Cable

Code publications on optical fiber installation can be purchased from national and international code-issuing organizations (e.g., National Fire Protection Association [NFPA] and International Electrical Commission [IEC]), which are updated frequently. The designer and installer should be aware that the local regulatory body may have codes or ordinances that overpower those of the national and international organizations.

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Wireless Transmission in Premises

Wireless is a very generic term that may refer to numerous forms of non-wired transmission, including amplitude modulation (AM) and frequency modulation (FM) radio, TV, mobile telephones, portable telephones and wireless local area networks (WLANs).

Wireless transmission is typically sought when a wired solution is cost prohibitive or untethered access is required. Many technologies are available: RF, infrared (IR), wireless fidelity (WiFi), and Bluetooth® are a few of the most popular and readily available.

Topics in Wireless Transmission

The majority of signal types used in an AV system (audio, video, and control) can now be transmitted wirelessly, some better than others. The two main types of wireless technologies employed in AV systems are IR and RF.

Infrared (IR) and Radio Frequency (RF) Principles

IR and RF are wireless signal management methods, available from many manufacturers and used to transfer information (e.g., voice, data, and video) wirelessly. Wireless devices offer more flexibility and portability in their application. A wireless microphone allows presentation mobility. A wireless remote control allows control from multiple angles in a room. And, a wireless computer network frees laptop users to stay connected to the Internet while moving within the bounds of the wireless receivers.

IR transmitters and receivers are inexpensive but work only in direct line of sight (LoS) with a range generally limited to 9 m (30 ft). These devices must be directed or reflected toward the receiver.

RF signal management uses a radio signal to control the equipment. They are available in a variety of frequencies to allow multiple units to be used in a single area. Some RF transmitters and receivers are tunable to multiple frequencies, while others have fixed frequencies.

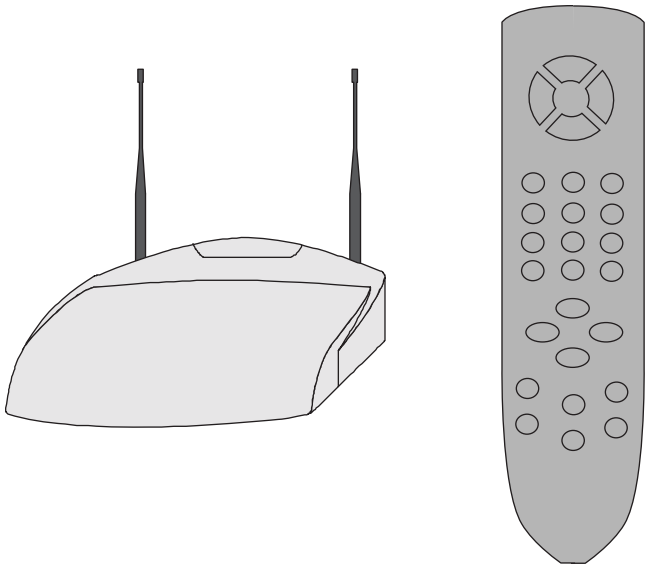
An RF device transmits information on a specific frequency and the receiver must be tuned to that frequency. Each RF device operates on its own frequency. Ultra-high frequency (UHF) systems (as opposed to very high frequency [VHF] systems) are less prone to radio interference and have narrow bands and more frequencies.

Frequency coordination is essential in any application. Because crosstalk or radio interference can result, two pieces of equipment should never be used on the same frequency in a single application or in close proximity in multiple applications.

Topics in Wireless Transmission, continued

Some RF equipment operates at a fixed frequency and other allows tuning. A set number of RFs is available and utilized by hundreds of thousands of electronics: TV stations, radio stations, 2-way radios, microphones, remote controls, and communication systems (see Figure 4.19). Governments dedicate some frequencies for specific uses and the restrictions change geographically.

Figure 4.19
Radio frequency devices



With wireless transmission of signals come other challenges including frequency allocation, band saturation, bandwidth, interference, and power.

Three basic types of interference are:

- Radio frequency interference (RFI).
- Electrical interference.
- Intermodulation.

RFI is caused by radio and TV transmitters, communications equipment, cable TV systems and other types of equipment that generate RF energy as part of their operation. Apparatuses such as computers and digital equipment, heavy electrical equipment, lighting systems, and faulty electrical devices cause electrical interference.

Topics in Wireless Transmission, continued

Intermodulation is a type of interference caused by the internal combination of strong radio signals in wireless receivers. Intermodulation noise is created whenever the complex modulating signal passes through any kind of phase or amplitude nonlinearity in the transmission facility. Intermodulation noise:

- Is present only when the system is being modulated.
- Increases with the level of the modulating signal.

The factors that determine the level of the baseband signal (e.g., the baseband load on the system) include:

- Total number of active message channels.
- Level of signaling and data tones.
- Individual speech levels.

Three basic types of electrical interference are:

- Noise from electrical equipment.
- Noise generated by electronic devices (e.g., computers).
- Interference from natural sources (e.g., lightning).

Electrical interference is the result of defects, failures, or maintenance problems. Manufacturers are required to design and manufacture their products so that they do not cause harmful interference. In many cases, this is a legal requirement with strict limits on unintentional generation of RF interference.

Wireless transmission systems are desirable where the installation of cable is cost prohibitive or the distribution of a signal needs to be flexible. When selecting a wireless transmission system, the designer needs to consider the type of signal transmission (closed or broadcast) and type of signal to be transmitted (analog or digital), and the type of medium (network or Internet protocol [IP]).

Topics in Wireless Transmission, continued

Modulation, Intermodulation, and Harmonics

Modulation is the process where an RF or light wave's amplitude, frequency, or phase is changed to transmit information. The characteristics of the carrier wave are instantaneously varied by another modulating waveform.

Intermodulation is the production, in a nonlinear element of a system, of frequencies corresponding to the sum and difference frequencies of the fundamentals and harmonics that are transmitted through the element. Intermodulation distortion is the nonlinear distortion characterized by the appearance, in the output of a device, of frequencies that are linear combinations of the fundamental frequencies and all harmonics present in the input signals (Federal Standard [FS] 1037).

Harmonics are frequencies that are an integral multiple of the fundamental frequency. Harmonic distortion is the production of harmonic frequencies by an electronic system when a signal is applied at the input. When an input signal goes through nonlinear electronic circuitry, the output signal will include some harmonic distortion or unwanted frequencies (FS 1037).

Application of Wireless Transmission in Audiovisual (AV) Systems

Wireless Fidelity (WiFi)

WiFi, also known as 802.11 (a family of specifications developed by the Institute of Electrical and Electronics Engineers® [IEEE®]) and 8802-11 IEC, is the wireless way of networking. The advantage of WiFi is its simplicity. It connects computers anywhere in a home or office without the need for wires. Computers up to 30.5 m (100 ft) apart can connect to a network using radio signals.

Higher frequencies allow higher data rates. WiFi radios use efficient coding techniques, such as orthogonal frequency-division multiplexing (OFDM) and complementary code keying (CCK), that contribute to higher data rates. The radios used for WiFi have the ability to change frequencies. WiFi cards can transmit directly on any of three bands or they can split the available radio bandwidth into dozens of channels and frequency hop rapidly between them. The advantage of frequency hopping is that it is more immune to interference and can allow dozens of WiFi cards to talk simultaneously without interfering with each other.

Application of Wireless Transmission in Audiovisual (AV) Systems, continued

Bluetooth®

Another method of wireless communication applied in the AV industry is Bluetooth.

Bluetooth is a wireless technology for low-cost, short-range, radio links between mobile telephones, computers, personal digital assistants (PDAs), and other consumer devices. The technology lets the devices easily interconnect and connect with home and business telephones and computers using short-range wireless connections. Basically, it allows dissimilar devices to talk to each other with the inclusion of a low-cost transceiver chip in each device.

Bluetooth may not be considered a wireless LAN technology because it communicates only between pairs of devices and does not use media access control (MAC) addressing. Bluetooth currently works best in closed systems.

The benefits of Bluetooth are that it:

- Transmits and receives in 2.45 gigahertz (GHz) frequency band.
- Provides up to three voice channels in addition to data.
- Has a unique 48-bit address.
- Connects to PTP or multipoint.
- Has a maximum range of 10 m (33 ft).
- Can exchange data at a rate of up to 2 Mb/s.
- Has a frequency hop scheme that allows devices to communicate even in the areas with high EMI.
- Provides built-in encryption and verification.

Microphones

Wireless microphone systems are used quite frequently in AV systems because they provide mobility and ease of use. Wireless microphone systems operate in a variety of frequency bands, with UHF the favored band due to over saturation of systems operating in the VHF band. Wireless systems offer handheld and body pack transmitters. Some manufacturers provide several microphone head options. Body pack transmitters connect to lapel and head-worn microphones.

Application of Wireless Transmission in Audiovisual (AV) Systems, continued

In a wireless system, each transmitter uses a unique frequency to transmit the signal to a receiver. Although some receiver models provide reception of signals from multiple transmitters, internally they are made of multiple receivers, one for each transmitter, with a summed audio bus to the output.

An antenna distribution system is typically employed to manage and send the signals received by the antennae to the appropriate receiver. Because of the sensitive nature of RF systems, consulting the manufacturer's installation recommendations would be prudent when multiple systems are used.

Assistive Listening Systems

Accessibility authorities mandate the use of assistive listening systems in public venues. Although not mandated, wireless systems have an advantage over wired systems because they can provide additional receivers as the need grows without the need to install wiring.

Monitoring Systems

Wireless monitoring systems can be used with in-ear receivers and receiver/loudspeakers. In the latter configuration a receiver is connected to a power amplifier, which in turn provides an output to the loudspeaker. Many manufacturers now make wireless monitor speakers with built-in amplifiers.

Controls

Wireless control systems employ RF and IR technologies to communicate serial data to a specific device to perform a specific function. The basic form is a remote control for home stereo, TV or video playback device. Because IR has a distance limitation, RF systems are used when a stronger signal is needed to reach a device.

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Application of Wireless Transmission in Audiovisual (AV) Systems, continued

Wireless Video

The transmission of wireless video can be achieved many ways. The two most widely used methods are RF and IR. In analog designs, proprietary transmitters and receivers provide the transmission bridge for the video signal. This design can be applied to long distance transmission schemes for broadcast and closed circuit TV systems.

In a networking environment, the video signal is converted to a digital signal and transmitted through the network using IP. Digital signals can also be transmitted over a wide area satellite network, with the signal being converted to match the format at its final destination (analog or digital) depending on the receiver type.

IR video transmission is typically bandwidth and distance limited due to the low signal strength of the light emitter and receiver sensitivity. IR transmission systems are also susceptible to interference from adjacent and overlapping light sources in the same frequency band. IR systems are typically used for privacy needs and when bandwidth or distance limitations are not a critical issue.

Patch Panels

Patch panels provide a simple mechanical method of connecting equipment inputs and outputs. Most commonly, they are flat panels installed in an electronic rack or console. Patch panels consist of rows and columns of connectors interconnected by cables in the rear to and from each source and destination device. To connect the source with the destination, one or more patch cords are inserted into the front panel, providing a physical signal path between the two devices.

When the source has to be connected to more than one destination (a common requirement), patch panels are a poor choice. This is particularly true with video signal switching, because distribution amplifiers send signals in many directions simultaneously.

Types of Patch Panels

Patch panels are manufactured for any type of signal. Each panel typically consists of only one type of signal and a connector. Commercially produced patch panels are available for the most common types of signals. Alternately, custom patch panels can be made for uncommon connectors and signals.

The patch panels most commonly used in the AV industry are:

- Audio.
- Video.
- Data.
- Optical fiber.

Patch panels are typically configured in two rows: the top row from the source and the bottom row to the destination.

Audio Patch Panels

Audio patch panels generally use TRS longframe (black shell) or bantam connections for the front panel patch points. Longframe patch panels typically have 24 to 32 jacks per row, while bantam connections provide 48 jacks per row. Rear connections are usually hard-wired and can be one of several types of connectors (e.g. punch down, solder, pin).

Audio patch panels have several types of grounding schemes. In one type of possible grounding schemes, all of the ground (shield) connectors are tied together for each row. In another, all of the ground connectors are separate. The best grounding choice would be a scheme that matches the grounding method for the remainder of the audio system.

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Types of Patch Panels, continued

Video Patch Panels

Video patch panels typically use standard or mid-size video patch connections for the front panel points. Typical configurations have 24, 26, or 32 jacks per row. Rear connections are generally BNC connectors.

NOTE: Video patch bays are available in different bandwidths. The installer must ensure to select a patch panel with a bandwidth that would fit the signals routed into the system.

Data Patch Panels

Data patch panels are typically 8-pin modular type. The most common configurations have 16 or 24 jacks per row. The jacks are usually simple pass-through connections, which provide more flexibility.

Optical Fiber Patch Panels

Optical fiber patch panels, like data patch panels, usually have pass-through connections and are available in all of the fiber termination types (e.g. SC, ST, and fiber connector [FC]). Optical fiber panels are generally custom made and, therefore, offered with various jack configurations.

NOTE: All of the termination types on a fiber patch panel should be the same.

Normalling

Normalling is a term used to describe a patch panel wiring pattern in which a circuit path is established from one point of contact to another (usually above or below the first point of contact) without the use of a patch cord.

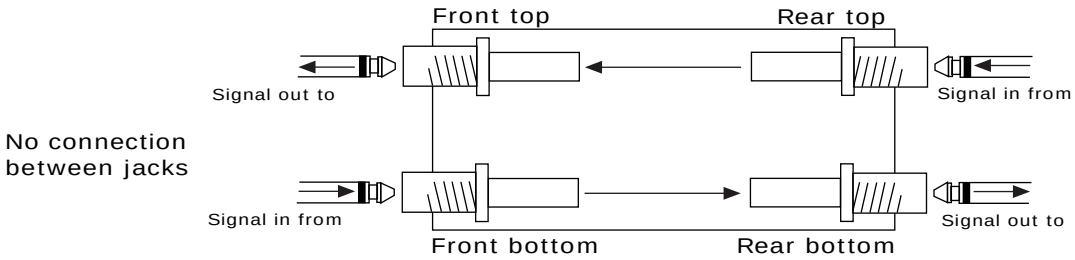
Normalled patch panels allow a common circuit path to remain connected without a patch cord. At the same time, a normalled patch panel provides the flexibility to connect either the source circuit or the destination circuit to an entirely different circuit. Inserting a patch cord interrupts and reroutes the established path. In some cases, using a terminating patch plug or a self-terminating patch panel ends the signal path of the destination circuit.

Normalling, continued

Patch panels support a number of normalling configuration standards:

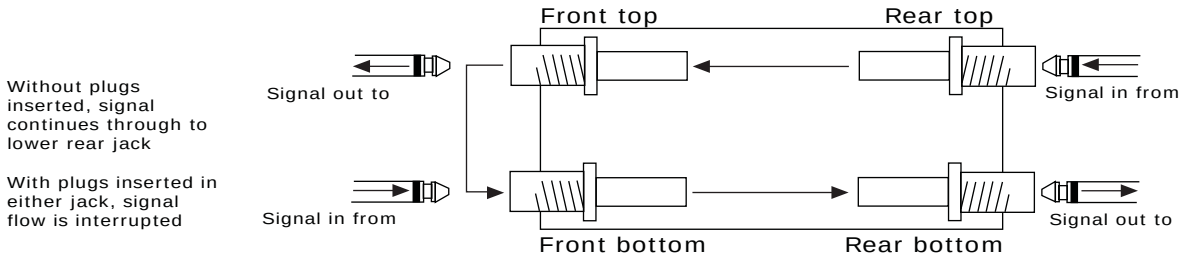
- Non-normalled—provides no connection until a patch is completed (see Figure 4.20)

Figure 4.20
Non-normalled connection



- Full-normalled—normally connected unless a patch cord is plugged into one of the points (see Figure 4.21)

Figure 4.21
Full-normalled connection

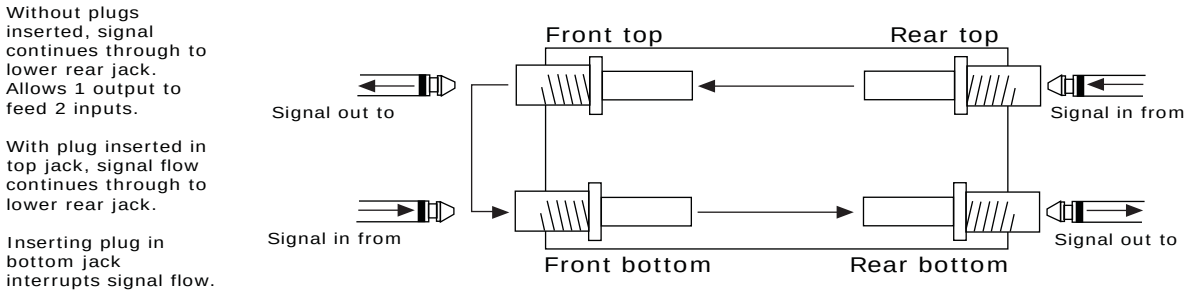


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Normalling, continued

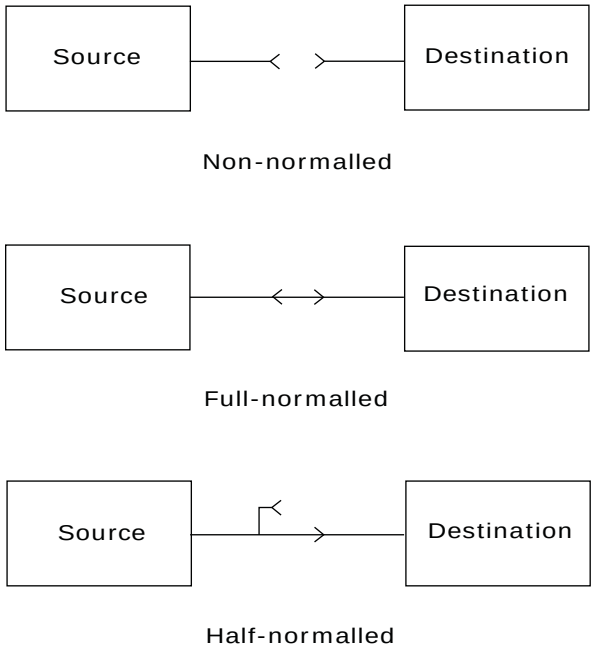
- Half-normalled—allows the monitoring of the source signal or routing to an additional destination (see Figure 4.22)

Figure 4.22
Half-normalled connection



Typically, normalling is found in audio and video patch panels. Video patch panels can only have non-normalled and full-normalled connections. Audio panels can have all three. See Figure 4.23 for normalling schematic types.

Figure 4.23
Typical normalling schematic



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InfoComm International. 2003. *Essentials of the AV Industry Online*. Online course. Fairfax, VA: InfoComm.

West Penn Wire. 2001. Coaxial Cable Loss Factors. Technical Data Sheet 806: RG-6 Type CCTV Coaxial Cable. Washington, PA: West Penn Wire.

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Chapter 5
Infrastructure

A carefully designed and coordinated infrastructure system provides an important backbone for the audiovisual (AV) system. This chapter provides the AV designer with the information necessary to plan out a robust infrastructure that will support the AV requirements now and into the future.

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Overview

Introduction

Wires and supporting materials associated with voice, data, building operations, and audiovisual (AV) systems used to be completed upon the building's construction. In the majority of cases, each of these applications were designed and implemented separately, leading to redundant installation efforts and material.

The technology growth, which has expanded the range of electronic devices and bandwidth, and the resulting evolution of multimedia-based applications have increased the volume of information shared among the various systems. This change demands that the design and implementation of standards-based structured cabling systems (SCSs) encompass the needs of the new applications.

A standards-based design and implementation generates savings regardless of the application, because it optimizes the building structure, systems, services, and management as well as the interrelationships between them. The savings are made not only in construction materials but also in labor, which leads to reduced costs and a more expedient installation for the entire facility.

A carefully planned design and implementation of AV system-related structured cabling pathways or infrastructure may:

- Allow a single project team to design, install, and manage the installation of all cabling.
- Reduce the initial construction and ongoing operational costs.
- Reduce installation labor hours by consolidating cabling and using a common pathway where possible.
- Decrease the time required for overall project engineering.
- Minimize the damage to finished surfaces by installing all cabling during the construction.
- Create a single cabling distribution system for easier administration and maintenance.
- Provide the customer with a single point of contact for integrating the cabling and pathways for all systems.
- Make construction and installation scheduling easier, improving the efficiency of the overall project.
- Provide flexibility for additions and rearrangements.
- Improve response time to end-user requests for cabling changes.
- Generate savings to the tenants by reducing or eliminating the:
  - Cost of installing separate voice, data, building operations, and AV cabling.
  - Time required for move-in and setup.
  - Rental costs by minimizing the cabling installation time.

Introduction, continued

- Provide a marketable advantage that could improve occupancy.
- Be reusable for the life of the structure (when using open office cabling).
- New cabling does not have to be installed every time end users move, nor when systems are changed or upgraded. This helps to eliminate cluttered floor and ceiling spaces. In addition, constant re-cabling within a structure tends to cause modifications that may affect the physical structure of the building and the integrity of the technology deployed in the structure.
- Reduce contention between trades.

This chapter briefly discusses internationally accepted standards. It then addresses infrastructure design considerations, followed by a discussion of the various available pathway options and, in conclusion, information concerning the effects of electromagnetic interference (EMI) and the importance of firestopping.

Standards

Infrastructure-related standards have undergone many updates due to changes in technology. Detailed information concerning infrastructure design for commercial AV projects in the United States can be found in the Telecommunications Industry Association (TIA) standard 569-B, *Commercial Building Standards for Telecommunications Pathways and Spaces*.

NOTE: In Canada, refer to Canadian Standards Association (CSA) T530, *Building Facilities, Design Guidelines for Telecommunications.* In Europe, refer to Committee for Electrotechnical Standardization (CENELEC) EN 50174-2, *Information Technology—Cabling Installation—Part 2: Installation Planning and Practices Inside Buildings.* In other countries, refer to International Standards Organization (ISO)/International Electrotechnical Commission (IEC) 11801, *Information Technology—Generic Cabling for Customer Premises*, which is application independent.

This document encompasses telecommunications considerations both within and between buildings. The aspects covered are the pathways into which telecommunications media are placed and the rooms and areas associated with the building used to terminate media and install telecommunications (including AV) equipment.

For residential facilities in the United States, TIA-570-B, *Residential Telecommunications Infrastructure Standard,* is applicable.

Standards, continued

Nothing impacts the design and construction of a network more than codes, standards, and regulations. In recent years, efforts have been made by national, regional, and international standards-making bodies to harmonize the standards. These efforts, along with the technological developments that impact standards and subsequently codes and regulations, maintain the documents' dynamic nature.

Because other disciplines are involved in AV design, the designer should be knowledgeable about the related codes and standards, which may be monitored by various agencies.

This manual provides requirements and guidelines for appropriate installation that seek to:

- Provide personal safety.
- Protect equipment from failure.
- Recognize regulatory considerations.
- Meet performance requirements.

Designing Pathways

Design

Regardless of the point where the AV project design and implementation begins, whether at the initial facility construction or as a separate project after the owners' occupy the facility, the importance of having an appropriate infrastructure design before the implementation plays the major role in completing a project successfully.

Appropriate design efforts reduce unit change time and cost (in materials, labor, and occupant disruption) and have a large impact on the overall life cycle maintenance and operational costs of an AV system. Designing appropriate infrastructure components allows for a prepared accommodation of cable-related work, and choosing appropriate horizontal cabling components allows for a wide variety of user technology applications.

Generally, cabling choices should not dictate pathway choices. The goal of the pathway component is to accommodate all standards-compliant cabling, thus recognizing the potential need for change during the life cycle.

Compromising the pathway system by a dependency on the cabling component may be counterproductive to reducing long-term maintenance and operational costs. During a new construction, the designer should focus on the pathway component and focus on the cabling component later in the design process. This strategy helps to ensure a robust pathway component that supports cabling installation over the facility life cycle.

When an AV project is implemented as an expansion or secondary project to an existing facility, the concept of appropriate infrastructure design is important, but the secondary design is likely to be limited to the project at hand. Depending upon the design efforts associated with the original infrastructure implementation, the efforts for a new project could be significantly reduced, having a direct effect on the costs associated with the project.

If, however, prior efforts do not provide for the needs of a new project, the design and implementation manager must develop an infrastructure design that would support the project's proposed structured cabling based on the new specifications. The designer should again ensure that the design allows for the accommodation of change over the facility life cycle with the goal of reducing long-term maintenance and operational costs. These efforts should include standards-based components to ensure vendor independence and, overall, be based on the requirements of the appropriate electrical codes and standards.

Elements of Design

In developing the infrastructure design, one of the first steps that the design and implementation manager should take is to obtain a set of scaled drawings that show the work area and other projects that might already be under way.

Depending on the size of the project, these drawings can be acquired from the project architect, engineer, general construction manager, facility owner, or end user.

For large projects, several drawing sets would need to be reviewed for the designer to appropriately research and develop the response to a request for quotation (RFQ). Conversing with the project architect or general construction manager should aid in obtaining the appropriate documentation. For small projects, the design and implementation manager may be required to develop drawings.

In either case, drawings play an important role in determining what has to be done on a project and should always be included in the project design.

The next step to an appropriate design is determining the specifications of a project. The four main types of specifications used to define the requirements of a project are:

- Performance—The focus is on results. Contractors can choose the materials and installation methods to provide the desired results.
- Proprietary—Specifications call out brand names and models to be used.
- Descriptive—The focus is on exact appropriate ties and installation methods.
- Reference—Requirements are based on established standards.

With the specifications known, the AV project design and implementation manager must develop cost estimates to respond adequately to the project RFQ. Cost estimates should take the following factors into consideration:

- Labor and subcontract costs
- Material and material waste
- Shipping, storage, and staging
- Equipment and tools for installation
- General conditions, such as:
  - Insurance costs.
  - Legal costs associated with agreements.
  - Advertising for bidding.
  - Bonding costs.
  - Contingency costs.

Elements of Design, continued

- Design and project management costs, such as:
  - Architectural fees.
  - Engineer and consultant fees.
  - Construction management fees.
  - Owner's internal costs.
  - Cutover and first-use charges.
- Market or regional conditions that can dramatically affect actual construction costs, such as:
  - Seasonal effects on the available labor pool or construction costs.
  - Strong or weak general economy.
  - Surrounding market conditions.
  - Other large projects in the region.
  - Construction time frame.
- Existing conditions that must be considered in the cost of the project, including:
  - Displacement and relocation.
  - Hazardous materials.
  - Environmental impact studies.
  - Abandoned cable.

NOTE: Sophisticated software programs can aid in the development and tracking of this information. Many of these programs can also be used for data cross-checking.

Finally, with the response to the RFQ developed, the designer should meet with the owner to discuss the estimate and the suggested design and implementation plans. The coordination and approval of design documents are usually accomplished through a series of meetings scheduled during the design phase of the project, as follows:

- Design coordination—The design team should meet on a regular basis to review the progress of each team member and to ensure all construction documents are coordinated.
- Owner review and approval—Meetings should be held with the owner during all design phases to review the design progress. Formal submissions to the owner are often scheduled at the end of the schematic design and the design development phase. These submissions serve as critical milestones in the design process.

Pathway Design and Selection

Horizontal pathways consist of structures that conceal, protect, support, and provide access to horizontal cables between two points or telecommunications elements. Pathway implementation involves a pathway for containment of cable and related spaces (e.g., pull boxes and splice boxes) that aid in the installation and change of cable.

When designing a building, the layout and capacity of the horizontal pathway system must be thoroughly documented in floor plans and other building specifications. The designer is responsible for ensuring that these systems have built-in flexibility to accommodate tenant movement and expansion. In addition, the horizontal pathway system should be designed to make the maintenance and relocation of cabling as easy as possible. The horizontal pathway system must be designed to handle all types of telecommunications cable (e.g., telephone, data, audio, video, and building automation system [BAS]). When determining the type and size of the pathway, the designer should:

- Consider the quantity and size of cables that the pathway is intended to house (for the current project and for future growth).
- Allow for growth of the area served over the planning cycle.

NOTE: All design and construction for pathway systems must meet national and local codes and standards.

Pathway Size

Manufacturers typically provide most pathways with design guidelines, including fill factors. Different types of pathways have different requirements.

In general, however, the size requirements for horizontal pathways depend on the following considerations:

- Usable floor space served by the pathway
- Maximum occupant density (e.g., floor space required per individual work area)
- Cable density (e.g., quantity of horizontal cables planned per individual work area)
- Cable diameter
- Pathway capacity (requires that fill factor be taken into account)
- Cabling requirements for other cabling systems

Pathway Design and Selection, continued

Pathway Types

The main types of horizontal pathways are:

- Underfloor ducts (one level or two).
- Cellular floors.
- Access floors.
- Cable trays.
- Ceiling distribution.
- Conduits.

Many buildings require a combination of two or more of these systems to meet all distribution needs. For example, an office area in a building may require an underfloor or overhead system, while an isolated telecommunications outlet location in the same building may be best served by an individual conduit.

NOTE: Because some local codes specify the type of horizontal pathway to be used, check all applicable codes and regulations before selecting a type of pathway.

If an existing pathway is used for an AV project, the installer must remember to contact the parties who own the pathway to verify that the usage is acceptable.

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Underfloor Duct Systems

Introduction

An underfloor duct system is a network of metal raceways embedded in concrete, which facilitates the distribution of horizontal cables (e.g., between telecommunications rooms [TRs] and work areas).

Ducts are generally rectangular and may be used in:

- Single, double, or triple runs.
- Combinations of large and standard ducts mixed to provide a larger or smaller capacity to match the needs of specific areas in a building.

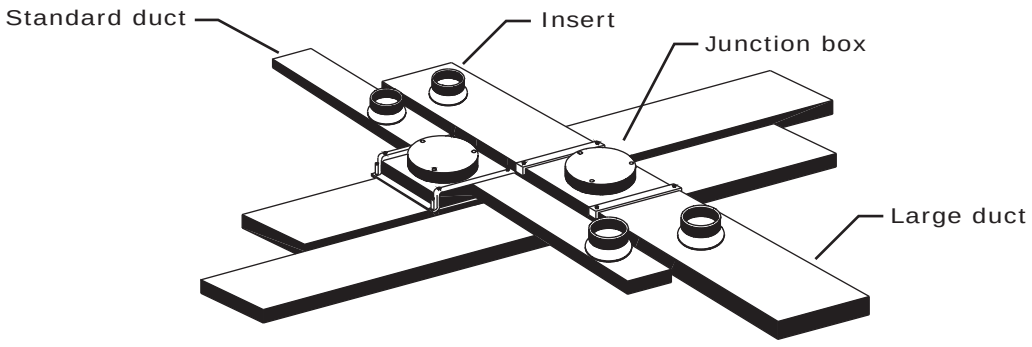
Underfloor duct systems are made up of:

- Feeder ducts (sometimes referred to as header ducts) that carry cables from the TR to the distribution ducts.
- Distribution ducts that distribute cables from a feeder duct to specific floor areas.

Distribution ducts are installed with preset inserts to provide access to horizontal cables both during and after installation. Preset inserts are not required on feeder ducts that extend under passageways or into other places where access to the horizontal cabling is not required.

Depending on the floor structure, ducts may be designed in one-level or two-level systems (see Figure 5.1).

Figure 5.1
Two-level enclosed feeder ducts

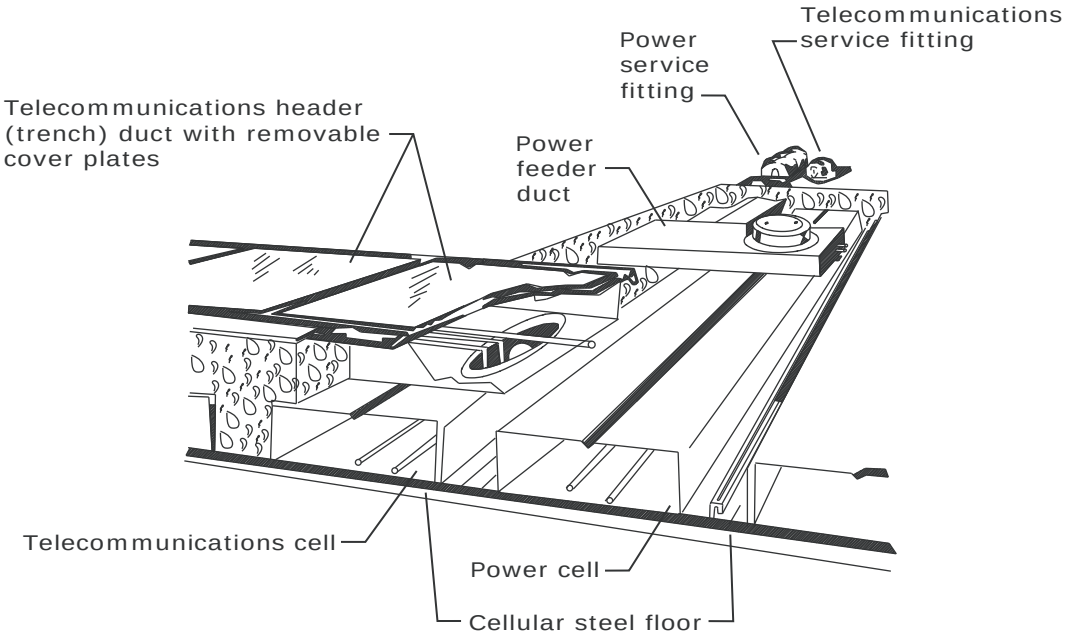


Cellular Floor Systems

Introduction

Cellular floor systems (see Figure 5.2) are generally used for in-floor raceway design in elevated steel-frame construction. Cellular floor structural members support the concrete floor slab, with the cells acting as distribution raceways.

Figure 5.2
Cross-section of cellular floor system



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Access Floor Systems

Introduction

An access floor (also called raised floors):

- Is raised above an existing sub-floor.
- Provides accessible space under the floor panels.

Access floors:

- Are most often used in computer rooms and equipment rooms (ERs).
- Are available with combustible, noncombustible, and composite panels and can be designed for seismic and other special conditions.
- Make use of a plenum area below the finished floor that may also be suitable for air-handling purposes.

Types

Two general types of access flooring are:

- Standard-height floors—Generally 152 mm (6 in) or higher, and the most common type of access floor.
- Low-profile floors—Typically less than 152 mm (6 in) and often used where structural limitations (e.g., insufficient slab-to-slab height) are encountered.

Floor Components

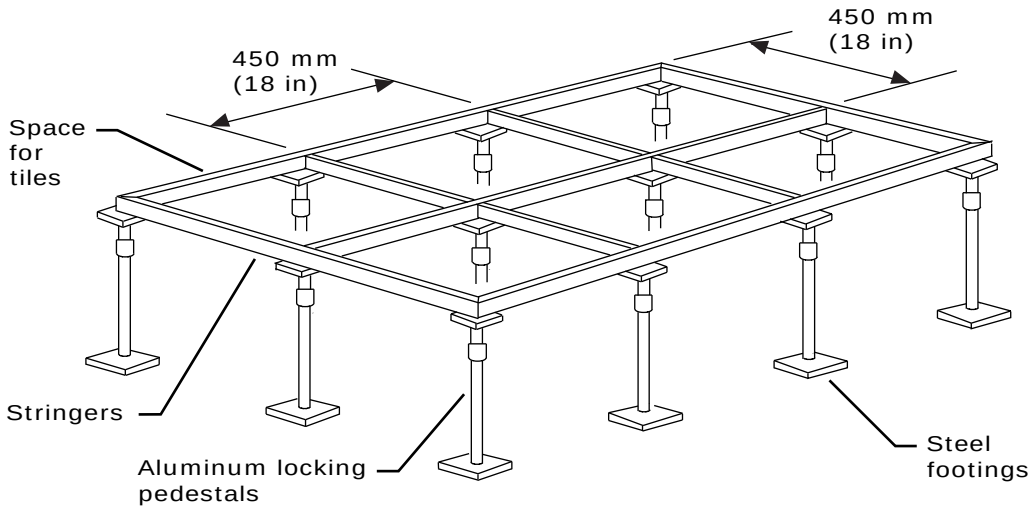
An access floor typically consists of:

- Steel footings that rest on the sub-floor. These footings provide distributed support for floor loads.
- Pedestals that support and interlock with lateral bracing (stringers) and panels. These pedestals are evenly spaced on the steel footings and are adjustable to compensate for unevenness of the sub-floor.
- Floors that may or may not be constructed with stringers. When used, they are assembled to form a framework of panel receptacles. These stringers provide lateral support by interlocking with the pedestals.
- Modular floor panels that rest on the stringers and/or pedestals. Panel sizes typically range from 457 mm (18 in) to 600 mm (24 in) square. Plain or carpeted panel surfaces may accommodate the functional and aesthetic needs of the area they occupy.

Floor Components, continued

The basic components of a stringered access floor system are shown in Figure 5.3.

Figure 5.3
Stringered access floor system



Stringered Systems

Stringered systems have lateral bracing (stringers) between pedestal supports. They are bolted or snapped to the pedestal heads. Stringered systems:

- Brace the pedestals for improved lateral stability.
- Provide additional support for the panels.
- Facilitate frequent removal and replacement of floor panels.

NOTE: Cable trays should be installed before the floor stringers are attached to the pedestals.

Freestanding and Corner-Lock Systems

Freestanding and corner-lock access floors consist of panels supported solely by pedestals. Freestanding systems rest on pedestal supports with no mechanical fastening,. Corner-lock systems mechanically fasten floor panels to the pedestal heads at each corner.

Of the two, corner-lock systems add increased stability and are preferred for general office use. Use of freestanding systems should be restricted to installations with finished heights of 300 mm (12 in) or less.

General Design Guidelines for Ceiling Systems

Introduction

The area above a suspended ceiling should be carefully planned to allow room for the different utilities and telecommunications services it contains. Coordination between the various trades that use the ceiling space is essential.

Determining Adequate Ceiling Space

To determine how much ceiling space is adequate, the designer should:

- Consider the size and depth of the:
  - Structural beams and girders.
  - Column caps.
  - Mechanical services.
- Allow for a minimum of:
  - 75 mm (3 in) of clear vertical space above conduits and cables.
  - 300 mm (12 in) of clear vertical space above the tray or raceway for overhead ceiling cable tray or raceway systems.

When designing the layout of horizontal pathways in ceiling spaces, the designer should ensure that other building components (e.g., lighting fixtures, structural supports, and air ducts) do not restrict access to cable trays or raceways.

Choosing the Ceiling Panels

The designer should choose the type of ceiling panel according to Table 5.1

Table 5.1
Types of ceiling panels

Ceiling Panel Types	For Use
Readily removable	Lay-in type panel on either a: • Single support channel. • Double support channel. NOTES: Securely install and trace support channels to prevent both vertical and horizontal movement. Use panels built from stable materials to reduce panel damage from periodic handling.
Not readily removable	Lock-in type panel that requires a conduit system.

Restrictions on Ceiling Cabling

Cabling within ceilings used as a plenum for environmental air must conform to the requirements of codes and regulations.

Ceiling Zone Conduit Restrictions

A zone conduit system may be allowed in an air plenum ceiling if:

- Conduits terminate in junction boxes.
- Short runs of smaller conduit are extended from the junction boxes to the telecommunications outlet/connectors.

IMPORTANT: Verify the use of ceiling zones in air plenums with local authority having jurisdiction (AHJ).

Pathway and Cable Support

Every ceiling distribution system must provide appropriate support for cables from the TR to the work areas it serves. Ceiling panels, support channels (T-bars), and vertical supports are not considered appropriate supports. Ceiling conduits, raceways, cable trays, and cabling must be suspended from, or attached to, the structural ceiling or walls with hardware or other installation aids specifically designed to support their weight.

The pathways must:

- Have adequate support to withstand cable pulling.
- Be installed with at least 75 mm (3 in) of clear vertical space above the ceiling tiles and support channels to ensure accessibility.

The designer should not allow horizontal pathways or cables to rest directly on or be supported by ceiling panels, support channels, vertical supports, or other components of the suspended ceiling. Providing sufficient space between the suspended ceiling structure and the telecommunications pathways/cables is important for installing, maneuvering, and storing ceiling tiles during service. When sufficient space is available above the pathway, up to 150 mm (6 in) should be provided between the suspended ceiling and the cabling pathways.

Where building codes permit placing telecommunications cables in suspended ceiling spaces without conduit, ceiling zone distribution pathways may consist of:

- Cable trays.
- Open-top cable supports (J-supports).

NOTE: J-supports should be located on 1.2 m (4 ft) to 1.5 m (5 ft) centers to adequately support and distribute the cable's weight. These types of supports may typically hold up to 50 cables 6.4 mm (0.25 in) in diameter.

Pathway and Cable Support, continued

Some evidence suggests that certain cable support devices can have a detrimental effect on transmission performance of higher performance cabling systems. Devices that have small surface areas to support the cable laying horizontally in them are the types of devices that have been identified. When a choice exists, selecting a device with a wider surface area to support the cable would be a precaution against potential problems. Another precaution would be to reduce the distance between the support devices.

Suspended cables must be installed with at least 75 mm (3 in) of clear vertical space above the ceiling tiles and support channels.

For large quantities of cables (50 to 75) that converge at the AV ER and other areas, cable trays or other special supports that are specifically designed to support the required cable weight and volume should be provided.

Cable Tray Design for Ceiling Systems

Cable Tray Systems

Cable tray systems are commonly used as distribution systems for cabling within a building.

They are often preferable to rigid conduit and raceway systems because of their greater accessibility and ability to accommodate change. Cable tray systems:

- Are rigid, prefabricated support structures that support telecommunications cables and cabling.
- Must be installed to meet local building codes.

Designers are strongly advised to not use shared cable trays to distribute telecommunications and electrical power cables, even though such practice may be allowed by some building codes. If trays or wireways are shared, the electrical power and telecommunications cables must be separated by a grounded metallic barrier.

When a tray is used in the ceiling area, conduit must be provided from the tray to the telecommunications outlet/connectors or zones, except in cases where loose cables are permitted by, and meet, the applicable codes.

NOTES: The inside of a cable tray must be free of burrs, sharp edges, or projections that can damage cable insulation.

For penetration of rated walls using cable trays, see the section on firestopping in this chapter.

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Conduit Systems

Introduction

A conduit system consists of conduits installed from the head-end equipment to the AV outlet. Conduit may also be used in building risers and building entrance facilities.

Advantages to installing conduit over exposed cabling include added protection and security for AV cabling. Metallic conduits provide additional protection from EMI and may also allow the use of non-plenum–rated cable in a plenum space.

A disadvantage of conduit systems is the additional labor required for installation. In addition, national and local jurisdictions may require specific installation practices (e.g., appropriate support of the conduit and boxes, grounding and bonding of metallic conduit, maximum number of bends, conduit fill ratios).

Conduit raceways are often installed by an electrical contractor. The AV systems installer should verify any licensing requirements or other restrictions with the regulatory bodies.

Plastic Conduit

Plastic (polyvinyl chloride [PVC]) conduits offer no protection against EMI so they should not be used in electrically noisy environments. This type of conduit would not be appropriate for protecting cables near electric motors or fluorescent lighting. Three common types of PVC conduit are:

- Electrical nonmetallic tubing (ENT).
- Innerduct.
- Rigid nonmetallic tubing.

Electrical Nonmetallic Tubing (ENT)

ENT is an easily bendable PVC tube. It can be bent by hand and pushed through walls and floors. ENT conduit is color-coded as follows:

- Blue—electrical power cables
- Red—fire alarm circuits
- Yellow—communications

Plastic Conduit, continued

Innerduct

Innerduct is also nonmetallic tubing but stiffer than ENT. It is used inside other conduits, creating multiple paths in the same conduit. The interior of the innerduct tubing reduces friction when pulling cable through conduit. Innerduct is also color-coded as follows:

- Blue—electrical power cables
- Red—fire alarm circuits
- Orange—communications

Rigid Nonmetallic Tubing

Rigid nonmetallic tubing has a thick wall and is very stiff but lightweight. It is similar to plumbing tubing. Because it is not flexible, it is available only in pre-formed pieces at various angles.

Metal Conduit

Unlike PVC, metal conduit can offer some EMI protection. The thicker the metal tubing, the more protection it can offer from external noise. Four common types of metal conduit are:

- Electrical metallic tubing (EMT).
- Flexible metal conduit (FMC).
- Intermediate metal conduit (IMC).
- Rigid metal conduit (RMC).

Electrical Metallic Tubing (EMT)

EMT conduit is the most popular. It is also called thin-wall conduit because the tube is not very thick. It gives minimal electrical protection from EMI and minimal physical protection.

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Metal Conduit, continued

Flexible Metal Conduit (FMC)

FMC is typically connected to a movable piece of equipment. For example, it may be used to house cable to a document camera on a cart that can be pulled away from a wall. It is used for short runs. This type of conduit may be coated with plastic to prevent liquid from penetrating the tubing.

IMPORTANT: FMC is not recommended for use in buildings and should be used only in situations where it is the only practical alternative. If it must be used, the conduit size should be increased by one trade size.

During cable pulling, flexible conduit tends to:

- Creep.
- Shift.
- Cause sheath damage to the cable.

Intermediate Metal Conduit (IMC)

IMC is heavier than EMT. It has a threaded metal end to join pieces together with couplers. It offers better EMI and physical protection.

Rigid Metal Conduit (RMC)

RMC conduit is the heaviest conduit and offers the best physical and EMI protection. It has the same thread base as IMC, making the couplers for each type interchangeable. This is the recommended choice conduit for an electronically noisy environment.

Conduit Fill Code and Standards

Determining Pathway Size

The number of cables that can be installed is limited by the allowed maximum cable pulling tensions. Fill ratios can be increased by use of cable lubricants.

Pull force should be monitored closely during cable installation to ensure that the manufacturer's requirements are not exceeded. Pull force is determined by several factors, including the:

- Cable type.
- Conduit type.
- Conduit diameter.
- Conduit length.
- Conduit layout.
- Number and configuration of conduit bends.
- Selection of lubricants.

The portion of the cable and additional footage used to grip and pull the cable should be cut off prior to termination.

Because of the possibility of damaging existing cables and other uncertainties involved, pulling new cables through a partially filled conduit is not recommended.

Permissible Area

Conduit has an outside and an inside diameter and comes in various sizes, referred to by their approximate outer diameter. Some typical sizes are 12.7 mm (0.5 in), 19 mm (0.75 in), 25 mm (1 in), 32 mm (1.25 in), 38 mm (1.5 in), 51 mm (2 in), 64 mm (2.5 in), 76 mm (3 in), 101 mm (4 in). Different conduit types like EMT, IMC, and RMC may have different inside diameters for the same size conduit.

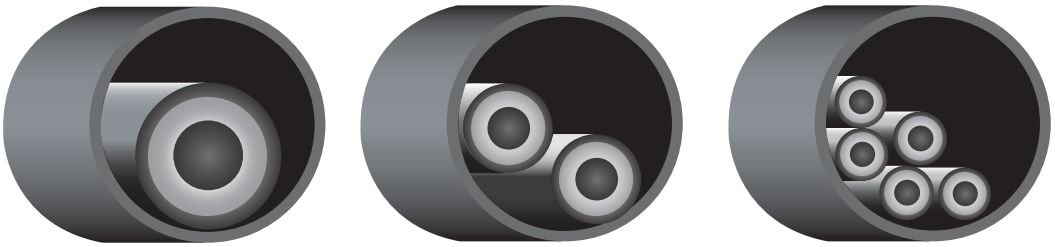
The inner diameter is important for determining the quantity of cable that can be placed in the conduit. Adding a new conduit can often be undesirable. In such cases, a different type of wiring scheme must be selected.

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Conduit Fill Code and Standards, continued

The maximum amount of space occupied by cables inside a conduit is called a permissible area (see Figure 5.4). Permissible area rules are usually identified in national or local electrical codes.

Figure 5.4
Permissible conduit fill areas



The following recommendations represent best practice:

- If only one cable is run in a conduit, the cable may occupy up to 53 percent of the inside area.
- If two cables are run inside a conduit, they may occupy up to 31 percent of the inside area.
- If three or more cables are run inside a conduit, the cables may occupy up to 40 percent of the inside area.

Conduit Fill Code and Standards, continued

Conduit Capacity

The following steps are used to determine the area the cables will occupy.

STEP	TASK
1	Check the cable information, and identify the diameter of each cable.
2	Multiply the outside diameter (OD) of each cable by itself
3	Add all OD^2 together
4	Multiply by 0.7854 ($\pi/4$ from geometry)

If three cables with the ODs of 0.1 in, 0.28 in, and 0.31 in, respectively, are used, the total OD^2 would be 0.1845 in. That number multiplied by 0.7854 gives 0.1449 in^2. The total is compared to the permissible area of the conduit as shown in Table 5.2.

NOTE: 1 in = 25 mm

Table 5.2
Electrical metallic tubing (EMT) conduit permissible areas

Conduit Trade Size	1 Cable (53%)	2 Cables (31%)	3 Cables (40%)
21 mm (3/4 trade size)	0.28	0.17	0.21
27 mm (1 trade size)	0.46	0.27	0.35

1 in = 25 mm

Therefore, if the building has 1/2 in conduit, the cables from the example above would exceed the permissible area. On the other hand, a 3/4 in conduit would match the need.

Appropriate selection and installation of cable conduit is discussed in electrical codes.

The typical types of conduit used by AV designers and installers are:

- Metal (EMT, RMC).
- Plastic.
- FMC.

The term jam ratio refers to a ratio of conduit inside diameter (ID) to the cable OD. This ratio is used to determine if a series of cables would jam inside a conduit when pulled through a bend in the conduit. (At the bend points, conduits are narrower). If the ratio is less than 2.5, the cable will likely not jam when being pulled through the conduit. Also, ratios of over 2.8 should be avoided.

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Conduit Fill Code and Standards, continued

In the United States, National Fire Protection Agency (NFPA) standard 70, *National Electrical Code*® (*NEC*®), addresses the design of a conduit system with bends. The *NEC*® requires a pull box within a conduit run with 360 degrees of bend to enable the installer to access the cables for a cable pull. In most cases, a pull box is recommended with 270 degrees of bend.

In general, the bend radius should be no less than six times the conduit size. For example, a 90-degree bend in an 0.5 in conduit should have a radius of at least 3 in.

Conduit Support

Bend Radii for Conduits

The bend radius of any portion of the conduit pathway must be at least six times the diameter of the conduit, depending on its size. Choose the bend radii for conduits according to the guidelines in Table 5.3.

Conduit bends should be smooth and even and should not contain kinks or other discontinuities that may have detrimental effects on pulling tension or cable integrity during or after installation.

Table 5.3
Bend radii for conduits

If the conduit has an internal diameter of...	The bend radius must be at least...
50 mm (2 in) or less	6 times the internal diameter
More than 50 mm (2 in)	10 times the internal diameter

NOTE: For additional information on conduit bend radius requirements and recommendations, consult national and local codes and standards.

Designs with Conduit Bends

Table 5.4 provides guidelines for adapting designs to conduits with bends.

NOTE: Consider an offset as equivalent to a 90-degree bend.

Table 5.4
Adapting designs to conduits with bends

If a conduit run requires...	Then...
More than two 90 degree bends	Provide a pull box between sections with two bends or less
A reverse bend (between 100 and 180 degrees)	Insert a pull point or pull box at each bend having an angle between 100 and 180 degrees
A third 90 degree bend (between pull points or pull boxes)	Derate the design capacity by 15 percent for this additional bend

Using Three Bends in Conduit

A third bend may be acceptable in a pull section without derating the conduit's capacity if one of the statements below is true:

- The total run is not longer than 10 m (33 ft).
- The conduit size is increased to the next trade size.
- One of the bends is located within 300 mm (12 in) of the cable feed end. (This exception only applies to placing operations where cable is pushed around the first bend.)

Conduit Terminations

All conduit ends should be reamed and fit with insulated bushings to eliminate sharp edges that can damage cables during installation or service.

Conduits that enter a TR should terminate near the corners to allow for appropriate cable racking. These conduits should also terminate as close as possible to the wall where the backboard is mounted (to minimize the cable route inside the TR).

Conduits that protrude through the structural floor 25 mm (1 in) to 75 mm (3 in) above the surface should be terminated to prevent cleaning solvents or other fluids from flowing into the conduit.

NOTE: The integrity of all firestop barriers for all floor penetrations should be maintained. Where possible, the TR ceiling should be higher than the office ceiling. The difference in height eliminates a bend in the conduit.

Pull Boxes for Conduits

Installing Boxes

Pull boxes should be installed in easily accessible locations. Horizontal cabling boxes should be installed immediately above suspended ceilings.

NOTE: The following pull box information applies to inside plant cables only.

For direct access to a box, provide a suitable, marked, hinged panel (or equivalent) in the suspended ceiling. This access panel can also serve as the cover for the box.

Slip Sleeves or Gutters

A slip sleeve is a conduit sleeve that is:

- Larger than the main conduit.
- Slipped over an opening in a conduit run after the cable is in place.

A gutter is a square sheet metal housing, which is placed over an opening in a conduit run.

Pull Boxes for Conduits, continued

Using Slip Sleeves or Gutters

Slip sleeves or gutters:

- Can be used in place of a pull box.
- Provide more space for pulling.
- Are more economical to install than a pull box.

Slip sleeves and gutters should not be used as splice locations.

To allow for the installation of slip sleeves and gutters, the main conduit should have an opening that is long enough to form a cable loop during the pull-in operation.

Sizes and Purposes of Boxes, Slip Sleeves, and Gutters

For horizontal cable, the box, slip sleeve and gutters:

- Width and depth must be adequate for fishing, pulling, and looping the cable.
- Length must be 12 times the diameter of the largest conduit. In some cases (e.g., large cables are planned to serve multiple work areas), a box length of 16 times the diameter of the largest conduit may be appropriate.

These requirements facilitate:

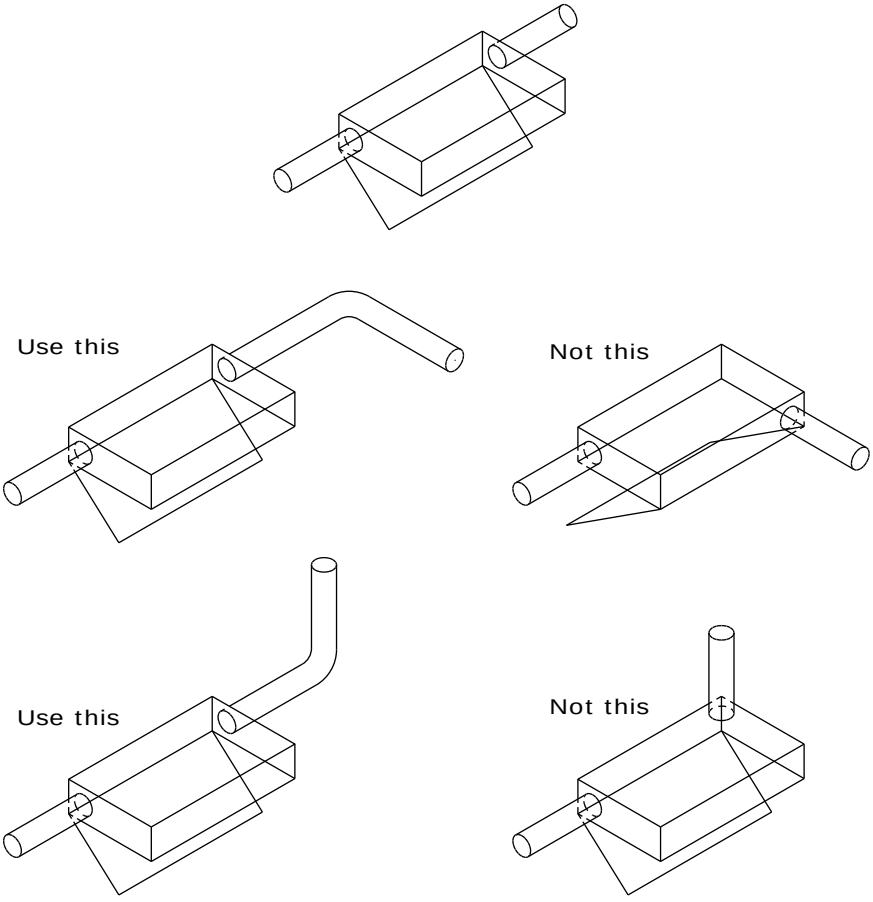
- Pulling cable into the box.
- Looping cable for pulling into the next length of conduit.

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Pull Boxes for Conduits, continued

Figure 5.5 depicts recommended box configurations.

Figure 5.5
Recommended box configurations



Boxes for Pulling and Looping Cable

Boxes for pulling and looping cable are suitable only for cables that have an outside diameter of 50 mm (2 in) or less. If the cable is larger than 50 mm (2 in) in diameter, the box should not be located in the ceiling; the cable and conduit should be routed down a wall or column.

Pull boxes must be placed in readily accessible locations. A pull box should be placed in an interstitial ceiling space only if the pull box is:

- Listed for that purpose.
- Placed above a suitably marked, removable ceiling panel.

Pull boxes should not be used for splicing cable.

NOTE: Splices are not permitted in balanced twisted-pair horizontal cables.

Pull Boxes for Conduits, continued

Placing Pull Boxes in Conduit Sections

Place pull boxes in sections of conduit that:

- Are 30 m (98 ft) or more in length.
- Contain more than two 90-degree bends.
- Contain a reverse bend.

A pull box should not be used in lieu of a bend. Conduits that enter the pull box from opposite ends should be aligned.

Choosing a Pull Box Size

Table 5.5 helps to select the appropriate size of pull box.

Table 5.5
Minimum space requirements in pull boxes having one conduit each in opposite ends of the box

Conduit Trade Size mm (in)	Width mm (in)	Length mm (in)	Depth mm (in)	Width Increase for Additional Conduit mm (in)
27 (1)	102 (4)	406 (16)	76 (3)	51 (2)
35 (1-1/4)	152 (6)	508 (20)	76 (3)	76 (3)
41 (1-1/2)	203 (8)	686 (27)	102 (4)	102 (4)
53 (2)	203 (8)	914 (36)	102 (4)	127 (5)
63 (2-1/2)	254 (10)	1067 (42)	127 (5)	152 (6)
78 (3)	305 (12)	1219 (48)	127 (6)	152 (5)
91 (3-1/2)	305 (12)	1372 (54)	152 (6)	152 (6)
103 (4)	381 (15)	1524 (60)	203 (8)	203 (8)

in = Inch
mm = Millimeter

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Other Horizontal Pathways

Introduction

Other types of horizontal pathways include:

- Perimeter (surface) raceway systems (metal, wood, and PVC).
- Molding raceways.
- Poke-thru.

Perimeter and molding pathway systems are typically not used to any great extent in new buildings. However, they may be appropriate for building renovations (especially older structures) and other special uses. Perimeter raceways and molding raceways are limited to use only in dry locations.

These pathways must not have any sharp edge; bushings should cover any sharp edges.

These pathways should not be routed through gaps in the floor structure, the ceiling structure, the curtain wall, or any other penetration where a firestop barrier is required.

Perimeter Raceway Systems

Perimeter raceways are available in:

- Plastic, metal, or wood.
- Recessed or surface-mounted designs.
- Baseboard or chair rail heights.

In most designs:

- The front panel is removable.
- Telecommunications outlet/connectors may be placed at any point along the run and may be moved or added after initial installation.

In a perimeter raceway, electrical power, telecommunications, and AV services must be run in separate compartments and must comply with applicable electrical codes. When a metallic barrier is provided, it must be bonded to ground.

The assignment of raceway compartments to either telecommunications or electrical power circuits must be consistent throughout the premises.

Perimeter raceway systems are similar in design to the raceway systems provided with open office (also called modular) furniture systems. Much of the distribution methodology used for perimeter raceway systems may also be applied to open office furniture systems. When these systems are used to distribute and conceal horizontal cabling (as with movable partitions), the pathways must be accessible via a snap-in panel or removable covers.

Molding Raceways

The types of molding raceways include large:

- Picture molding for use in rooms.
- Wood or eaves trough metal moldings for use in hallways.

Sleeves should be placed in the walls to connect room and hall moldings. Conduits should be used to connect hallway moldings to work area locations.

Generally, this type of installation is outdated. However, it is acceptable in some buildings (e.g., apartments and hotels) if the moldings are accessible from the work area.

Poke-Thru

Poke-thru distribution is typically implemented by installing cable from the TR, running it beneath the floor on which the TR is located to a point below where service is desired on the same floor, and then poking through the floor to allow attaching the cable to a telecommunications device.

Because of significant drawbacks, poke-thru distribution is not generally recommended as a horizontal cabling solution. However, there are situations where poke-thru is the only available method.

For example, in the United States, poke-thru distribution should be performed in strict accordance with the procedures found in TIA-569-B and the Underwriters Laboratories Inc.® (UL®) publication *Fire Resistance Directory*.

Floor Boxes

Floor boxes (see Figure 5.6) are used for distributing power, communications, and AV signal cabling throughout a building space. Larger floor boxes can also include air, water, and sewer connections. These boxes are commonly used in large convention centers and exhibit halls

Floor boxes are normally installed in floors with slab-on-grade foundations (with conduits in the ground), in access floor systems, or in wooden stage floors (with or without access underneath).

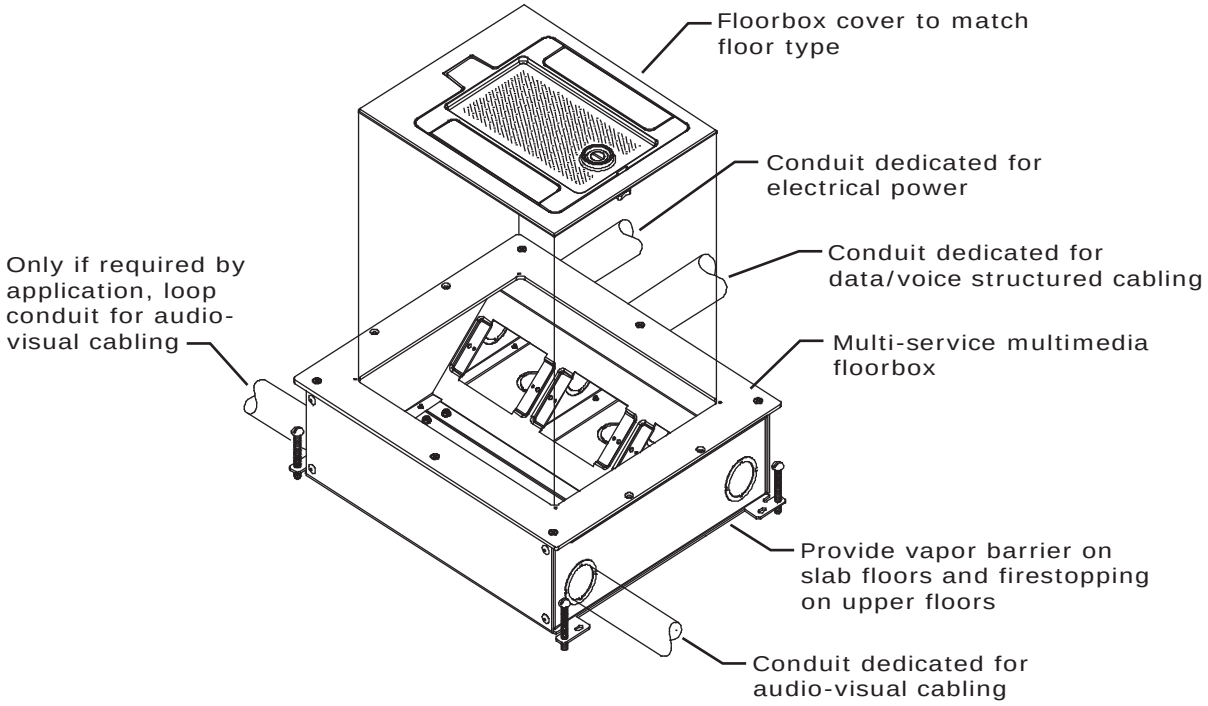
Floor boxes should be installed with conduit systems for the AV system cabling separately from the communications and power systems. In most cases, conduit should be homerun from each floor box and not looped between them. The specified floor box should have distinctly separate spaces for each of these systems.

In a new construction, floor boxes are often installed well in advance of any wall construction.

For floor boxes installed on a grade, a vapor barrier should be installed below the box to prevent moisture intrusion. On upper level floors, the floor box is often deeper than the slab itself. In such case, installing a firebox around the floor box may be necessary to establish the appropriate fire rating of the floor.

Floor Boxes, continued

Figure 5.6
Typical floor box



Miscellaneous Pathway System Considerations

Wall-Mounted Audiovisual (AV) Outlet/Connectors

AV outlet boxes must be used in fire-rated wall installations and firestopped appropriately. Low-voltage mounting brackets (e.g., mud ring, plaster ring, square-drawn cover, and box eliminator) may be used where the wall is not fire-rated.

AV outlet boxes installed in drywall, plaster, or concrete block wall must be at least 100 mm (4 in) by 100 mm (4 in) by 64 mm (2.5 in) deep.

AV outlet boxes that are placed back-to-back to serve adjacent rooms can compromise the effectiveness of the wall as a sound barrier and as a firestop. When possible, the box locations should be offset to the next stud space.

Suitable cover plates should be provided for all AV outlet boxes.

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Miscellaneous Pathway System Considerations, continued

Mounting Audiovisual (AV) Outlet/Connectors in Walls

The following guidelines should be observed when mounting AV outlet/connectors in walls.

For walls with:

- No obstructions for a width of at least 750 mm (30 in), telecommunications outlet/connectors should be mounted 375 mm (15 in) to 1220 mm (48 in) from the finished floor (front reach).
- No obstructions more than 250 mm (10 in) deep for a width of at least 1220 mm (48 in), telecommunications outlet/connectors should be mounted 229 mm (9 in) to 1370 mm (54 in) from the finished floor (side reach).

NOTE: When it is desirable to conceal the telecommunications outlet box behind surface mounted telecommunications equipment (e.g., a telephone), the standard mounting height is 1220 mm (48 in) from the finished floor to the center of the telecommunications outlet box, provided that the location has no obstruction greater than those specified in the preceding bullets.

To provide uniform appearance and accessibility in the work area, it is desirable to mount telecommunications outlet boxes at the same height as the outlet boxes that provide electrical power. It is recommended that the entire faceplate area of telecommunications outlet boxes be installed to meet the specifications above. For example, the height of the lower inside surface of the telecommunications outlet box should be no less than 381 mm (15 in) above the finished floor.

Miscellaneous Pathway System Considerations, continued

Mounting Audiovisual (AV) Outlet/Connectors above Counters and Cabinets

Follow the guidelines below when mounting AV outlet/connectors above counters and cabinets. Mount telecommunications outlet/connectors:

- 1220 mm (48 in) or less above finished floor for surfaces that are behind counters that are:
  - No more than 510 mm (20 in) deep.
  - No less than 750 mm (30 in) wide.

The space below the counter must be unobstructed to provide leg access (e.g., front reach).

- 1120 mm (44 in) or less above finished floor for surfaces that are behind counters that are:
  - Between 510 mm (20 in) and 635 mm (25 in) deep.
  - No less than 750 mm (30 in) wide.

The space below the counter must be unobstructed to provide leg access (e.g., front reach).

- 1170 mm (46 in) or less above finished floor for surfaces that are behind counters and cabinets that are:
  - No more than 600 mm (24 in) deep.
  - No more than 864 mm (34 in) tall.

The space below the counter may only be obstructed up to the depth of the counter/cabinet (side reach).

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Electromagnetic Compatibility

Introduction

Electromagnetic Radiation (EMR)

Electromagnetic radiation (EMR) includes light, radio waves, microwaves, infrared radiation, ultraviolet rays, x-rays, and gamma rays. Known collectively as the electromagnetic spectrum, all of these are fundamentally similar in that they travel at the speed of light (3×10^8 meters/second [m/s]). Electromagnetic waves are distinguished by their wavelength, which is inversely related to frequency, as follows:

$$f \times l = c$$

Where:

f = frequency in Hz

l = wavelength in m

c = velocity of light in m/s

Visible light represents only a very small portion of the electromagnetic spectrum. At one end of the spectrum are radio waves with wavelengths billions of times longer than those of visible light.

At the other end of the spectrum are gamma rays. These have wavelengths millions of times smaller than those of visible light.

The potential for EMI occurs when devices or systems share a common electromagnetic environment and their frequencies of operation overlap. If they operate over a different range of the electromagnetic spectrum, they do not interfere with each other.

Need for Compatibility

As electronic equipment becomes more sophisticated, the required performance levels, operating speeds, and frequencies rise. Forms of EMI that did not cause problems in the past can now impact telecommunications systems.

Earlier generations of telecommunications systems used electromechanical devices that by nature were fairly robust to EMI. Operating these electromechanical devices required a deliberate electrical energy strong enough to accomplish a conversion to mechanical force that was sufficient to sustain an “on” cycle (e.g., contact closure for a relay operation). Random EMI signals typically are not strong enough or sufficiently long to qualify as deliberate electrical energy and sustain an “on” cycle in an electromechanical device. In addition, the mechanical construction and large mass of electromechanical devices rendered electrical power quality considerations (e.g., line voltage sags, surges, dropouts) of minimal concern.

Introduction, continued

By contrast, modern electronic telecommunications systems use solid-state devices that are more susceptible to EMI. Operating these electronic telecommunications systems requires a less deliberate electrical energy that must only be strong enough to accomplish a molecular displacement within the electronic device. Random electrical noise can mimic this electrical energy. Because of the molecular construction and small mass of electronic devices, electrical power quality considerations (e.g., line voltage sags, surges) are crucial. Momentary low-energy signals can cause some electronic devices (e.g., logic gates) to go into a self-latching mode.

Conducted interference enters electronic devices primarily through:

- Input signal lines.
- Output signal lines.
- Electrical power cords.

Radiated interference enters electronic devices primarily by means of:

- Missing or inadequate enclosures.
- Missing or inadequate device shielding.
- Signal lines and proximity to radio frequency (RF) sources.

The designer must take precautions in the design, procurement, and installation to protect against EMI and ensure electromagnetic compatibility (EMC). Telecommunications installations that experience malfunctions and failures often have one or more problems in the electrical power and grounding system. The designer's precautions should involve interaction and interdependence among the following:

- Powering
- Grounding
- Electrical protection
- Cabling
- Shielding
- Filtering
- Interface design

Responsibility for Electromagnetic Compatibility (EMC)

Designers are not directly responsible for the EMC of telecommunications systems. However, being appropriately informed and knowledgeable can greatly contribute to the EMC performance of the installation. In complex situations, an EMC specialist should be consulted.

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Minimizing Electromagnetic Interference (EMI)

Equipment Rooms (ERs)

Telecommunications systems should not be placed next to ER equipment that can generate EMI.

Electrical feeders and branch circuits of the interfering equipment should be separate from telecommunications systems. Likely sources of EMI are heavy-duty electromechanical equipment (e.g., copiers, door openers, elevator systems, factory equipment). Shielding can be used to minimize EMI in the locations that permit and require such solution.

Design of Horizontal Pathways and Spaces

Potential sources of EMI should be a primary consideration when selecting types of horizontal cabling and designing the layout of horizontal pathways. Typical sources of EMI include:

- Electric motors, electric pencil sharpeners, electric erasers, transformers, and fluorescent lighting that share distribution space with telecommunications cabling.
- Large fax machines.
- Copiers that share work area space with equipment cords and terminals.
- Electrical power cable that supports such equipment.

EMI should be avoided by maintaining physical separation between the possible sources and the telecommunications cabling.

Firestopping

Introduction

National fire codes provide guidelines for reestablishing the integrity of fire-rated architectural structures and assemblies (e.g., walls, floors, ceilings) when these barriers are penetrated by:

- Pipes.
- Ducts.
- Cables.
- Conduits.
- Innerducts.
- Cable trays.
- Other items.

IMPORTANT: The designer/installer should understand the phrases fireproof, fire break, fire shield, and fire zone.

Terms

When referring to firestopping systems, the following terms are essentially synonymous:

- Qualified
- Tested
- Listed
- Classified
- Approved

Each term refers to firestopping systems that have been tested by an independent laboratory and certified as effective (different laboratories use different terms). For simplicity, this chapter will use the term qualified to represent all of these terms.

The terms system and design are also nearly synonymous; both refer to an arrangement of specific firestopping materials in a specific configuration.

The user must understand that a qualified system refers to the complex arrangement of construction assembly (floor or wall), the penetrating item (cable, conduit, tray, innerduct, etc.), and the proprietary seal material or device. Substitution of one seal material for another voids the qualification and is not recommended. The AHJ typically rejects undocumented systems.

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Firestopping Requirements

General firestopping guidelines are provided by national and international standards-setting organizations (e.g., NFPA, International Code Council [ICC], ISO). Firestopping requirements more rigid than those described in national codes may be set by:

- Local building codes.
- Construction documents.
- Reference standards.
- Insurance underwriters.

Secondary Functions of Firestop Seals

In many cases, firestop seals may be required to perform secondary safety or security functions such as:

- Acting as environmental protection seals.
- Special requirements (e.g., EMI/electromagnetic pulse [EMP] barrier).
- Sealing around pipes that reach high temperatures and may move axially or laterally.
- Resisting effects of explosion.

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Chapter 6
Networking

The convergence of communications systems is resulting in an increasing amount of audiovisual (AV) equipment that utilize networking protocols. Having a solid understanding of networking basics has become a necessity for the successful AV designer. This chapter addresses basic networking concepts as they apply to the AV field.

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Overview

Introduction

Networks are implemented to enable the sharing of resources and the exchange of information between users. As the number of resources, users, and connections increases, most networks must be routinely modified to accommodate growth—ideally without any reduction in the features and performance levels users have come to expect. This makes network design applications a dynamic and continuous process within most organizations using audiovisual (AV) applications.

An organizational network is defined as an interconnected system of computers, peripheral devices, and software. This kind of network enables the transfer of all types of messages between users, administrators, and devices.

Physically, a network can be identified as two or more connected devices and the media used to enable the connections—a cabling system, wireless links, or telecommunications circuits.

In addition to the media, a network must be equipped with a set of services designed to accommodate multiple simultaneous requests for communications. These services include:

- Access control—Necessary in cases where two or more devices attempt to use a shared resource (e.g., a telecommunications circuit between two sites, a specific printer) at the same time.
- Synchronization—Necessary to ensure that a receiving device is listening when a sending device is transmitting to that device.
- Flow control—Necessary to monitor and adjust the rate at which data is transferred from the sender to the receiver to minimize transfer time and data loss. For example, if a receiving device is occupied with other tasks, it will ask the sending device to delay the transmission.
- Error control—Necessary to verify that a message was transferred successfully between a sender and a receiver. It is also needed to request a retransmission in case a message or part of a message was not transferred successfully.

In its basic form, a local area network (LAN) is a group of personal computers (PCs) called stations connected with cabling or wireless links to a centralized network access device called a hub or switch. A special-purpose PC called a server is also connected to the same hub or switch and is used to coordinate network activities and store the shared data.

Introduction, continued

A LAN:

- Serves a relatively small number of users (e.g., an organizational department located on one floor of a building).
- Creates a single broadcast domain containing all of the connected devices. Any device connected to the LAN can transmit a message simultaneously receivable by all of the other devices connected to the same LAN (as opposed to transmitting the message individually to each device).
- The operating speed is measured in millions or billions of bits transferred per second, expressed as megabits per second (Mb/s) and gigabits per second (Gb/s).

NOTES: The word bit is a contraction of the phrase binary digit. Bits are the smallest units of information used by a computer network. Bits are strung together into digital words, which are the coded representation of numbers, words, and commands.

An 8-bit word is called a byte. The letter that designates bits is lowercase, b; for bytes it is the uppercase, B.

An organization can implement an internetwork by linking together two or more internal LANs or by linking an internal LAN to an external network (e.g., the Internet or a LAN belonging to another organization). In both cases, the internetwork functions as a control and transit point for the messages that are generated on each of the connected networks.

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Communications and Storage

Once the physical connections are made between the devices forming a LAN, all devices must use a common set of rules for network communications services. These rules are known as protocols. In most LAN implementations, the technology used to provide network communications services is Ethernet.

When connecting one LAN to another—within a building, on a campus, in a metropolitan zone, or across a wide area—to form an internetwork, a second set of network communications services is required. For any device on one LAN to communicate with any device on another LAN, all devices on an internetwork must use addressing that includes both device and network identification. On a LAN, only the devices need to be identified, since there is only one network connecting all devices. In most implementations, the technology used to provide internetwork communications services is Internet protocol (IP).

Historically, network storage devices (e.g., hard disks) were located within shared computers called servers. This form of storage is called direct-attached storage (DAS), since the storage device is directly connected to the servers. DAS is the combination of a high-speed interface and shared disk drives.

In recent years, other forms of shared storage have been developed to accommodate the rapid growth in the volume of data on most networks. Currently, it is possible to connect a storage device containing multiple hard disks to a LAN rather than a server, using a technology called network-attached storage (NAS). NAS is a form of data storage where shared data is placed on a high-capacity storage device with a built-in network interface card (NIC).

Another option is to use a storage area network (SAN), which consists of multiple storage devices on a specialized high-speed network connected to one or more LANs.

Bandwidth

In networks (and digital technology) bandwidth is used to describe how fast data flows on a given transmission path—how much data can be transmitted in a fixed time. Speed is defined in bits per second (b/s).

The term bandwidth is also used as an analog performance measurement indicating the range of frequencies between a minimum and maximum value that circuitry can handle without distortion. In radio frequency (RF), video, display and digital audio technology, the wider the bandwidth the better the quality that results—the sharper pictures and the better sound. On a network, the higher the data rate the better the performance of the network.

Network bandwidth is the rated throughput capacity of a communications network medium or protocol. It is expressed as data speed in b/s or B/s.

Open Systems Interconnection (OSI) Reference Model

Communications on a LAN or an internetwork occurs at many levels (e.g., between devices as well as between the software programs running on those devices). In 1978, the International Organization for Standardization (ISO) introduced a framework for classifying all of the processes associated with message exchange on a network. This framework is formally called the Open Systems Interconnection (OSI) Reference Model, commonly referred to as the OSI model.

The objective of the OSI model is to provide a structured approach for the development of all types of networks. The model specifies the sequence of processes required for network message transfer between applications running on different systems.

This broad definition of a system enables using the OSI model to describe any type of network, from a small LAN to the Internet.

The OSI model (Figure 6.1) uses an approach called layering to illustrate and explain the message exchange process. This approach divides the various functions and services provided by a network into discrete groupings called layers. In the OSI model, seven layers are used.

In the OSI model, each layer provides services to the layer above, while hiding from that layer the processes used for services implementation. This enables making changes to any layer without requiring changes to any of the other layers, as long as the inputs and outputs of the changed layer remain the same. For example, specifications for signaling over a new type of transmission medium can be incorporated into the Physical layer of an existing LAN technology without modifying LAN operations in any other layers. This enables taking advantage of the new technologies without sacrificing compatibility with the existing networks.

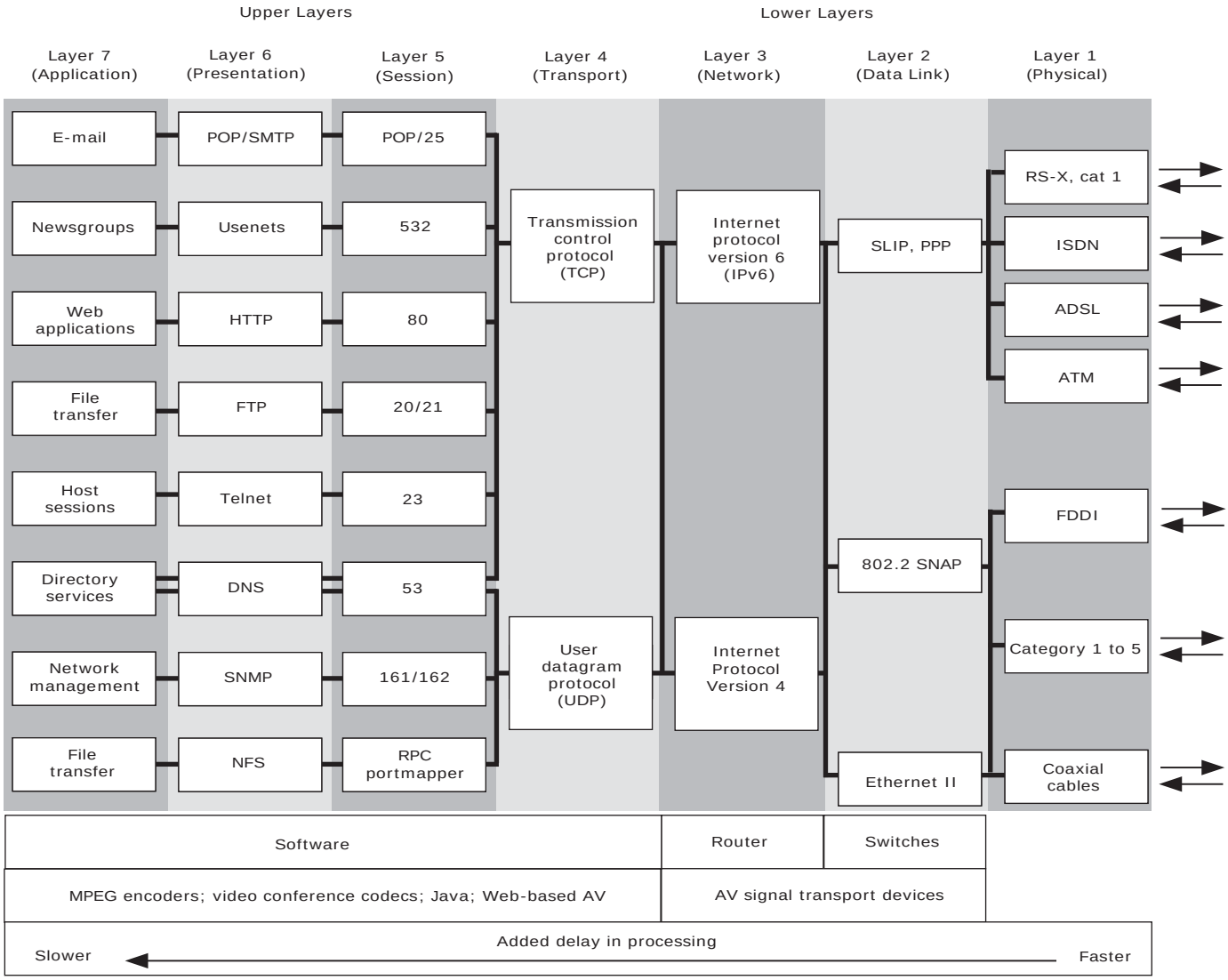
The layers in the OSI model are commonly described as being interconnected in vertical form, also called a stack or protocol stack. The stack defines how network hardware and software interact at various levels to transfer messages between devices on a LAN and between LANs on an internetwork. Protocol stacks have the following characteristics:

- Each layer provides a set of services.
- Services of each layer and the stack are defined by protocols.
- Lower layers provide services to upper layers.
- Service access points (SAPs) are the connection points between layers.

When a message has to be transferred between two systems, a peer-to-peer relationship is established between the corresponding layers in the protocol stack of each system—a given layer communicates with its counterpart over the network. The message, along with any control information, is passed down from the sending layer to the layer below. This process continues until the lowest layer in the stack is reached. The data is then transmitted from the lowest layer of the sending system to the lowest layer in the receiving system, where it is passed up through the layers until it reaches the counterpart, or peer, of the sending layer.

Open Systems Interconnection (OSI) Reference Model, continued

Figure 6.1
Open Systems Interconnection model



ADSL = Asymmetric digital subscriber line
ATM = Asynchronous transfer mode
AV = Audiovisual
DNS = Domain name server
FDDI = Fiber distributed data interface
FTP = File transfer protocol
HDSL = High bit rate digital subscriber line
HTTP = Hypertext trasfer protocol
ISDN = Integrated services digital network
MPEG = Moving Picture Experts Group
NFS = Near field communication
POP = Post office protocol
PPP = Point-to-point protocol
RPC = Remote procedure call
SLIP = Serial line Internet protocol
SMTP = Simple mail transfer protocol
SNAP = Subnetwork attachment point
SNMP = Simple network management protocol

Open Systems Interconnection (OSI) Reference Model, continued

Physical Layer (Layer 1)

The Physical layer protocols are responsible for the transfer of bits over various media.

NOTE: The OSI model does not define cabling or other transmission media.

Data Link Layer (Layer 2)

The Data Link layer protocols are responsible for intranetwork data transfer (e.g., between devices connected to a LAN). Some of the functions include device identification and managed access to shared transmission channels.

Network Layer (Layer 3)

The Network layer protocols are responsible for internetwork data transfer (e.g., between LANs connected to the Internet). When multiple routes exist, the Network layer protocols choose the most appropriate one based on certain criteria as message priority, route congestion, or route cost.

Transport Layer (Layer 4)

The Transport layer protocols enable introducing various levels of quality to the data transfer process. After a connection has been established between network devices, the Transport layer protocols can be used to select a particular class of service, monitor the transfer for billing purposes, ensure that the appropriate service quality is maintained, and generate an alert if this quality has been compromised.

Session Layer (Layer 5)

The Session layer protocols provide the services needed to synchronize and manage data transfer between network devices. For example, Session layer protocols direct devices to start, stop, restart, or abandon data transfer activity.

Presentation Layer (Layer 6)

The Presentation layer protocols are responsible for various forms of data conversion. They negotiate and establish a common form for data representation, which includes character code translations, data compression and decompression, or data encryption and decryption.

Application Layer (Layer 7)

The Application layer protocols enable identical or different applications running on different systems to use the services of a network to exchange information. Services defined by this layer include file transfer, message handling, and remote management. For example, various types and versions of e-mail software can use the same Application layer protocols to exchange messages over the Internet.

Network Components

This section describes the hardware and software components associated with LAN environments. The characteristics and operations of each type of component are presented and, where appropriate, the OSI model is used for classification.

The following LAN components are covered in this section:

- Stations
- Servers
- Shared peripherals (e.g., network printers)
- Hubs
- Switches
- Routers

Stations

The term station is used to describe the device that allows a user to access the network. Stations can be local or remote. A local station connects to the network over cabling or wireless media. A remote station connects to the network over a telecommunications circuit.

The most common type of local station is a desktop or laptop PC.

Two essential components are:

- Network interface cards (NICs).
- Station software.

Network Interface Card (NIC)

The hardware component that connects a station to the network medium is called a NIC.

Most station NICs are capable of multi-rate operations. For example, a 10/100/1000 Mb/s NIC can be configured to automatically detect the maximum operating rate of the hub or switch port to which it connects. The NIC then configures itself to operate at that rate. This feature is called auto-negotiation (AUTONEG).

Station Software

Different types of software are used to transform a stand-alone PC into a station. These software components include drivers, utilities, and clients. Drivers are needed to link a NIC to its station's operating system (OS), enabling the station to use the NIC. The NIC manufacturer typically supplies various utilities to perform diagnostic tests on the NIC and the network communications channel.

Servers

The term server is used to describe a device that manages one or more resources shared by users and administrators on a network. The types of resources that can be accessed through a server are diverse. They include software applications, shared peripheral devices, user-created files, Internet access, and management tools.

A server can be specialized in form, function, and components. Mainframes and minicomputers can be configured to operate as servers on networks with thousands of users. Alternatively, a desktop PC can be used as a server in a small workgroup environment.

Shared Peripherals

The term peripheral device (or peripheral) describes any equipment that can be connected to and controlled by a PC. Examples of peripherals include printers, scanners, modems, and removable storage devices (e.g., compact disk [CD] or tape drives).

Switches

A switch is a network access device that provides a centralized point for LAN communications, media connections, and management activities—like a hub. Unlike a hub, where all ports connect to a single (shared) communications channel, each port on a switch is a separate communications channel representing a different collision domain. This enables multiple devices on a switch-based network to transmit simultaneously, as long as they are connected to different ports on the switch.

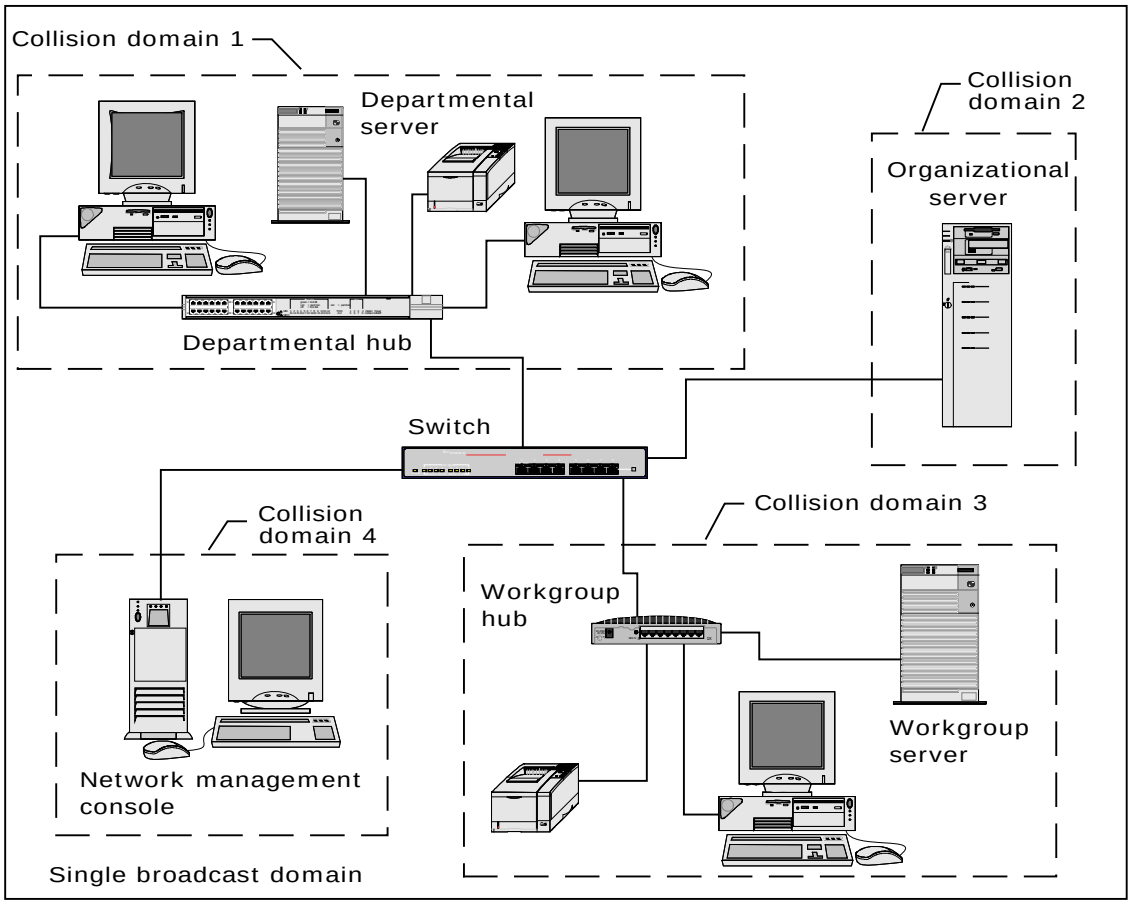
In addition to servers, stations, and network-attached peripheral devices, connecting a hub to a switch port is also possible. In such cases, all devices connected to the hub contend for access to the switch port. Switches and hubs can be deployed in various configurations to form a LAN containing both shared and dedicated communications channels.

Within the OSI model, the Data Link layer (Layer 2) deals with communications between devices in the same broadcast domain. A switch is classified as a Data Link layer device.

Switches, continued

Compared to a hub-based network, switches enable sustaining more devices on a LAN by enabling multiple collision domains, one for every switch port. However, switches cannot contain the increase in broadcasts generated by the additional devices. At some point, the level of broadcast traffic increases network response time significantly, which makes adding devices to the LAN impractical. When this happens, an internetwork must be implemented to divide the LAN into multiple broadcast domains, in the same way a switch is used to create multiple collision domains on a LAN (see Figure 6.2).

Figure 6.2
Hybrid local area network with four collision domains



Switches, continued

Virtual Local Area Network (VLAN) Operations

One advanced feature of a network switch is to provide virtual LAN (VLAN) segmentation without the need to connect a given station, server, or shared peripheral device to a specific switch port. Assuming all switches on an organizational network provide the same features, any device can be connected to any switch port.

The VLAN groups various combinations of ports into a common broadcast domain. Devices in the same VLAN group operate as if they were connected to the same switch and cabling system, even though each device may be physically connected to a different switch using any type of approved cabling. If stations need to be relocated, the switch ports to which they are transferred can be assigned to the same VLANs as their previous ports, making the relocation transparent from a network traffic point of view.

On a conventional LAN, a single broadcast domain spans all of the hubs and switches as well as the devices connected to them. This is described as a flat network. Any broadcast frame issued by a device is delivered to all other devices, regardless of the speed or type of connection used. The greater the number of devices on a LAN, the greater the number of broadcasts transmitted. Excessive broadcasts limit the total number of devices on a LAN, even when all connections are switched.

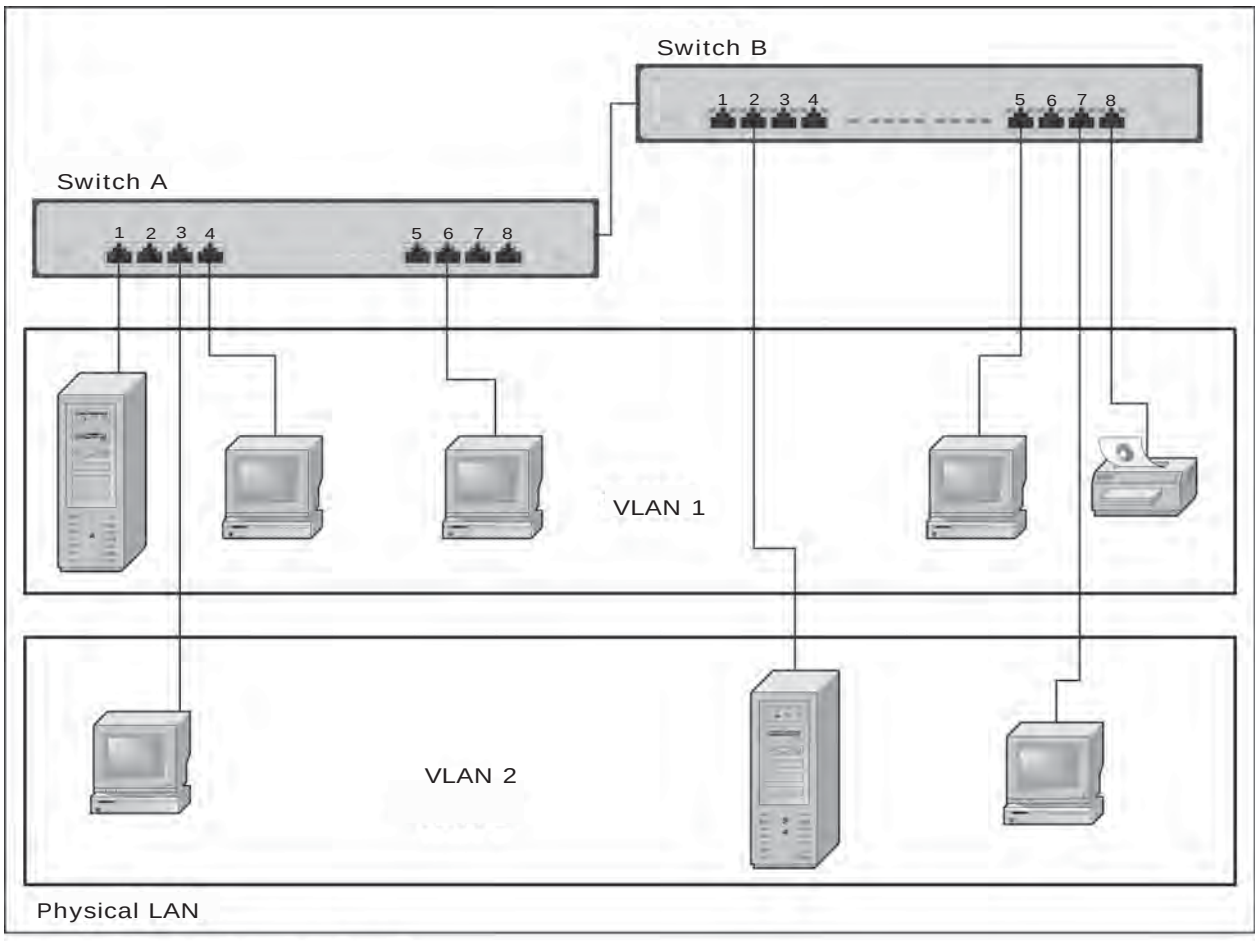
In most cases, a broadcast does not have to be sent to every device on the organizational network. For example, a broadcast request for configuration or management data issued by a station in one department is usually intended for a server in the same department. However, if the organizational network is made up entirely of hubs and switches, every station and server in the organization will receive the broadcast.

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Switches, continued

On most networks, it is necessary for some devices to have broader access than others. For example, some stations may require access to servers in other VLAN groups. A common way to enable communications between VLANs is to use a router to transfer frames from one VLAN to another (see Figure 6.3).

Figure 6.3
Simple virtual local area network configuration



LAN = Local area network
VLAN = Virtual local area network

Switches, continued

Quality of Service (QoS)

Managing a network is about increasing performance of the network. A higher level of such management in networks is referred to as quality of service (QoS), as shown in Figure 6.4. QoS is the ability to define and specify a level of performance in a data communications system.

QoS can specify modes of service that ensure optimum performance for traffic such as real-time voice and video, guaranteeing that the data arrives in time for real-time playback without interruption. QoS is responsible for the delivery of real-time dependent data (audio and video) over a network.

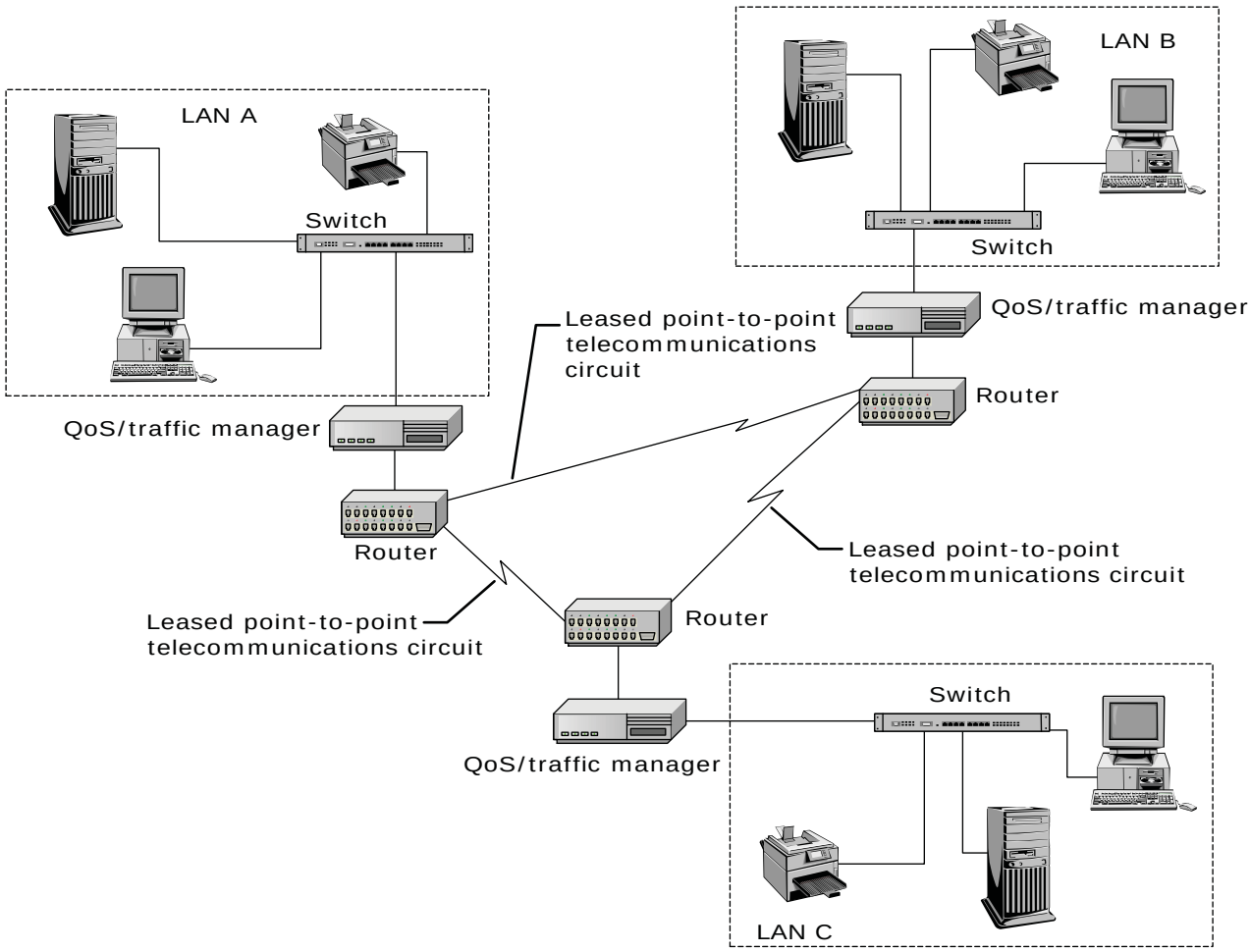
Many IP-based data networks currently do not have protocols that can guarantee either the route or the time it will take for an audio and video data packet to reach the receiver. This is common when viewing multimedia elements on the Internet.

The term QoS is broadly used to describe any technology developed to manage network traffic. In all cases, the role of QoS is to provide the means to assign both network bandwidth and a guaranteed level of latency to any network application for some or all users. Other terms used to describe QoS include:

- Packet prioritization.
- Resource allocation.
- Resource reservation.
- Bandwidth reservation.
- Bandwidth management.
- Bandwidth throttling.
- Traffic management.
- Traffic shaping.
- Traffic tuning.
- Differentiated services.
- Intelligent traffic handling.
- Congestion management.
- Route control.

Switches, continued

Figure 6.4
Quality of service and traffic management



= Zone in which traffic is managed
LAN = Local area network
QoS = Quality of service

Switches, continued

In general, QoS technologies can be divided into two groups:

- The integrated services group of QoS technologies reserve and assign network resources to specific types of traffic, guaranteeing network availability for a data stream prior to its generation by the sending device. This approach is referred to as reservation.
- The differentiated services group of QoS technologies uses identifiers to indicate the priorities or paths of various types of messages generated by sending devices. Network devices between senders and receivers process and forward messages on the basis of these identifiers. This approach is referred to as prioritization.

Both integrated and differentiated services can be used for individual data streams (also referred to as data flows) as well as groupings of streams with similar characteristics (also referred to as aggregates).

Various classes of products (e.g., switches and routers) provide tools to manage the flow of traffic entering and exiting their ports and interfaces. However, the long-term goal is to provide end-to-end QoS, where traffic is prioritized and managed from the sending device to the receiving device—regardless of the number of network or internetwork access devices between the endpoints.

These levels range from nonexistent QoS through end-to-end QoS over the public Internet, which is expected in the future as Internet technologies evolve.

Institute of Electrical and Electronics Engineers® (IEEE®) Standards 802.1Q and 802.1P

Two important international standards have been defined for networks addressing, network architecture, and QoS. IEEE 802.1Q involves bridged VLANs, essentially allowing separate networks to be established in software.

IEEE 802.Q adds a tag for the Ethernet media access control (MAC) structure. Within this tag are fields for the identification of a specific VLAN and a field for prioritization of network traffic. However, 802.1Q does not define the prioritization. However, there is an expansion on IEEE 802.1Q, called IEEE 802.1P.

Whereas IEE 802.1Q defines VLANs, IEEE 802.1P defines QoS on the network. IEEE 802.P also works at Layer 2 of the OSI model. QoS is concerned with bandwidth availability, transmission delays, and network reliability.

IEEE 802.1P sends higher priority data packets before transmitting lower priory packets. Network administrators may implement a network policy guaranteeing a QoS for certain applications that are critical or affected by latency (e.g., voice and video transmission).

Routers

Routing is used for interconnecting various types of LANs at Layer 3 of the OSI model. Routers enable segmenting an organizational network into multiple broadcast domains, also referred to as subnetworks (or subnets), using network address assignments. In cases where multiple LANs are interconnected using routers, the role of each router is to direct Layer 3 datagrams to their destination LANs—and ultimately, their destination devices—over the most efficient path.

A router is a combination of hardware and software, typically in the form of a specialized device. Installing multiple NICs and routing software on a general-purpose server is also possible. This allows the server to function as a router. In both cases, the software used to implement routing operations can be described as an internetwork operating system (IOS). The functions of an IOS include:

- Enabling communications between a variety of LAN technologies and subnets.
- Choosing the most appropriate path through a multi-path internetwork for any given datagram.
- Configuring internetwork devices and traffic control parameters.

A router can process traffic selectively, using the values found in various fields of a datagram. For example, broadcast traffic generated on one subnet is prevented from reaching other subnets, a process called filtering. By discarding broadcast datagrams, instead of forwarding them, the filtering capability of a router eliminates a common source of unnecessary traffic on an organizational network. The filtering capabilities of a router can also be used to grant or deny access to routing resources on the basis of network addressing information. Each interface on a router can be programmed with a set of rules listing access privileges for that interface. The term access control list (ACL) is also used to describe these rules.

Routing and LAN switching functionality can be incorporated into a single device. Such hybrid units are typically modular in form, enabling the linking of various types of LANs as well as other routers to a centralized unit, often referred to as a backbone chassis. To provide Internet connectivity to all attached LANs, the backbone device can be linked to a router managed by an Internet service provider (ISP).

Traffic Management

The traditional method of improving the performance of a congested network is to increase the data transfer rate on some or all of the channels. In most cases, this approach is feasible only for LANs, where Gb/s NICs and switches are readily available and affordable to most organizations. By comparison, the cost of most high-speed telecommunications circuits typically limits the maximum speed of such connections to a much smaller value, measured in Mb/s. In such cases, the result is acceptable performance for users when connecting to a local device and increased response times when the connection extends beyond the LAN (e.g., when connecting to a branch office over the Internet).

Traffic Management, continued

Network congestion is easiest to observe with a limited bandwidth, as in the case of multiple users sharing a modem-based connection to the Internet. However, even on a high-speed LAN where bandwidth is not an issue, running certain applications can still be difficult due to problems with overall latency.

Network latency can be defined as the amount of delay in delivering a message from the source device to the destination device. In particular, applications that transfer voice or AV content require stable and limited latency from the network. This is particularly important in cases where the content is generated in real time, as with videoconferencing. It is possible, for example, for two users to successfully communicate using a videoconferencing application on some occasions but not on others—using the same stations, software, and network—due to the changes in the level of network activity. Similarly, if the latency of the network increases significantly during the videoconferencing session, the voices and video images of the individuals will be noticeably degraded.

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Open System Interconnection (OSI) Layer Components

Telecommunications Circuit Fundamentals—Layer 1

Physical layer includes telecommunications circuits that make remote networks appear local by providing equivalent data transfer rates. Suppliers of telecommunications circuits include telephone companies as well as specialized carriers. Typically, circuit costs increase with distance and maximum data transfer rate. Common telecommunication circuits include:

- Public switched telephone network (PSTN).
- T-carrier system.
- Integrated services digital network (ISDN).
- Digital subscriber line (DSL [xDSL]).
- Asymmetric digital subscriber line (ADSL).

PSTN is a telecommunications circuits referred to as dial-up lines, analog circuits, or more generally as the telephone network.

T-Carrier System

T-carrier system is a digital communications service offered by circuit providers in many countries. In North America, the most common leased T-carrier circuits are T-1 and T-3. The signaling hierarchies used in Europe and Japan differ from the T-carrier hierarchy used in North America. To distinguish between them, the terms E-1/E-3 and J-1/J-3 are used to describe the European and Japanese counterparts to T-1/T-3.

Integrated Services Digital Network (ISDN)

ISDN is an international digital communications infrastructure intended to replace the analog PSTN used for voice communications. As a switched end-to-end digital service, ISDN can transport all types of traffic—voice, data, facsimile, and video—over a common network.

ISDN provides two types of circuits, referred to as rate interfaces:

- Basic rate interface (BRI)
- Primary rate interface (PRI)

A BRI circuit consists of two B channels, each with an operating speed of 64 kilobits per second (kb/s), and one D channel with an operating speed of 16 kb/s. Each B channel can function like a PSTN circuit and have its own telephone number—called a directory number (DN) in ISDN terminology. Some ISDN circuit access devices can combine, or bond, the two B channels to form a single 128 kb/s channel.

NOTE: BRI is sometimes referred to as 2B + D.

Telecommunications Circuit Fundamentals—Layer 1, continued

In North America and Japan, a PRI consists of 23 B channels and one D channel (23 B + D). Each of the 24 channels operates at 64 kb/s. This makes a North American or Japanese PRI the equivalent of a T-1 or J-1 circuit, each of which contains 24 64 kb/s DS-0 channels. In Europe, an ISDN PRI consists of 30 B channels and one D channel (30 B + D), all operating at 64 kb/s—making the European PRI the equivalent of an E-1 circuit.

Digital Subscriber Line (DSL)

DSL technology can be described as the successor to ISDN, capable of providing high-speed data transfer services to residential and commercial subscribers over an infrastructure normally used for analog PSTN circuits. A DSL circuit can operate at various rates, ranging from 16 kb/s to 52 Mb/s.

Asymmetric Digital Subscriber Line (ADSL)

ADSL is the most widely offered type of DSL service. A subscriber with an ADSL circuit can receive data at a maximum rate of 6.1 Mb/s (downstream channel) and can transmit data at a maximum rate of 640 kb/s (upstream channel).

Ethernet—Layer 2

Ethernet is a LAN protocol that uses a logical bus structure and carrier sense multiple access with collision detection (CSMA/CD). Ethernet is a peer-based network of devices that share communication on the same medium.

Carrier sense multiple access (CSMA) refers to the constant monitoring of a shared communications channel by each connected device. Collision detection (CD) refers to the detection of collisions and the subsequent generation of jamming signals.

A common medium physically links all network devices to form a single collision domain. Typically, the medium is balanced twisted-pair or optical fiber cabling, although wireless media can also be used.

The increase in the number of devices on most networks and the advances in the processing power of each connected device have necessitated the development of faster Ethernet data transfer rates. The introduction of Gigabit Ethernet (GbE) has enabled network designers and administrators to relieve congestion and accommodate future growth in network traffic.

The following versions of Ethernet have been published as IEEE® standards:

- Classic Ethernet—10 Mb/s data transfer rate
- Fast Ethernet—100 Mb/s data transfer rate
- Gigabit Ethernet (GbE)—1000 Mb/s data transfer rate
- 10 Gigabit Ethernet (10 GbE)—10 000 Mb/s data transfer rate

Ethernet—Layer 2, continued

Unlike Ethernet and Fast Ethernet, GbE is rarely implemented in a shared communications mode using hubs—although it is technically possible to accomplish. Most GbE vendors offer only switched connections, not hubs. In such cases, each GbE port on a switch is a separate collision domain, dedicated to the connected device. Since no other device shares the port, CSMA/CD functionality can be disabled and the device can transmit at any time, without the need to check that the communications channel is available. In addition, both ends of a link can transmit at the same time, using the full-duplex operating mode.

A number of techniques have been developed to enable transmission at 1000 Mb/s over the same type of cabling associated with Fast Ethernet—category 5 (or higher) balanced twisted-pair cabling. 1000Base-T permits bidirectional signaling at 1000 Mb/s over four pairs of category 5 (or higher) balanced twisted-pair cabling. For added performance, each pair can simultaneously transmit and receive signals—a technique called dual-duplex signaling.

Media Access Control (MAC)—Layer 2

A MAC address is the actual hardware address of a NIC device (usually, but not necessarily, an Ethernet card). Each NIC device has a unique 48-bit number in its hardware (48 bits allows for about 281 trillion addresses). These addresses come from within a table of numbers assigned to NIC manufacturers.

Internet Protocol (IP) Addressing—Layer 3

An IP address is used to define the unique identity of a computer attached to a transmission control protocol (TCP)/IP network such as the Internet. Every client and server station must have a unique IP address. An IP address defines the device and its location on a network. Client workstations have either a permanent address (static address) or one that is dynamically assigned to them each dial-up session (dynamic address). Every device put on a network (including AV and controls system gear) must have an IP address assigned to it.

Internet Protocol (IP) Address Structure

An IP address can be divided into two parts. The first is known as the network prefix and the second as the host number.

An IP address is a 32-bit number that contains both the network prefix and the host address of the network device on that network. IP addressing uses a dot notation to break the 32-bit number into 4 numbers of 8 bits each (from 0.0.0.0 to 255.255.255.255).

The current version of IP, version 4 (IPv4) may have 2^{32} (4 294 967 296) addresses.

All devices on a given network share the same network prefix but must have a unique host number. Similarly, any two devices on different networks must have different network prefixes but may have the same host number.

Internet Protocol (IP) Addressing—Layer 3, continued

Internet Protocol (IP) Address Class

The network prefix portion of the IP address is further divided into three different address classes—A, B, and C. This is often referred to as classful addressing because the address space is split into three predefined classes, groupings, or categories. Each class fixes the boundary between the network prefix and the host number at a different point within the 32-bit address, as follows:

- Class A addresses with 1 through 126 (e.g. 10.1.23.19).
- Class B addresses begin with 128 through 191 (e.g. 172.16.19.48).
- Class C addresses begin with 192 through 223 (e.g. 193.18.9.10).

NOTE: The number 127 is reserved for special purposes.

Subnets

A subnet is a portion of a network. It shares an IP address component with the main network. It may or may not be physically independent of the main network. (A subnetwork [subnet] is to a network what a network is to the Internet). A subnet mask is the method used for splitting IP networks into a series of physical subgroups or subnets.

Network devices use the subnet mask to help route information. They do this by performing logical and mask operations between the subnet mask and the computer's own IP address, comparing the results to the destination address, and determining if the information needs to go to a device on that network.

On most local networks, the subnet mask is 255.255.255.0.

The subnet mask is a binary pattern that is matched up with the IP address to turn part of the host identification (ID) address field into a field for subnets.

Dynamic Internet Protocol (IP) Address

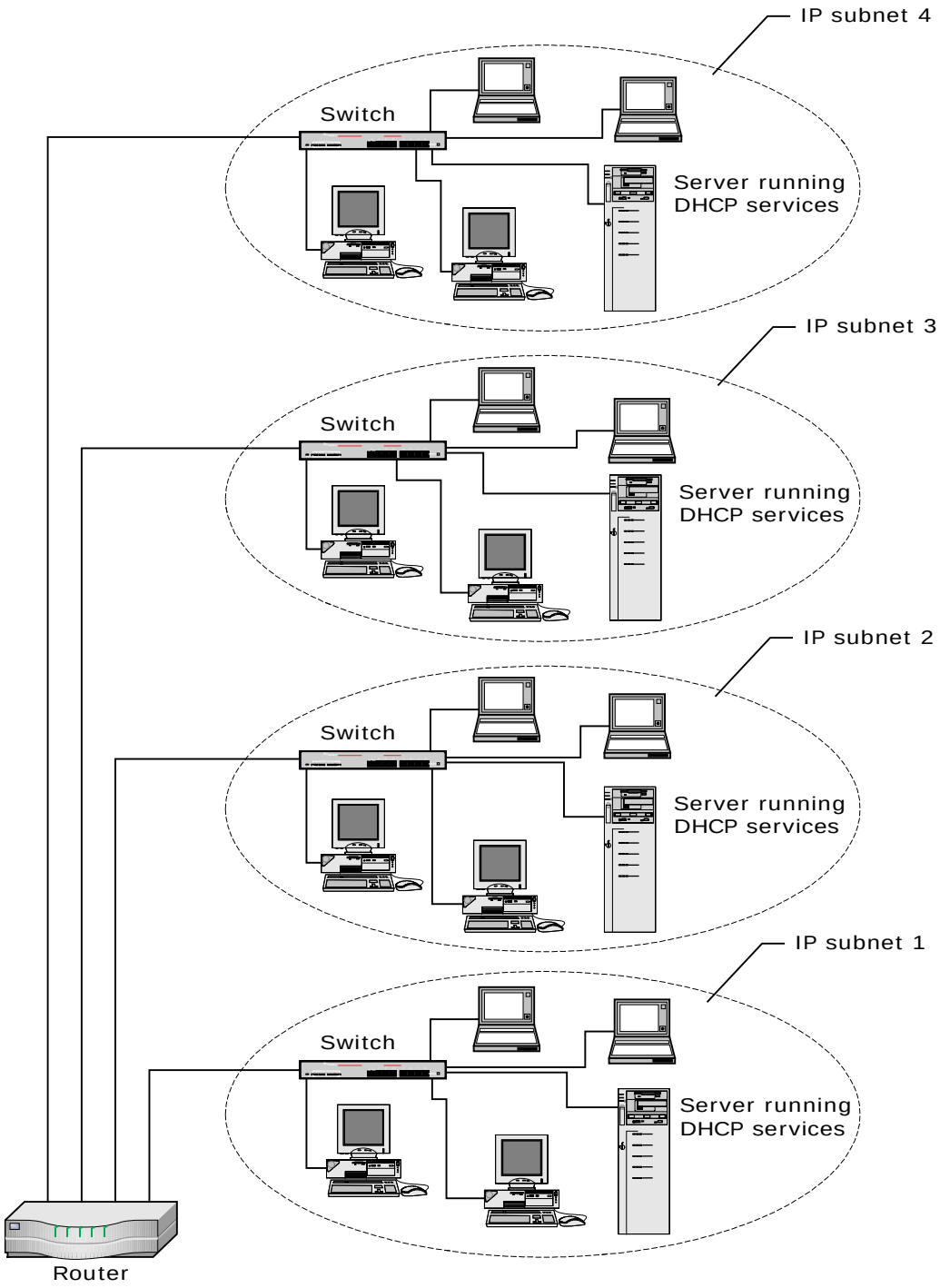
The two types of IP addresses are static and dynamic.

A dynamic IP address is a nonpermanent address assigned to a network device upon connection to a transmission control protocol/Internet protocol (TCP/IP) network. The connection to the network and address assignment is made through a dynamic host configuration protocol (DHCP) server to which the network device connects over a dial-up connection (i.e. telephone modem) or Ethernet connection (i.e. cable modem).

Installing DHCP services on multiple servers and assigning a valid pool of addresses to each server can assure administrators that clients will always receive addresses consistent with the broadcast domain to which they are connected, with no possibility of address duplication (see Figure 6.5).

Internet Protocol (IP) Addressing—Layer 3, continued

Figure 6.5
Multiple dynamic host configuration protocol servers on a network



DHCP = Dynamic host configuration protocol
IP = Internet protocol

Internet Protocol (IP) Addressing—Layer 3, continued

A dynamic IP address requires configuration for the host device, and is the most common means of IP address obtainment for client network devices. A new IP address is given each time the device reconnects to the network.

Static Internet Protocol (IP) Address

A static IP address is a permanent address for a particular network device and usually implies that the device is permanently connected to a TCP/IP network. For a static IP address, a network device must be manually configured with the network address supplied by the network systems administrator of the network to which the network device is connecting.

The means of configuring a network device for a permanent IP address is dependent upon the device's OS. To properly configure the address, the subnet mask, router, and name servers for the network to which the device is connecting must be known. For dynamic IP addresses, the DHCP server supplies this information.

Domain Name Server (DNS)

Domain name servers (DNSs) are the directory assistance computers of the Internet. They contain databases that translate World Wide Web (WWW) names into IP addresses.

First, a check is made to see if the name is already resolved as a HOSTS file that resides locally on the network. This is a simple text file with domain names and their corresponding IP addresses. If it is not found, then a query of the name is sent to the DNS server configured in the TCP/IP settings. All DNS servers provide a cache for frequently and recently requested addresses. However, if that DNS server does not have a resolution for the name either in the cache or in the configuration, it will make a query to another top-level DNS server to resolve the address.

Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) Transport—Layer 4

The TCP/IP architecture provides various protocols to manage the packaging and delivery of data streams generated by applications. The two most common protocols are TCP and user datagram protocol (UDP). In a sending device, TCP and UDP place application data into one or more outgoing datagrams after adding appropriate header information. In a receiving device, TCP and UDP extract the data from the incoming IP datagrams and pass each data segment to its corresponding application.

Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) Transport—Layer 4, continued

Transmission Control Protocol (TCP)

TCP/IP is a suite of over 100 communications protocols that work together and follow the Ethernet standard. It is through the use of TCP/IP protocols that AV devices may be integrated on worldwide networks.

TCP is characterized as a highly reliable transport protocol, designed to transfer large volumes of data between devices over an internetwork with unknown characteristics (e.g., the Internet). The terms connection-oriented and guaranteed delivery are often used to describe the TCP communication process between sending and receiving devices.

Prior to data transfer, a TCP connection or session is negotiated between the sending and receiving devices. Once the connection is in place, the data to be transferred is divided into segments in the sending device. All outgoing segments are assigned a sequence number, which is used by TCP in the receiving device to place the incoming segments in the correct sequence.

For each segment received, a reply in the form of an acknowledgement message is issued to the sending device. Any unacknowledged segment within a given period of time is assumed to be lost and is retransmitted by the sending device until it is acknowledged. After the delivery of all segments has been confirmed, TCP terminates the connection.

User Datagram Protocol (UDP)

UDP is characterized as a highly efficient transport protocol, designed to transfer data with minimal delay and no acknowledgement of delivery. UDP is optimized for use in cases where short messages need to be sent by devices on a frequent basis (e.g., management commands and alerts). The terms connectionless and best-effort are often used to describe the UDP communications process.

Unlike TCP, no prior connection or session needs to be negotiated between the sending and receiving devices when UDP is used. The sending device issues its message and assumes it was delivered over the network.

If a UDP-based message cannot be delivered, it is the responsibility of the higher layer application to request a retransmission from the sending device. Time-sensitive applications (e.g., voice and video communications) use UDP to minimize delay, with the risk of occasionally losing segments of their content.

Network Services—Layer 6

Layer 6 protocols take the data from the application layer and convert it into a standard format other layers can understand. Some of the standard formats for these protocols include compression, coding/decoding, and encryption. The following protocols are typically used at this layer:

- DNS is used to associate names with numeric IP addresses, making it easier for individuals to access devices and services.
- Lightweight directory access protocol (LDAP) provides a uniform, application-independent set of services for creating, storing, accessing, and updating directory-based information on a network.
- Hypertext transfer protocol (HTTP) is used to access content that is stored on Web servers, using various applications software (e.g., a browser).
- Simple mail transfer protocol (SMTP) enables exchanging messages created using any SMTP-compliant e-mail software. It enables organizations using different messaging applications to communicate without changing their software.
- Network news transfer protocol (NNTP) is used to read and reply to messages posted on news servers.
- Internet relay chat (IRC) enables real-time text-based communications sessions between individuals on a network. Also described as instant messaging, presence, or chat services, text messages created in an IRC session are displayed on the receiver's screen immediately after the sender types them.
- File transfer protocol (FTP) is used to reliably transfer files between devices over a network.
- Internet printing protocol (IPP) allows printers to be independently accessed and managed remotely over a network, which enables, for example, sending files directly to a printer over the Internet.

Applications—Layer 7

The applications layer includes application programs such as processing applications, word processing and spreadsheet applications, messaging applications, and collaboration applications..

Wireless Networking

Introduction

Wireless network applications are becoming more prevalent in data connected conference and presentation rooms.

For example, in a presentation room, a wireless access point may be connected to a network hub or switch. Any computer with a wireless NIC may access the network. Some digital projectors may also be connected to a wireless network. This can eliminate analog interface cables or LAN cables to either the computer or the projector.

Advances in wireless communications enable linking many types of devices to networks spanning both small and large geographic areas. The span of a wireless network can extend from a single work area to a multi-building campus and include point-to-point (PTP) links between buildings separated by public or private rights-of-way (e.g., highways, shopping malls). In all cases, wireless connections can be used in place of network cabling or telecommunications circuits to extend the span of LANs or internetworks.

IEEE has issued, and continues to develop, a series of standards intended to expand the existing LAN capabilities by including wireless functionality. Working Groups (WGs) have been formed to address specific types of wireless networks.

- The IEEE 802.15 WG is responsible for wireless private area network (WPAN) specifications. WPAN is a protocol based on linking a limited number of computing devices over short distances, typically less than 10 m (33 ft). A WPAN is intended to serve the connectivity needs of a single individual, linking such items as a PC and peripherals (that are carried, worn, or located near the body) in an area described as a personal operating space (POS) with a large consideration given to power consumption, size, and realizable product cost.
- The IEEE 802.11 WG is responsible for wireless local area network (WLAN) specifications. This group of standards uses the Ethernet protocol and carrier sense multiple access with collision avoidance (CSMA/CA) for path sharing and includes an encryption method, the wired equivalent privacy (WEP) algorithm. WLANs, like wired LANs, serve a group of users and their computing devices in a common space, such as an office in a commercial building.

To date, the IEEE 802.15 WPAN and 802.11 WLAN WGs have issued specifications in the form of approved standards. When described using the OSI model, WLAN and WPAN specifications cover the Physical layer and the MAC sublayer of the Data Link layer.

Wireless Transmission

All of the wireless communications use electromagnetic energy to transfer signals from the source to the destination. Examples of electromagnetic radiation include radio waves, light particles, and x-rays. National and international communications agencies use a subset of the spectrum to create an RF allocation chart, which is used to display the allocated and available frequencies for the purposes of radio wave communications in a given area. The chart, issued by the Office of Spectrum Management (OSM) in the United States Department of Commerce, spans the frequency range from 3 kilohertz (kHz) to 300 gigahertz (GHz).

Many devices and applications use RF, creating the possibility of interference in a given location. To minimize disruption caused by simultaneous transmissions in the same RF band, regulatory agencies allocate and control usage rights to specific radio band frequencies in every geographic area within their jurisdiction. A narrowband license, for example, provides its holder with the right to transmit over a limited frequency range in a specific geographic area.

In addition to licensed narrowband frequencies, there are also unlicensed frequency bands where the right to transmit is freely available to anyone. An example is the 2.4 GHz industrial, scientific, and medical (ISM) band, used by Bluetooth® WPANs as well as several IEEE WLANs.

NOTE: Other devices (e.g., microwave ovens and cordless telephones) also operate in this range, at various power levels. This type of frequency sharing in unlicensed bands can cause disruptions in network communications if such devices operate in close proximity to a wireless network.

Most wireless network devices exchange messages using RF signaling, although it is also possible to use light beams (infrared). RF signaling can be narrowband or spread spectrum. Narrowband RF is associated with fixed-base-to-fixed-base signaling, also referred to as wireless PTP or wireless bridge. In such cases, the devices at both ends of the wireless link cannot be moved (e.g., the connection between two buildings on opposite sides of a river).

RF-based WPANs and most WLANs use spread spectrum RF technologies in the unlicensed ISM band. In contrast to narrowband RF, spread spectrum uses a large band of frequencies for signaling. Two types of spread spectrum signaling are available, frequency hopping or direct sequence.

Wireless Local Area Network (WLAN)

In general, WLANs provide a wire-free environment to LAN users within a given facility. A properly designed and installed WLAN enables connection to a LAN from any location within a predefined zone. They are intended to provide network connectivity, flexibility, and mobility to the controllable set of users within a common physical area where network wiring is not practical.

Although flexibility and mobility in today's working environment is important, WLANs should not be considered equivalent substitutes for a switched 10Base-T or 100Base-T network, as their connectivity is limited to a shared environment and are highly dependent on their ability to transmit and receive radio waves with minimal interference. As an example, a building construction makeup can help or hinder the WLAN's range and performance levels.

Wireless Local Area Network (WLAN), continued

The performance of the application is also dependent on the number of devices (e.g., PCs, network-based printers, network-controllable video equipment) accessing the WLAN and the distance between the device and the remotely placed access point (AP).

Independent Basic Service Set (BSS) WLANs

Wireless access to a wired LAN is governed by a wireless network access point (WAP). A WLAN (see Figure 6.6) may be implemented without APs. In such a case, the stations communicate directly with each other on a peer-to-peer basis. This type of WLAN can be implemented more rapidly than an infrastructure network since devices can exchange messages as soon as they are within a communicating distance. This type of WLAN is frequently described as an independent, peer-to-peer, or ad hoc network, since it can be created spontaneously by placing devices equipped with wireless interfaces in a common area.

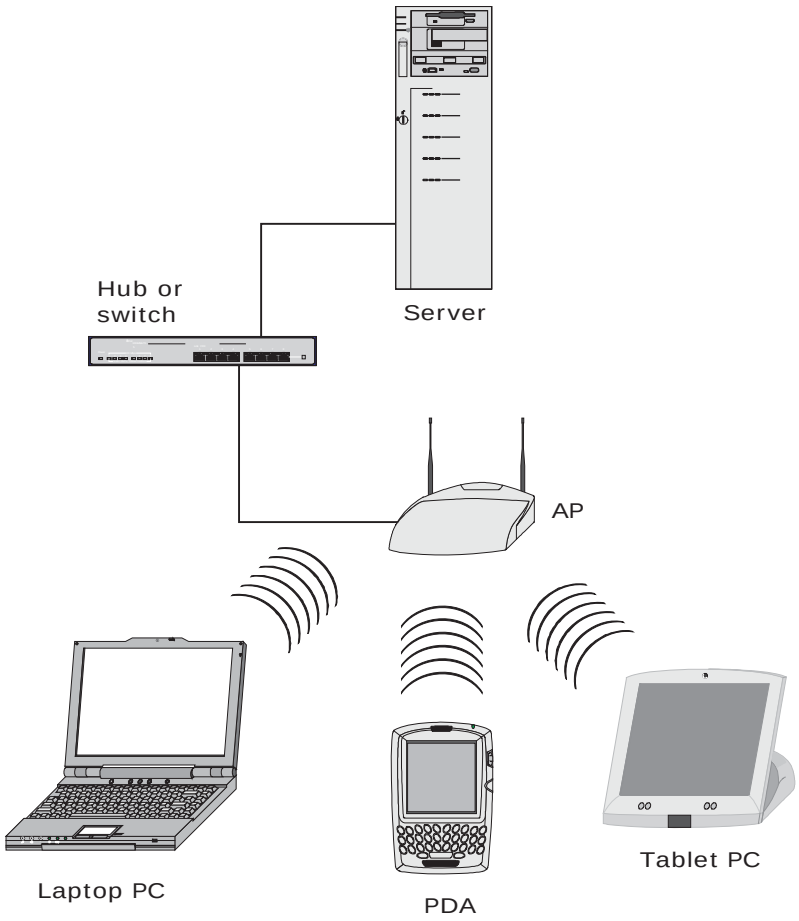
An independent basic service set (BSS) is a group consisting of two or more connected devices sharing a common wireless medium. WLANs are often used in locations where a network is required for a limited period (e.g., in a meeting room for a few hours). In such cases, the absence of cabling and an AP reduces setup time and increases the flexibility of the network.

NOTE: An independent BSS IEEE 802.11 WLAN is similar in description to a Bluetooth® WPAN. However, it:

- Has a greater operating range and can connect a larger number of devices than a Bluetooth® piconet.
- Can, in most cases, operate at a higher speed than a WPAN.
- Can be converted into an infrastructure BSS or extended service set (ESS) WLAN by adding one or more APs.

Wireless Local Area Network (WLAN), continued

Figure 6.6
Wireless local area network



AP = Access point
PC = Personal computer
PDA = Personal digital assistant

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Wireless Local Area Network (WLAN), continued

Extended Service Set (ESS) Wireless Local Area Network (WLAN)

The need for a scalable LAN and the costs of multiple ad hoc wireless networks typically necessitates the usage of APs.

The ESS WLAN links together multiple APs, with each AP and its corresponding stations forming a separate BSS. The group of linked APs is referred to as a distribution system, which can be wireless or wired. In cases where an AP is wired, it is referred to as an infrastructure BSS.

Wireless Local Area Network (WLAN) Operations

Before the introduction of IEEE standards for wireless networking, a number of vendors introduced proprietary WLAN systems. Most of these were spread-spectrum systems intended for use in the United States, operating in the license-free 902 megahertz (MHz) ISM band—spanning a 26 MHz range from 902 MHz to 928 MHz.

The IEEE 802.11b standard updates the original 2.4 GHz specifications in the IEEE 802.11, *Standard for Information Technology—Telecommunications and Information Exchange between Systems—Local and Metropolitan Area Networks—Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*. This update specifies direct sequence spread spectrum (DSSS) signaling with a maximum operating speed of 11 Mb/s. However, to maintain compatibility with older IEEE 802.11 devices, an IEEE 802.11b WLAN can operate at 1, 2, 5.5, or 11 Mb/s. In addition, the lower speeds can be used to extend the range of the WLAN or enable operation in environments with excessive interference at higher speeds.

NOTES: Most IEEE-compliant WLAN systems currently available conform to the IEEE 802.11b standard.

The maximum allowable number of active users on a WLAN is both frequency and vendor specific.

More recent revisions to the WLAN technology use the widest set of frequencies for broadband WLAN operations. In the United States, a 300 MHz frequency span over three 5 GHz unlicensed national information infrastructure (U-NII) bands is available, as follows:

- A 100 MHz span from 5.15 GHz to 5.25 GHz (lower band for indoor use)
- A 100 MHz span from 5.25 to 5.35 GHz (middle band for indoor and outdoor use)
- A 100 MHz span from 5.725 GHz to 5.825 GHz (upper band for indoor use)

The operating speed of an IEEE 802.11a WLAN can be as high as 54 Mb/s, with a lower probability of interference than it is found at the 2.4 GHz band. This is due to the many types of devices that operate in the 2.4 GHz band including cordless telephones, Bluetooth® WPANs, and microwave ovens.

Wireless Local Area Network (WLAN), continued

Due to the different range of frequencies and types of signaling, IEEE 802.11a products cannot interoperate with systems conforming to IEEE 802.11b. To account for this, the IEEE 802.11g standard was developed. This standard uses orthogonal frequency division multiplexing (OFDM) signaling to increase performance in the 2.4 GHz band to 54 Mb/s—the same as IEEE 802.11a—while maintaining compatibility with IEEE 802.11b networks.

Regardless of the type of signaling used—frequency hopping spread spectrum (FHSS), DSSS, or OFDM—all IEEE-compliant WLANs must use, by default, the CSMA/CA protocol for sharing the wireless medium.

Wireless Local Area Network (WLAN) Design Guidelines

The overall effectiveness of a WPAN or WLAN design depends mostly on the presence or absence of physical and electromagnetic obstacles in the path between the sending and receiving antennas. Physical obstacles in the path of a signal can reflect, deflect, or absorb part or the entire signal, causing signal loss or data corruption. If other devices are operating in the same frequency band as the WPAN or WLAN, their signals can create enough interference to disable the detection of a valid message by a network device antenna. Using spread-spectrum signaling minimizes this type of interference, making the identification and avoidance of physical obstacles the key consideration in WPAN and WLAN design.

An omnidirectional (omni) antenna has a uniform coverage pattern, radiating its signals equally in all directions.

A directional antenna sends signals in a specific direction. Examples of directional antennas include dipole, Yagi, and parabolic.

The coverage zone of a wireless device is directly related to the transmission power of its transceiver and inversely related to the operating speed of the network.

NOTE: Power settings can be expressed in either milliwatts (mW) or decibels (dB) referenced to 1 mW (dBm).

As the transmission power increases, the coverage zone of the device also increases. The size of the increased coverage depends on the environment, considering that physical and electromagnetic obstructions are rarely identical in any two locations.

NOTE: If a device is battery-powered, the battery life will decrease as the transmission power increases.

The coverage zone can be increased by decreasing the operating speed of a device. For example, a WLAN device may have a typical indoor range of 30 m (98 ft) when operating at 11 Mb/s, and a range of 90 m (295 ft) at an operating speed of 1 Mb/s.

In some cases, a second antenna is added to a network device (e.g., an AP) to improve its reception ability. The term diversity reception is sometimes used to describe this technique. The backup antenna is used only for receiving signals, while the primary antenna both transmits and receives. The device uses the antenna with the best reception to read an incoming signal.

Wireless Local Area Network (WLAN), continued

Site Survey Information

Decisions about the type of wireless network (ad hoc or infrastructure) and the transmission frequencies are made based upon many factors: the number of users, the physical size and environmental challenges of the area, and budget. To complete this design process, the wireless designer performs a survey of the area.

The site survey process should generate the following types of information:

- Facility map
- Radio transmission constraints
  - Physical
  - Electromagnetic
- Potential locations for APs
  - Primary
  - Backup
- Type of antenna for each potential AP location
  - Omnidirectional
  - Directional
- Electrical power source at each potential AP location
  - Dedicated circuit
  - Uninterruptible power supply (UPS) backup
- Pathways and cabling required for linking APs:
  - To each other
  - To a wired network

Summary

Although the AV designer would likely not be responsible for the WLAN installation, knowing if the devices use a wireless connection or could possibly cause interference to an existing wireless network is helpful. Collaboration with the local LAN support staff would assist the AV designer in implementing a system that meets all of the AV needs of the customer and reduce to the risks of network conflicts and incompatibility.

Wireless Personal Area Network (WPAN)

Bluetooth® is the technology most closely associated with WPANs. Bluetooth® is a radio-based WPAN technology sponsored by the Bluetooth® special interest group (SIG), which consists mostly of vendors in the communications and networking industries. The project was launched in 1998 with the goal of eliminating the vast number of proprietary cables and connectors used to attach various peripherals to computers and telephones.

Bluetooth® enables networking between devices over a limited range—typically not more than 10 m (33 ft) in all directions and through most obstructions found in commercial and residential spaces. A maximum operating speed of 1 Mb/s is defined, using frequencies in the unlicensed 2.4 GHz ISM band.

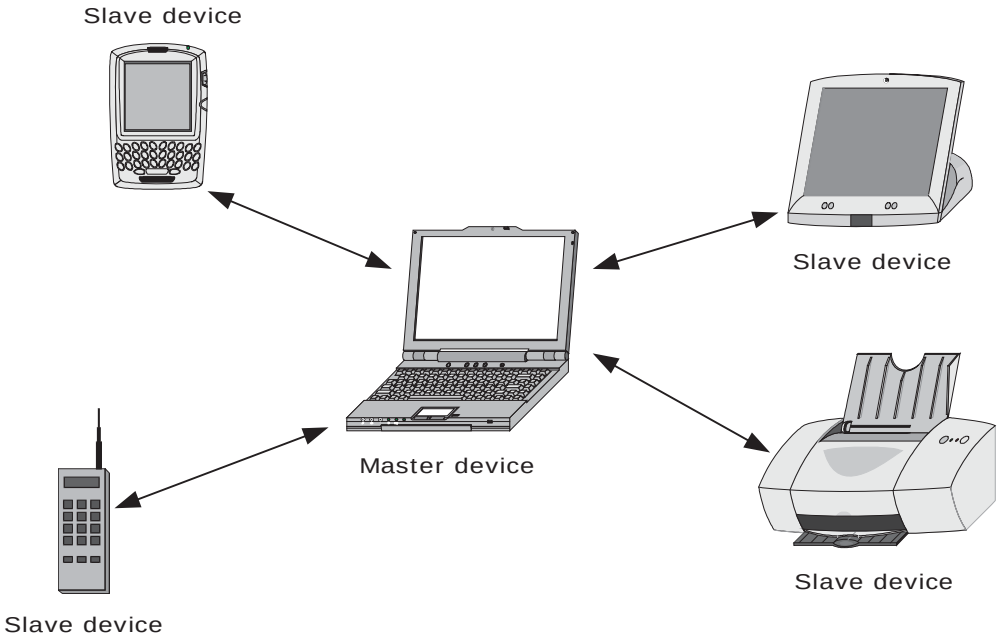
The IEEE 802.15.1 task group has issued the first IEEE WPAN standard, which is based on Bluetooth® specifications.

Wireless Personal Area Network (WPAN) Addressing

A single Bluetooth® WPAN can contain a maximum of eight active devices. This type of network is referred to as a piconet.

One device in a piconet is designated as the master; the other devices are referred to as slaves. Any Bluetooth® device can function as a master or a slave. Typically, the device that initiates communications on a piconet is designated as the master. The main role of the master device in a piconet is to synchronize and supervise communications taking place between the network devices (see Figure 6.7).

Figure 6.7
Bluetooth® piconet



Wireless Personal Area Network (WPAN), continued

Wireless Personal Area Network (WPAN) Components

It is possible to integrate the Bluetooth® WPAN interface into a variety of computing and communication devices. The purpose of such an interface is to replace the assorted ports and cables currently used to interconnect devices such as:

- Desktop, laptop, or handheld computers.
- Wired, cordless, or cellular telephones.
- Computer or telephone headsets (integrated microphone and speaker units).
- External speakers and microphones.
- Printers and scanners.
- Keyboards, mice, and joysticks.
- Digital cameras and camcorders.

A Bluetooth® device requires three components to communicate with another Bluetooth® device on a piconet. These components are the:

- Radio transceiver, responsible for sending and receiving signals over the open-air medium.
- Link controller, responsible for choosing a frequency for communications and directing the flow of data to and from the device.
- Link manager, responsible for scheduling transmissions, enabling security processes, and managing power consumption.

Wireless Personal Area Network (WPAN) Operations

As mentioned previously in this section, Bluetooth® WPANs operate using signaling in the 2.4 GHz ISM band. The number of channels that can be used varies by country. For example, in the United States 79 channels are available, each using 1 MHz of bandwidth. The frequency hopping takes place at a rate of 1600 hops per second when transferring data and 3200 hops per second when initiating a request. The high hopping rate keeps a given frequency clear a majority of the time, minimizing the possibility of interference caused by multiple devices simultaneously transmitting on the same frequency.

On a Bluetooth® piconet, the master device establishes the frequencies to use in the hopping pattern. This information is sent to the slave devices, which then synchronize with the master device. Once synchronized, all devices hop to the next frequency in the pattern at the same time.

Wide Area Network (WAN)

Telecommunications circuits enable an organizational network to grow beyond the physical boundaries of a building or campus. Terms such as metropolitan area network (MAN) and wide area network (WAN) are used to describe networks that span an extended geographic area.

The components of a typical WAN include:

- Two or more sites, each equipped with a LAN or an internetwork.
- Routers with WAN interfaces connected to each LAN or internetwork.
- Internal or external circuit access devices connected to each router's WAN interface.
- Telecommunications circuits connected to each circuit access device.

The combination of routers, circuit access devices, and telecommunications circuits enable the linking of the site networks. The combination of the circuit-based internetwork and the site networks forms the WAN.

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Networking Applications in Audiovisual (AV) Industry

Introduction

The method of connecting and controlling audiovisual systems is changing. Networked devices are having, and will continue to have, a profound impact on core AV technologies in the following ways:

- Stand-alone and distributed devices can operate as part of a common networked system.
- Infrastructure and operating costs can be reduced
- Network technology can:
  - Reduce the physical and wiring complexity of a system.
  - Provide existing standards for design and implementation.
  - Allow centralized management and efficient use of facility systems.
  - Permit sharing of resources between centrally located devices and distributed AV systems.

Networking evolved from a general, worldwide need for the sharing and managing of resources. Networks offer users the benefits of data collaboration and coordination. Integrating an AV system to include an information technology network adds price performance benefits, standardization, and management efficiency.

Information technology and AV systems have been converging. AV systems have become increasingly more reliant on information technology infrastructure. Information technology applications have taken on roles previously held by AV hardware, including Web-based presentation, tele-videoconferencing, and digital media distribution.

Common uses of an information technology network for AV applications are:

- Real-time distribution of AV signals via information technology infrastructure.
- Media content storage and delivery.
- Distance collaboration and tele-videoconferencing.
- Remote diagnostics, monitoring, and control of AV systems.
- Asset management of distributed AV devices.

A key benefit of AV networking technologies is resource sharing. Resource sharing typically refers to a group of AV devices located in a central room (most often referred to as a head-end) that can be accessed from remote rooms. Accessibility covers audio, video, and control distribution of these devices. Many universities and corporations choose this topology so that they require only a few devices of different types (such as video servers) and amortize the cost across many rooms (rather than having a codec dedicated to one room).

Introduction, continued

If planning to add AV systems to an existing network, coordination of network requirements with the owner's network administrators is critical. The most common questions to be discussed when integrating AV systems into the owner's network are:

- What types of network connections are required?
- How does the AV equipment communicate?
- How much network bandwidth will the AV system consume?
- What network related security issues will be created?
- Can the AV equipment be placed on an existing network or will a dedicated network be needed?
- What are the benefits of putting the system on the LAN?
- How is the network managed?
- What is the existing network structure?
- What QoS structure is currently in place?
- Will network cabling be terminated to the wall?
- Who owns the device?

An alternative to integrating equipment into an existing network is creating a dedicated network to handle the AV content. Such network must provide the bandwidth and the protocols to support the required QoS.

Audiovisual (AV) Signal Distribution

AV systems can utilize an information technology network as a means to distribute signals between devices in real time.

AV interconnections are commonly distributed in an analog domain with home runs of analog signals to a central signal processing and routing system. However, the benefits of a network-based system include:

- Multiple channels of AV signals combined to a single cable.
- Simplified signal routing and patching of signals.
- Reduced cable costs.
- Distance capabilities increase between devices.
- Reduced number of transitions from analog to digital and from digital to analog.
- AV sources and destinations located anywhere with access to the network.

AV devices use a network endpoint that converts and transmits an AV signal or multiple signals from one location to another through the information technology network. The endpoints combine multiple AV signals using analog-to-digital (A/D) or digital-to-analog (D/A) converters and an information technology chipset to parse the AV content into data packets that can be sent across the information technology network. Other endpoints on a network can then combine the packets and redistribute the signals as needed.

Audiovisual (AV) Signal Distribution, continued

A disadvantage of distributing AV signals through a network is packet collision. A packet collision occurs when two devices on a network attempt to send information at the same time. When a packet collision is detected on the network, a request is dispatched to resend the data. However, with real-time AV signals, the packet is not resent in time and is dropped by the receiving endpoint. Advanced error correction algorithms are used to construct the probable packet and reduce the effects of the packet loss on the AV signal.

The greatest disadvantage to using information technology networks for AV signal distribution is latency. Latency in an information technology network can be described as a delay in the AV signals distributed across an information technology network. Latency in signals distributed across an information technology network occurs:

- During any required A/D or D/A process.
- When signals are broken into packets for distribution.
- As added by network devices (e.g., as switches and routers).
- With an increase of devices on an information technology network increases collisions.
- When signals are compressed and decompressed to lower network bandwidth requirements.
- When signals are encrypted or decrypted.
- When signals are buffered at endpoints.

A total signal transmission latency of 8 to 10 milliseconds (ms) is commonly acceptable in the AV industry for the distribution of real-time media content without a discernable delay.

To reduce the amount of latency introduced to an AV signal, the information technology network should have less than 30 percent saturation and AV devices should be located on a completely separate network from the other types of network traffic. An AV network should avoid multiple network hops through routers and switchers. A star configuration should be used with all of the AV devices in an area connected to a single switcher or router.

Each layer of the OSI model increases the level of latency. In general, Presentation and Application layers of the OSI model introduce more than 8 to 10 ms of latency and, therefore, are not best suited for real-time signal distribution (e.g., conference codecs and streaming media applications, which have latency of 150 ms or more).

Most manufacturers of AV endpoints typically operate at the Transport and Network layers of the OSI model. This allows an endpoint to operate on TCP/IP addressed data packets, which can be distributed to switches and routers across multiple VLANs. The latency of audio signals in these types of products typically ranges between 1.5 and 5.5 ms, although latency can be higher based on the number of signal hops.

Other manufacturers have designed equipment to work at the Data layer of the OSI model. These endpoints receive content based on the MAC address of the unit. The content can be distributed via switchers and hubs but cannot be distributed via routers. The latency of audio signals in these types of products can be as low as 80 microseconds (µs).

Audiovisual (AV) Signal Distribution, continued

Typically, real-time video signal distribution is not provided on an information technology network infrastructure. This type of signal distribution is based on the bandwidth requirements of the video signal. Video signals over a network typically have a latency of 150 ms to several seconds. This is not acceptable for real-time signal distribution; however, these systems are acceptable for near real-time content distribution and collaboration.

Audio and video remote diagnostics can include firmware upgrades, signal level monitoring, gain staging checks, and signal routing.

Audiovisual (AV) Content Storage and Delivery

AV systems can utilize information technology infrastructure for media storage and delivery. Network storage devices allow vast amounts of information to be stored in distributed or centralized locations and delivered in near real time to accessible end-points.

Typical applications for content storage and delivery systems include multimedia libraries, production broadcast, digital signage, and corporate/educational media publication.

Things to consider when developing a storage system are:

- What types of digital media are to be stored?
- How much content will be stored?
- Where will the content be stored?
- Who requires access to the content?
- How many people require access to the storage at a given time?
- What types of compression are required?

Several types of media storage are often required for a single system. A system may require archived media storage, remote media storage, virtual local storage, or local storage systems to meet the user demands and distribute the load of the media distribution across multiple points on the information technology network. For example, large media files used regularly by a particular user may need to be stored on the user's workstation to reduce traffic on the information technology network, while rarely used stock media may be stored on a slower, compressed, storage device to reduce the amount of used storage space.

Things to consider when developing a delivery system are:

- What is the available bandwidth for content delivery?
- What are the end-points for the media content?
- What types of compression are to be used if any?
- What quality of service is required?
- Is the content to be delivered near real-time?
- How many users will require content delivery at any given time?

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Audiovisual (AV) Content Storage and Delivery, continued

The delivery of digital media can create a heavy burden on an information technology network. A single uncompressed channel of high-definition (HD) audio and video can require over 1.5 Gb/s bandwidth. However, the same signal can be compressed and distributed as a 19.4 Mb/s data stream. The level of quality required at each endpoint should be considered and, based on that information, a data stream of comparable quality should be provided.

As the number of content channels increase on an information technology network, the networks requirements for QoS increase.

Distance Collaboration and Digital Signage

One of the greatest advantages of using an information technology infrastructure in AV applications is distance collaboration. AV systems no longer require dedicated PTP communication channels for tele-videoconferencing, streaming media and Web-based collaboration.

Digital signage can be served from a centralized server through a network connection. The content can be tailored for each display location based on adjacencies, regional preferences, or viewer preferences. Digital signage can also be interactive with a touch screen or button interface with up-to-date information from a number of active databases or data streams.

Displays

The traditional design uses analog signal distribution, red green blue horizontal sync vertical sync (RGBHV) cables to the projector, and coaxial cables running from each input device to a switcher and interface. Also, this system requires audio, control, and computer interface cables.

Technologies now permit carrying these signals on a category 5e wire. Category 5e cabling is significantly less expensive than the high-resolution RGBHV coaxial cabling traditionally used in analog systems. A projector connected to network with category 5e cabling creates a simplified integration path into a small corporate boardroom, conference room, or training room application. Some manufacturer approaches integrate the system switcher for ceiling projectors using category 5e instead of RGBHV.

In a networked room, the projector might receive all of the video, sound, and display information directly from a server on the network connected with a twisted-pair Ethernet cable. It operates through a control system or its own remote. This system can reduce the costs associated with a fully-wired network AV system and increases the potential applications of the system.

A projector connected to the network may be monitored for usage, lamp hours, power status, orientation, and inputs. It can be programmed to notify a service technician through e-mail, triggered by events that alert to a failure. Through the network, the lamp life can be monitored and trigger a replacement reminder with the model number, room number, and part number.

Remote diagnostics are not limited to display devices. It can include videotape recorder (VTR) head usage, audio gain, and audio level settings, and trigger upgrades to control system software.

Distance Collaboration and Digital Signage, continued

Displaying Files

Files can be displayed with a projector in several ways. Some projectors use a PC card. This solution permits a user to copy files onto a PC card using a computer and then review the files using a projector.

Another solution is to dedicate a network PC connected to the projector or use a nondedicated computer and use a projector as if it were a shared printer on the network. A file is sent to the display where it is stored in the memory (cached) and played in real time or replayed on demand. A further benefit of this solution is that files can be sent simultaneously to multiple projectors on the network (or across the Internet).

Integration with Audiovisual (AV) Control Systems

A control system connects and allows integration of various manufacturers' equipment into an AV system and provides the ability to control the equipment through a central processing device. A control system is the central point for the user inputs and the controlled devices. The traditional control system incorporates a network.

Different manufacturers have different strategies for approaching network control. The simplest system method to network enabled control systems is to use an Ethernet hub and category 5e media. This allows the access and control of one system from the other. A more sophisticated implementation permits the use of a Web browser from a dedicated computer to manage the devices on the control system from anywhere on the Internet. Yet another level of connectivity permits the use of a control system to control other IP-control–capable AV devices on the network that are directly connected to a hub.

A dedicated PC may be added to act as a server for the control system, expanding control system applications beyond control functions to include greater reliability and protection against imminent system failures. Such applications are:

- E-mail notification of network device maintenance requirements and failures.
- Database capabilities that log different aspects of system usage (e.g., videoconference calls) and build a database of information (e.g., presets) for all systems.
- Scheduling of facilities and resources that also maintain a database (e.g., videoconference phone numbers) accessible by any user on the system.
- Real-time system diagnostics.
- Loading of new programs and touch-panel screens from any computer on the LAN to any control system on the LAN
- Reporting that justifies system changes and prepares accurate budgets.

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Integration with Audiovisual (AV) Control Systems, continued

Because information technology networks are not designed with the intent of distributing media content in real time, networks used for AV systems must be set up to:

- Avoid delays in transmission caused by data collisions and excessive numbers of routers and switcher in the transmission path.
- Reduce packet dropping or loss. This occurs when the error checking protocol examines a packet of data and finds that the control information or data in the packet is damaged. If it is, the packet is dropped, and a request to resend the packet is made. Common packet dropping or data resending exhibited by some Ethernet networks is not acceptable for the reliability of real-time media delivery.
- Ensure adequate bandwidth requirements.
- Maintain a high QoS.
- Maintain AV signal quality using no compression or lossless compression and introduce no digital distortion or audio artifacts.

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Chapter 7
Electrical Principles

The majority of audiovisual (AV) equipment must integrate with the building's electrical system. While not promoting electrical system design, this chapter provides the AV designer with an overview of electrical systems and how they commonly interact with AV systems.

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Overview

Introduction

This chapter presents general information for the safe installation and management of electrical systems. It is not intended to be a comprehensive or stand-alone design guide but to provide background information and an overview of electrical power distribution. For detailed engineering, design and implementation, consult a registered electrical engineer.

Countries have their own codes, standards, methods, and practices. However, the references to codes in this chapter are derived from documents published by National Fire Protection Association (NFPA) standard, the American National Standards Institute (ANSI), and the Institute of Electrical and Electronics Engineers® (IEEE®). Other regions and countries have local and specific power distribution requirements that differ from the contents of this chapter. NFPA's *National Electrical Code*® (*NEC*®) references in this chapter are based on the 2005 edition. The NFPA publishes a new edition every three years.

The authority having jurisdiction (AHJ) does not generally cover the installation of communications equipment controlled exclusively by communications utilities, whether the equipment is located outdoors or in building spaces used only for this equipment.

In certain instances (e.g., the installation of an uninterruptible power system [UPS]), a permit may be required by the AHJ. In these instances, only licensed personnel can apply for the electrical permit. The audiovisual (AV) installer should always check with all interested parties about the requirements before beginning the work.

The information presented is in part the result of personal experience, knowledge, and research of the authors. The reader is hereby advised that special situations may exist. For more information about electrical codes in the United States, see Appendix A at the end of this chapter; for more information about power distribution in the United States, see Appendix B.

Current

The flow of electrons through a conductor is called current (Table 7.1) and is symbolized by intensity (I). Current is measured in amperes (A). One A is 6.25×10^{18} electrons moving through a point in an electrical circuit for 1 second (s). An increase in current is an increase in the quantity of electrons and not the speed of electricity.

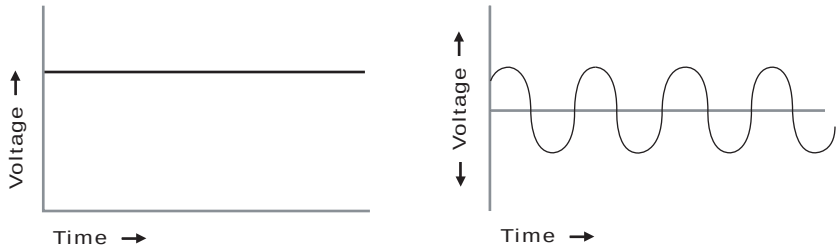
Table 7.1
Characteristics of current

Characteristic	Symbol	Definition	Measurement
Current	I	Flow of electrons through conductor	Amperes (A)

I = Intensity

The two types of electrical current are alternating current (ac) and direct current (dc). See Figure 7.1.

Figure 7.1
Direct current and alternating current



A battery is a dc device; it has both a positive and a negative terminal. In a dc circuit, the negative terminal sends electrons into the wire, where the electrons move toward the positive terminal, which attracts the electrons.

The dc:

- Charge stays at a constant flow and does not reverse direction.
- Charge can be either positive or negative.
- Is extremely common for electronic equipment and power supplies of AV equipment, as well as batteries.

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Current, continued

The ac current refers to an electrical signal or current that reverses its polarity and its direction at regular (e.g., 60 Hz) or irregular (e.g., lightning) intervals.

The ac:

- Signals alternate back and forth.
- Current travels in cycles and can be thought of as oscillating.
- Is quantified by frequency, measured in cycles per second or Hz.
- Frequency varies depending on location (e.g., 60 Hz in the United States, 50 Hz in Europe).

To convert the ac power arriving at a building into dc power used by most electronics, a power supply is used. A power supply may be internal or external.

Voltage

Voltage is a difference of potential that exists between two points of an electrical circuit (see Table 7.2). It is the force that causes current to flow through an electrical conductor. Voltage represents the greatest difference of potential between any two conductors of a circuit. It is symbolized by an electromotive force (E) or, sometimes, a volt (V).

The voltage of the ac power in a wall outlet varies depending on location (e.g., 120 V in the United States, 230 V in Europe). The voltage level in most installed AV hardware is usually lower.

Table 7.2
Characteristics of voltage

Characteristic	Symbol	Definition	Measurement
Voltage	V	Electrical pressure	Volts (V)

Voltage, continued

Resistance (R) and Impedance (Z)

The amount of current that will flow in a dc circuit is a factor of voltage divided by the circuit resistance (R), measured in ohms. Resistance is the opposition to the flow of electrons in a nonsinusoidal waveform.

The measure of resistance in a conductor is based on the size of the wire and the conductor length. One way to reduce resistance is to use a wire with a larger diameter. The lower the resistance, the easier electrons flow in the conductor path.

A longer cable run will result in a weaker signal at the end of the cable. When resistance increases significantly, it degrades the signal or prevents it from reaching its destination.

Impedance (Z), which also is measured in ohms, must not be confused with resistance (see Table 7.3). Impedance includes resistance as well as circuit reactances, which vary with the frequency of the ac current. If the current is direct or one-way, the reactive component is zero, and the impedance equals the resistance.

Table 7.3
Characteristics of resistance and impedance

Characteristic	Symbol	Definition	Measurement
Resistance	R	Opposite of the flow of electricity in dc circuits	Ohms
Impedance	Z	Opposite of the flow of electricity in ac circuits	Ohms

Real Power

Energy expended in one form manifests itself in another form (e.g., motion, heat, or light). In physics terms, energy is dissipated or consumed by the performed work. This is power (P) or the rate at which work is performed (see Table 7.4). It is measured in watts (W). One watt is the power expended when 1 A of dc current flows through the resistance of 1 ohm.

Table 7.4
Characteristics of real power

Characteristic	Symbol	Definition	Measurement
Real power	P	The rate at which work is performed	Watts (W)

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Apparent Power

The apparent power is the product of the measured voltage and measured amperage (see Table 7.5). This value is expressed in volt-amperes (VA). The measurement of voltage and amperage are performed on the line side of the system. This calculation does not include the effects of the inductive and capacitive reactance of the system and, therefore, the value is apparent, as opposed to real or true, power.

Table 7.5
Characteristics of apparent power

Characteristic	Symbol	Definition	Measurement
Apparent power	S	Product of voltage and current less reactance	Volt-amperes (VA)

Power Factor (PF)

The ratio of real power to apparent power is a percentage called the power factor (PF). The PF is used to show the relationship between W and VA. The PF will always be equal to, or lower than, 1 and is expressed as a decimal (e.g., PF = 0.7). Real power is always lower than apparent power in all reactive circuits, as shown in the following formula:

$$W = VA \times PF$$

Or

$$VA = W/PF$$

$$PF = W/VA$$

Electrical Circuits

The flow of electricity requires a continuous (closed) circuit. A circuit always has a source and a load. The source is the supplier of information, power, or signal. The load is the receiver of a reactive component.

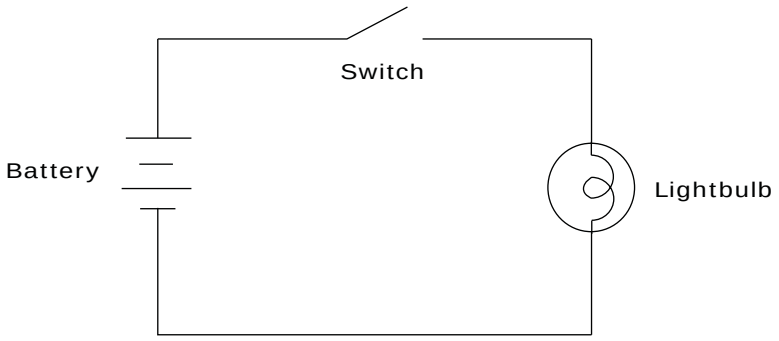
One of the simplest examples of a circuit involves a battery and a light bulb. A battery uses chemicals to produce electricity. The light bulb turns the flow of current into heat and light. A conductor, typically a wire, provides a path for the electricity to the light bulb from the battery. A switch is used to turn on and off the electrical flow and subsequently the light bulb.

Electrical Circuits, continued

Basic Circuit

In a basic circuit (Figure 7.2), a battery is the source and a light bulb is the load.

Figure 7.2
Basic circuit



NOTE: The complexities of the circuits found in AV systems are far greater.

Managing power properly protects the equipment, the signals, and the users. An important technique that protects electronic systems is grounding.

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Basic Power Distribution

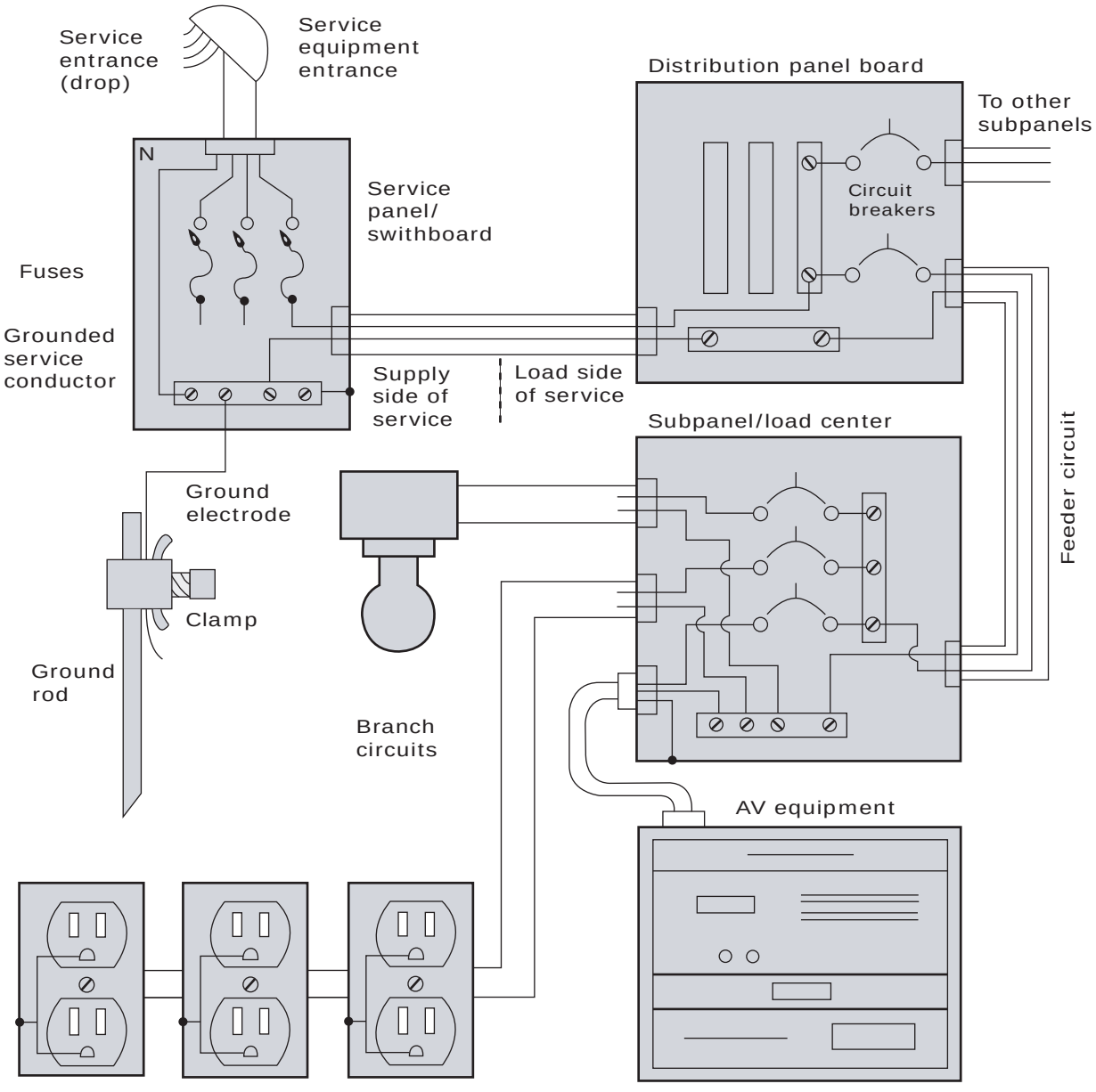
The following are some of the electrical components and their functions:

- Service conductors—the supply conductors that extend from the utility-provided power source (e.g., transformers) to the service equipment of a building.
- Service drops—the overhead service conductors from the last pole or other aerial support (including splices) that connect to the service-entrance conductors at a building or other structure.
- Service laterals—the underground service conductors between the street main and the first point of connection to the service entrance conductors in a terminal box, meter, or other enclosure.
- Phase conductors—the portion of the power supply cable that carries the current. Power systems can be distributed in single- or three-phase form.
- Grounded circuit (neutral) conductor—a conductor that is intentionally grounded at the utility power source or main service entrance and intended to provide electrical power at line-neutral voltages and carry the unbalanced load current between phases.
- Panelboards—a single panel (or group of panel units designed for assembly to form a single panel) that includes buses and automatic overcurrent devices (circuit breakers or fuses) with or without switches for the control of light, heat, or power circuits.
- Branch circuits— the circuit conductors between the final overcurrent device protecting the circuit and the ac outlets. An individual branch circuit is a branch circuit that supplies a specific device or component (such as an equipment rack).
- Electrical service—the conductors and equipment used to deliver energy from the electricity supply system to the wiring system of the premises.
- Technical power system—a dedicated power system for technical systems. A building typically derives all of its power from one central location. The main technical distribution panel distributes the power to all necessary locations within the facility through feeders and subpanels. In a presentation theater or training facility, the subpanels are often located in or near a control room or equipment closet.
- Service entrance—the point at which power enters the building.
- Electrical service equipment entrance panel—receives the incoming power and derives the equipment grounding conductor.
- Main distribution panel—located at the service entrance, distributes the power to subpanels throughout a facility.
- Feeders—the circuits carrying the power between the electrical service equipment entrance panel and the distribution panel, then to the subpanels.
- Overcurrent protection devices (OCPDs)—thermal or thermal-magnetic devices such as circuit breakers or fuses. An individual circuit might provide power to all of the lights in a room or several electrical convenience outlets, but the total power consumed on the circuit cannot exceed the current limiting device's rating. If it did exceed the rating, the circuit breaker or a fuse would overheat or fail.

Basic Power Distribution, continued

Figure 7.3 describes power distribution elements and functions.

Figure 7.3
Power distribution



AV = Audiovisual
N = Neutral

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Power Issues

AV designers should understand the characteristics of electrical power systems to ensure that the electrical power system can support the required AV components.

The parameters that describe the characteristics of an electrical power system within a building include:

- Voltage.
- Phase.
- Quality.
- Distribution.

Voltage

Examples of power distribution systems used in commercial buildings include:

- Single-phase 208 V electrical systems.
- Single-phase 120/240 V electrical systems.
- Three-phase, 277/480 V or 120/208 V electrical systems.

Phase

Electrical systems provide a variety of phase configurations:

- Single-phase systems—used by residential buildings and small commercial facilities
- Three-phase systems—used by commercial buildings

Quality

The quality of electrical power is an issue of specific concern to AV designers. Disturbances in the electrical power can affect the quality of AV signals or damage the AV equipment.

Incoming electrical power should be:

- Free of common-mode or transverse-mode voltages.
- Properly grounded.

Power conditioning can be used to ensure a quality power supply. Examples of power conditioning systems include:

- Line filter and condensers.
- Transformers.
- Voltage regulators.
- Uninterruptible power systems (UPS).
- Transient voltage surge suppressors.

Power Issues, continued

Distribution

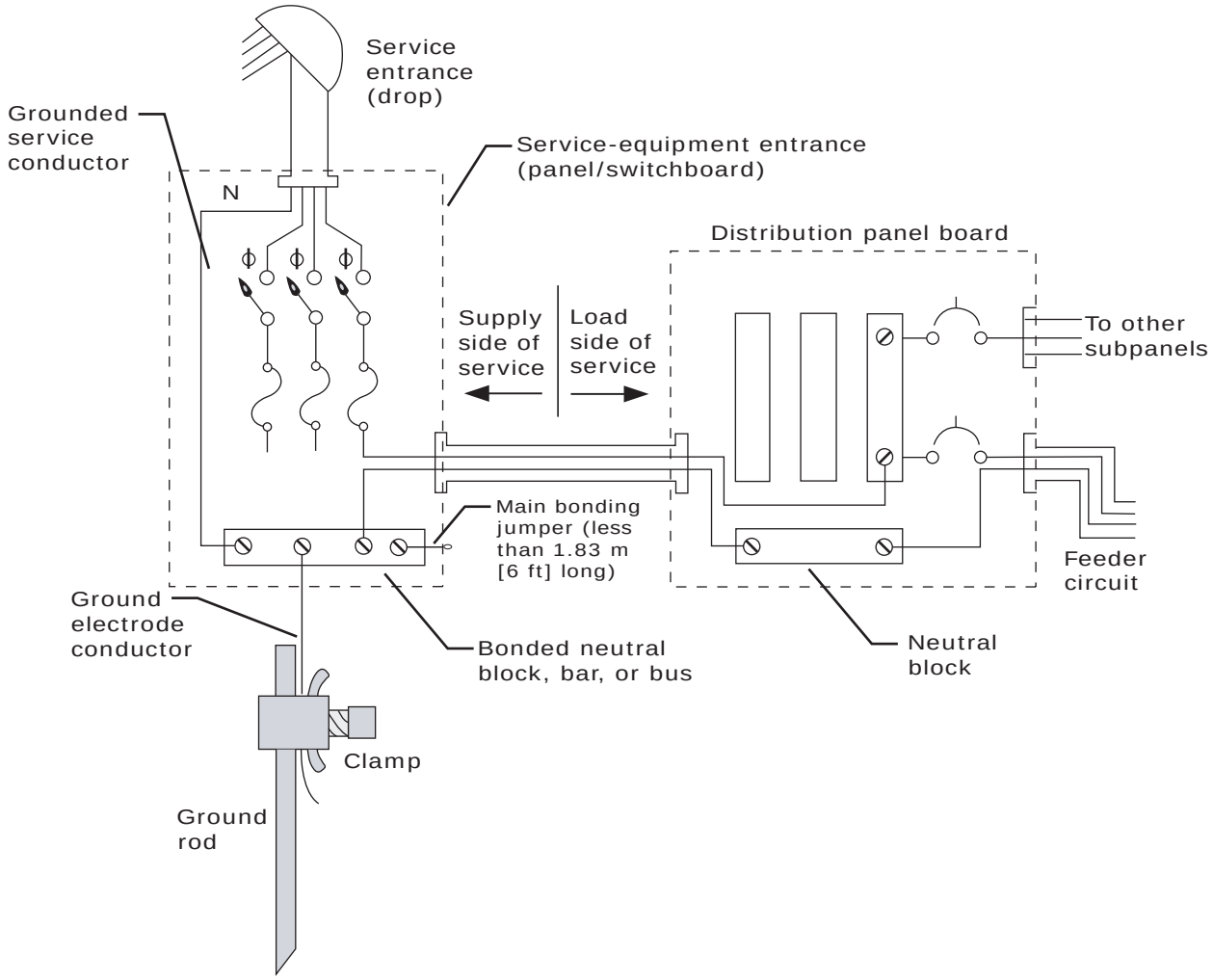
The layout and design of a power distribution system (Figures 7.4 and 7.5) has an impact on the design of an AV system. Examples of characteristics that an AV designer should consider when assessing a power system include the:

- Convenience of the main panel or branch circuit panelboard location in the event of a tripped circuit breaker.
- Need for a branch circuit panelboard to provide power to the AV system components.
- Locations of outlets and conduits that contain ac electrical circuit conductors.
- Proper load calculations so that each branch circuit is sufficient for powering the components on the circuit.
- Proper coordination of overcurrent protection to reduce fire hazard and personnel shock in the event of a ground fault.
- Outlets installed at component locations.

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Power Issues, continued

Figure 7.4
Power distribution system (example 1)

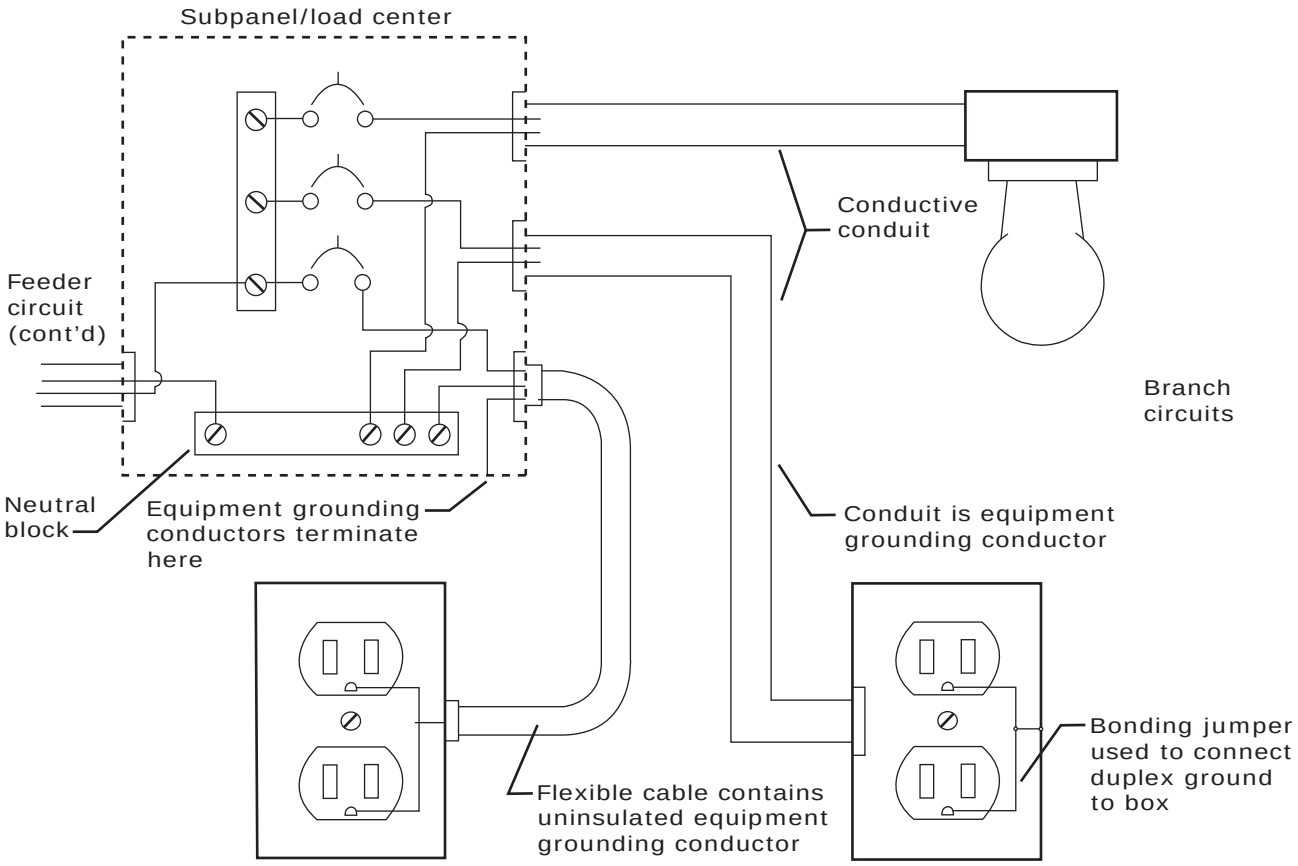


ft = Foot
N = Neutral

NOTE: Bonding—special precautions taken to ensure a permanent low-resistance.

Power Issues, continued

Figure 7.5
Power distribution system (example 2)



Audiovisual (AV) System Electrical Distribution

The AV system relies on ac electrical distribution designed and coordinated to provide reliable ac power to AV equipment and its components.

All ac electrical power systems should be free of any disturbances that may be introduced into the AV environment Power disturbances can affect the performance of AV components and damage some types of equipment. Power disturbances also can degrade components over time so that when a device fails, the cause of failure is not immediately apparent. Two types of power disturbances are:

- Transverse mode.
- Common mode.

Audiovisual (AV) System Electrical Distribution, continued

Transverse mode events are disturbances that occur between circuit conductors (e.g., phase and neutral). Some transverse mode events are:

- Under-voltages and over-voltages.
- Sags and surges.
- Oscillatory or impulsive transient impulses.
- Notches in the ac voltage waveform.
- Frequency variations.

Common-mode events are disturbances that occur between circuit conductors and ground (e.g., neutral and ground). Some examples of common-mode events are:

- Radio frequency interference (RFI).
- Lightning.
- Electromagnetic interference (EMI).
- Fault equipment power supplies.
- Power conditioning equipment operation.

System designers can use a number of methods to reduce the impact of power disturbances:

- Power line conditioning can be used to mitigate power disturbances but it may be expensive and difficult to implement. A wide range of power line conditioning systems is available, providing different levels of conditioning and cost.
- Line filters are designed to minimize the impact of transient disturbances. These devices provide the lowest level of conditioning and can be used to deal with both common mode and differential mode noise.
- Isolation transformers are designed to deal with common mode impulses. These devices isolate dc voltages and remove high frequency (HF) energy that can create noise.
- Line voltage regulators maintain the voltage level of the electrical system with a specified range. These devices can be used with clean power systems, which are subject to summer blackouts and lightning strikes.
- UPS utilizes a battery system to provide clean, noise-free, controlled electrical power. These systems provide an ideal solution to power problems; however, they can be expensive.

Audiovisual (AV) System Electrical Distribution, continued

Designers should evaluate a range of issues to determine whether a system should be supplied with an independent technical power source. For example:

- Is any other non-technical equipment on the same phase as the technical equipment? (The components can potentially cause interference to the AV components).
- Is other industrial or commercial equipment on the same feeder? (These devices can introduce noise into the system).
- Does the technical ac power supply have its own feeder circuit from the main distribution power panel for the building? (That information will help the designer determine the level of isolation that is needed).
- What is the electrical power configuration for the building? (This information helps to determine the appropriate approach for installing technical power).
- What is the cost of downtime? (If the AV system is critical, an investment in a reliable back-up power source is necessary).
- What is the likelihood of damage from ac power? (The designer should investigate the overall level of instability in the ac power system and whether the application of power conditioning equipment is necessary).

Technical Power Systems

The terms technical power, technical power panel, and technical power system are generally used to denote dedicated panelboards, equipment, and systems used for the purpose of supplying ac power to technical systems. A technical system may include audio, video, telephone, or computers.

Technical power systems are used in larger AV systems that are not continually used and when the consequences of system failures caused by power problems are considered unacceptable.

AV systems are best served from three-phase 120/208 volts alternating current (Vac) branch circuit panelboards that supply power to equipment through individual branch circuits.

The additional requirements for ac power in technical systems may include:

- A reliable redundant power source, which would not cause damage or operational failure of the AV equipment.
- A properly designed electrical distribution system where the placement of electrical circuits and signal cables would mitigate EMI/RFI.

Audiovisual (AV) System Electrical Distribution, continued

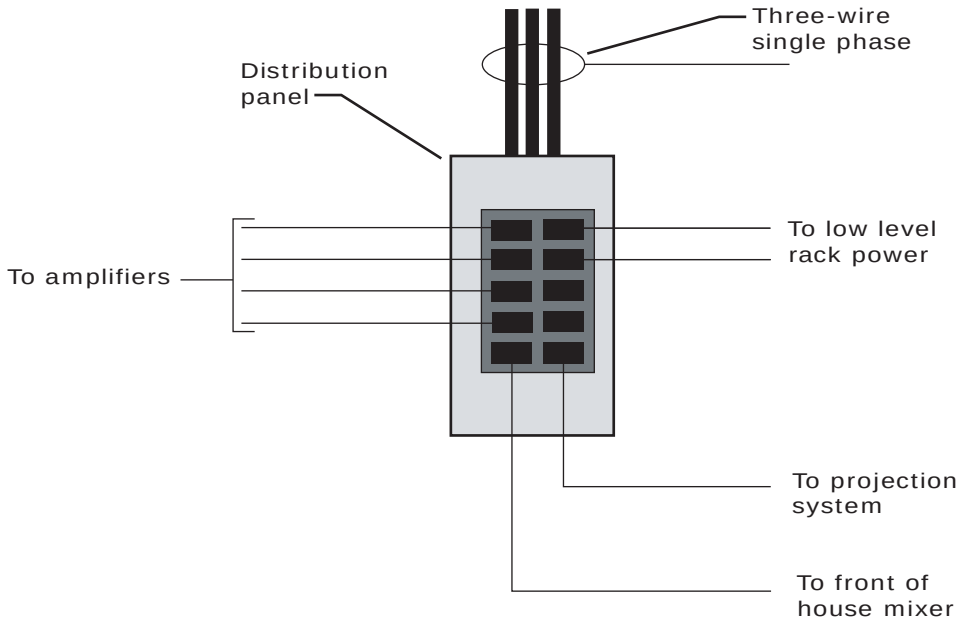
Panel Layout

A technical power system should have a separate ac power panel responsible for distributing the ac power to the AV system (see Figure 7.6).

The master technical power panel should:

- Feed ac power directly by its own primary feeder.
- Feed from its own transfer winding at the primary power distributor in the building.

Figure 7.6
Technical power panel layout



Master Technical Power Panel

The technical facility usually derives all of its power from one, central, location—the master technical power panel. As mentioned previously in this section, three-phase power would be the ideal design criteria for the technical power supply. Three-phase power panelboards would afford the designer flexibility in balancing the loads. This would have the added benefit of reducing the amount of load current on each phase, which in turn would reduce the possible EMI on ac electrical circuits.

Audiovisual (AV) System Electrical Distribution, continued

The master technical power panel distributes the power (and the equipment ground) to all other locations within the facility. Its location varies, as follows:

- In a one-room studio, this may be the service entrance panel for the entire building and only branch circuits are used, without feeder/branch circuit panelboards.
- In a small theater or studio facility, the master technical power panel is often located in or near the control room and provides all of the branch circuits for local and remote locations.
- In a large complex, it is in either an equipment or utility room and powers feeders, which power feeder panelboards or branch circuit panelboards. Several levels of feeder/branch circuit panelboards may be implemented in very large complexes.

Close coordination with the electrical contactor is essential to ensuring that the AV system is not adversely affected by the building's electrical system. For example, the AV designer must be aware of the location of ac power to route the AV cables in a manner that would minimize electrical interference.

The designer should specify the amount of power required for each component, the amount of power required for the control room, the power outlets required for audience members, and the location of outlets throughout the room.

Distribution within Equipment Rack

Power within the equipment rack is another consideration. The designer should plan how to connect the rack to the power infrastructure of the room to address power and grounding issues. The designer also must ensure that power cables are separated from any cables carrying signals since power can create hum or other interference within the program signals. Running the power lines on the opposite side of the rack from signal lines can minimize interference. Designers should always use power strips, if power strips are allowed by the local building codes. Some components may require use of the existing plug; others may require twist-locks or hard-wired terminations.

Power distribution and conditioning components may be required to protect equipment within some applications. These may include:

- Transient voltage surge suppressors.
- Isolation transformers.
- Uninterruptible power system (UPS).

NOTES: These types of components can generate heat and take up rack space, and also will add to cost.

Ascertaining the power conditions at the site may prove difficult for the system designer. A good practice is to ask the client or the client's information technology (IT) representative about the quality and character of the power at the site. Since IT equipment is especially sensitive to power irregularities, the IT department may have hard data about the historical character of the power at the site.

Power Conditioning / Protection

Introduction

Power conditioning devices are intended to correct one or more power abnormalities and can be divided into three categories:

- Devices that filter and/or regulate the utility-supplied power. These include:
  - Isolation transformers.
  - Shielded isolation transformers.
  - Surge protective devices (SPDs).
  - Voltage regulators.
  - Power line conditioners.
  - Harmonic filters.
- Equipment that regenerates the utility-supplied power or generates its own power:
  - Motor generators
  - Engine generators
- Static UPS:
  - Offline or standby UPS units
  - Online hybrid UPS units
  - Online double-conversion UPS units

Devices That Filter / Regulate Utility Lines

Isolation Transformer

An isolation transformer has no electrical connection between the primary and the secondary windings. They are effective in rejecting common-mode (line-to-ground) noise but have a limited ability to prevent normal mode (line-to-line) noise.

Shielded Isolation Transformer

Shielded isolation transformers are electrically isolated and have a grounded (earthed) electrostatic shield between primary and secondary windings. Shielded isolation transformers can attenuate common-mode noise and fast transients.

Devices That Filter / Regulate Utility Lines, continued

Surge Protective Device (SPD)

SPDs, also called surge arresters or transient voltage surge suppressors (TVSS), limit, clamp, or divert surges and transients. A surge arrester is defined as a protective device for limiting surge voltages by discharging or bypassing surge current.

A TVSS is defined as a protective device for limiting transient voltages by diverting or limiting surge current.

There are many different types of SPDs. Therefore, the choice and positioning of these devices are important. Properly designed units minimize the current, voltage, and energy surge. Surge suppressors are usually hybrid devices combining two or more suppression techniques.

A stage concept for installation of surge suppressors is recommended. This involves installing an SPD at the:

- Service entrance panel as a service protector.
- The distribution panelboard level
- The branch circuit panelboard level.

A fourth level of protection at the outlet (e.g. receptacle) also can provide point-of-use protection. This method of installation not only steps down the surges and transients in stages, but protects critical loads from internally generated surges and transients. Coordinated sizing of devices is important. A typical installation would have the highest rating at the service entrance panel and would decrease at each subsequent level. A qualified electrical engineer should be consulted for appropriate sizing.

A clamping voltage level of surge suppressors should be selected for all of the protected equipment. When installing these devices, the lead length should be maintained as short as possible (less than 300 mm [12 in]).

NOTE: A solid ground (earth) connection with low impedance is required to make these protection devices effective.

Voltage Regulator

Voltage regulators adjust the line voltage to the load, while maintaining the input voltage within the range of the regulator. Voltage regulators are useful where the utility line is reliable but of poor quality.

Devices That Filter / Regulate Utility Lines, continued

Some voltage regulators:

- Provide transient filtering and limited subcycle ride-through because of their transformer design.
- Are unsuitable for use with loads that have their own built-in regulators. Under certain conditions, the regulators interact with each other and oscillate.
- Offer excellent regulating, filtering, and transverse mode noise reduction, but have limited output current capacity (ferroresonant regulators). If this limit is exceeded, the output voltage can decrease.

Power Line Conditioner

Power line conditioners are units that:

- Incorporate two or more conditioning and protection methods.
- Sometimes have a power distribution complete with main and branch circuit breakers.

These power distribution centers allow flexible installation and bring the branch circuit panel as close as possible to the loads.

Devices discussed above that filter or regulate a utility line do not offer:

- Complete protection against power abnormalities.
- Any protection against frequency variations or power blackouts.

Harmonic Filter

Harmonic filters are used to reduce voltage waveform distortion that affects sensitive electronic equipment. These filters screen out harmonics and high frequency noise. Some of the better surge-protecting devices, voltage regulators, and power line conditioners include harmonic filters.

Generator Equipment

Motor Generator

Motor generators provide electrical isolation from the utility line by using the utility to drive a motor, which in turn drives a generator, producing an ac waveform at the desired voltage. A flywheel is used to ride through short outages of up to a few seconds. Some devices use batteries and inverters in a hybrid, UPS-type, arrangement for longer power outages. These devices are discussed in greater depth in IEEE® 446, *Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications.*

NOTE: Motor generators should not be confused with static UPS units.

Generator Equipment, continued

Engine Generator

An engine generator is a unit that uses a fuel-powered engine to drive a rotary generator. It is usually used as a standby power source when long-term backup is required. However, startup time is slow (nominally 15 seconds). Also, an engine generator does not provide any conditioning or protection when it is not running. Engine generators are generally used with automatic transfer switches to provide power during extended outages.

Static Uninterruptible Power Supply (UPS) Units

Static UPS units are solid-state devices designed to protect critical loads from most types of power fluctuations. Several different types of static UPS units are available. Some units work better than others. A brief explanation of each basic group follows.

Off-Line or Standby Uninterruptible Power Supply (UPS) Units

Off-line or standby UPS units are devices that power the load directly from the utility and only provide backup power when the utility power goes below the preset tolerances. Calling these off-line devices UPS units is really a misnomer since the inverter is normally off and transfer time is involved to start the system. This transfer time can easily exceed the hold-up tolerance of the power supply in the load.

Off-line or standby UPS units do not provide any line conditioning. Standby power systems (SPS) are not recommended for the support of critical communications loads.

Line-Interactive Uninterruptible Power Supply (UPS) Units

Line-interactive UPS units are basically off-line UPS units with line conditioning included. Electronic or magnetic energy storage is used to hold up the load during transfer to the inverter. These units work well in most circumstances but have the following limitations:

- No frequency regulation
- Limited battery reserve and recharge times
- Unsuitable for use with generators
- The isolation of power source to load in a line-interactive UPS unit is not as good as in an online double-conversion UPS unit.

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Static Uninterruptible Power Supply (UPS) Units, continued

Online Double Conversion Uninterruptible Power Supply (UPS) Units

Online double-conversion UPS units are the conventional UPS units that completely rectify the ac line from ac to dc, and use this dc to both charge the battery and power a dc/ac inverter. Under normal circumstances, the full UPS unit:

- Is always online and provides isolation, regulation, filtering, and frequency control.
- Does not involve any switching time to transfer to the battery.

Online double-conversion UPS units are available in different designs, each having its own unique advantages and disadvantages.

NOTE: All of the above UPS units use batteries for reserve power.

Choice of Protection

The form of power conditioning or UPS unit should be chosen based on the:

- Knowledge of site power quality.
- Installation environment.
- Specific application.
- Type and importance of the load.
- Future expansion needs.
- Backup (battery reserve) time required.

The selection of protection method may be simplified by determining the importance of the load and whether it is more important to maintain power or protect the equipment from damage. The amount of protection required depends on the:

- Site power distribution design.
- Known power problems.
- Potential power problems.

Power protection is becoming a specialized science. Substantial installations require employing the services of a professional familiar with powering telecommunications systems.

Specifying Uninterruptible Power Supply (UPS) Units

It is beyond the scope of this chapter to detail a generic UPS unit specification. However, designers should be aware of the following information:

- The size of the UPS required for the loads and the duration of required run time should be calculated.
- Switch mode power supplies can exhibit high-crest factors (ratio of peak current to root-mean-square [rms] current) so the UPS unit should be capable of handling crest factor ratios of 2.5 or above.
- The UPS should have a sine wave output with a total harmonic distortion of 5 percent or less.
- Certain nonlinear loads can develop a leading power factor so the UPS should have the ability to support these loads.
- The UPS should provide continuous power during momentary or complete blackouts.
- The UPS should have the ability to recharge the battery to 90 percent capacity within a reasonable period of time (5 to 10 times the discharge time).
- The UPS output should be regulated with maximum deviations from the nominal +6 percent to –13 percent over the full input range for both ac and dc.

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Overview

Electrical systems vary by country but they have the following elements in common:

- The basics of electrical power and distribution
- The characteristics of electricity
- The operation of electrical circuits
- The management of electricity in audiovisual (AV) systems.

Some aspects of the design and installation of the electrical infrastructure and electrical components within a building are subject to the requirements of electrical codes. Electrical codes define the standards for safe and appropriate installation.

Electrical codes typically address the design and installation standards associated with the following electrical system issues and concerns:

- Power
- *National Electrical Code*® (*NEC*®) publications
- Grounding
- Return-air plenums
- Cables
- Boxes
- Conduit
- Clearances

Electrical codes can be mandatory construction requirements defined by the local authority having jurisdiction (AHJ). Compliance with these codes is mandatory within the jurisdiction of, and subject to inspections by, AHJ building inspectors.

National Electrical Code® (*NEC®*) and Audiovisual (AV) Equipment

Introduction

Electrical codes also can be published by trade associations, such as the National Fire Protection Agency (NFPA). The NFPA's *National Electrical Code®* (*NEC®*) provides construction personnel with the minimum standards for the installation of electrical systems. Many local building codes are based on the standards defined by the *NEC®*.

Formats

NEC® is published in a number of formats:

- *NEC®* Codebook provides detailed and comprehensive descriptions of electrical installation standards. The Codebook is typically used as a reference by the individuals interested in the details affecting an electrical system installation.
- *NEC®* Handbook provides a condensed version of the code, which may be more appropriate for AV system designers. This includes the basic codes and some explanations of code intent.

Articles

The 2005 *NEC®* articles of specific interest to AV designers and installers are:

- 100—Definitions.
- 250—Grounding and Bonding.
- 250.126—Equipment Grounding.
- 314.28—Junction/Pull Box Sizing.
- 640—Audio Signal Processing, Amplification, and Reproduction Equipment.
- 645—Information Technology Equipment.
- 800—Communications Circuits.
- 810—Radio and Television Equipment.
- 640.3.A, 800.52.B—Removal of Abandoned Cabling.

Audiovisual (AV) System Space Requirements

Some examples of code requirements applicable to AV system designers include:

- Working space required around electrical panels or systems.
  - 110.26—Spaces about Electrical Equipment
    - 1 meter (m [3 feet (ft)]) in front of panels (for 0 to 150 volts [V] to ground)
    - 760 millimeters (mm [30 inches (in)]) horizontal
    - 2 m (6.6 ft) vertical
    - Doors must be able to open to full 90 degrees
- Load calculations for various applications.
  - 220.12—Lighting Load for Specified Occupancies
    - 39 volt-amperes per square meter (VA/m^2) for general office
    - 11 VA/m^2 for auditoriums/assembly halls
  - 220.14 (H) —Fixed Multioutlet Assemblies
    - 180 volt-amperes (VA) per 300 mm (1 ft) for simultaneous use
    - 180 VA per 1.5 m (5 ft) for nonsimultaneous use
- Plenum space (an area connected to air ducts that forms part of the air distribution system) electrical system standards are stated. For example:

  – 300.22—Wiring in Ducts, Plenums and Other Air Handling Spaces—states that items placed in plenums cannot be combustible and cannot give off hazardous fumes. Affected AV system items would include loudspeakers, cables, tie wraps, and equipment.

Audiovisual (AV) System Infrastructure

The *NEC*® also provides standards and classifications for electrical cables:

- 725—Class 1—High Current
- Chapter 9, Table 11—Class 2 and Class 3
- Low voltage/low power—Class 2 and Class 3
- Middle voltage/low power—Up to 600 V
- High voltage/high power—Over 600 V

Even though the electrician will install the alternating current (ac) power to the site, the AV designer should be aware of the applicable code issues to be able to create a code-compliant design.

Audiovisual (AV) System Infrastructure, continued

Junction box requirements are defined by the *NEC*® in Articles 300.15 and 314. These articles define issues such as:

- Where junction boxes are required by cable pulls or where a splice occurs.
- Installation and use of junction boxes.

Other issues that a designer should consider when defining junction box requirements include determining the:

- Depth of the device.
- Room for cable bends.
- Depth of the wall where the box will be installed.
- Presence of ac power near the wall box.
- Size of the conduits going into the box.
- Location of outlets and jacks. (They should center at 0.5 m [18 in] AFF.)
- Location of switches and controls. (They should center at 1.2 m [48 in] AFF.)

Designers must consider the following issues as related to floor boxes:

- The type of floor in which the floor box will be installed (e.g., wood floors are handled differently from concrete).
- Fire rated boxes, which are sealed to prevent the escape of toxic gasses (cold smoke) produced by combustion.
- Functional issues, such as the use of cable slots as partitions to separate different types of cables and methods to prevent the jamming of dirt within the connectors.

Loudspeaker back boxes are installed when a loudspeaker is placed in a ceiling. The building code may require that the back box design address:

- The use of ceiling tile bridges.
- Additional considerations when the ceiling is used as a return-air plenum.
- The use of conduit versus plenum cable within the ceiling space.

The appropriate selection and installation of cable conduit also is covered by the *NEC*®.

The typical types of conduit used by AV designers and installers are:

- Metal.
- Plastic.
- Flexible.
- Cable tray.
- Walker duct.

Audiovisual (AV) System Infrastructure, continued

The criteria for selecting the appropriate size of conduit for a specific application are described within *NEC*® Chapter 9. These criteria address issues such as cable size and number of cables.

The *NEC*® defines the amount of space that cables can take up within a conduit. For example, the maximum amount of space that cables can take within a conduit is:

- 53 percent for a single wire.
- 31 percent for two wires.
- 40 percent for more than two wires.

These limitations are in place to reduce potential damage to cables when pulling multiple cables through a conduit. See Table 7.6 for limitations corresponding to specific conduit size.

Table 7.6
Usable conduit space for more than two wires

Electrical Metallic Tubing (EMT)	Nominal Internal Diameter Conduit Size (in)	Area (in^2)	Usable at 40% (in)
1/2	0.622	0.304	0.122
3/4	0.824	0.533	0.213
1	1.049	0.864	0.346
1-1/4	1.380	1.496	0.598
1-1/2	1.610	2.036	0.814
2	2.067	3.366	1.342
3	3.356	8.846	3.538

in = Inch

NEC® addresses the design of a conduit system with bends. Once 360 degrees of bends is reached, a pull box is required within the conduit run to enable the installer to access the cables for a cable pull. In most cases, a pull box is recommended when 270 degrees of bend is reached.

In general, the bend radius should be no less than 6 times the conduit size. For example, a 90 degree bend in a 1/2 inch conduit should take at least 3 inches.

Signal separation for cables within a conduit is another important consideration. Higher voltage signals will interfere with lower voltage signals, so cables should be separated according to the signal level to minimize the potential for electromagnetic interference (EMI).

Audiovisual (AV) System Infrastructure, continued

Cables are categorized according to the signal level to provide guidelines for separation, as follows:

- Type 1—Microphone (0.001 V)
- Type 2—Audio (0.1 V)
- Type 3—Loudspeakers (5 V)
- Type 4—Video (1 V)
- Type 5—Control (1 V)
- Type 6—Power (120 V)

The basic rule is to keep sensitive cables away from other cables. Electromagnetic (EM) theory and practice show that EMI is generated when cables are run parallel.

To reduce the potential for EMI in parallel runs:

- The conduit containing single-phase power should be kept at least 305 mm (12 in) from signal conduits.
- The conduit containing three-phase power should be kept at least 914 mm (36 in) from signal conduits.
- The greater the difference between signal voltages, the further the physical separation between conduits should be maintained.

Signal crossing is an important planning consideration. When planning the placement of the conduits that will carry critical signals, the conduits should cross other conduits at 90 degrees. This is an important design consideration because cables that contain critical signals can pick up crosstalk if they do not cross at 90 degrees.

Crosstalk is caused by inductance. EM waves radiate out in circular fields. When cables are placed in parallel runs, the cable carrying the lower power signal picks up interference from the cable carrying the higher power signal. However, when the wires cross at right angles, the fields do not interfere with each other.

Detailed design standards that comply with the standard electrical code can be found in the *NEC*®. The *NEC*® also is published in summary forms designed for rapidly locating specific information.

Overview

At a power generation station, the generator puts out very high voltage. To reduce loss during the long-distance trip down the power lines, a transformer steps up the voltage to a very high level. These voltage ranges are in the area of 138 000 volts (V [138 kilovolts (kV)]) to 765 000 V (765 kV).

The energy is fed through a transformer at the power generation station. The load side of that transformer is then connected to the primary transmission lines. (These lines operate at the previously mentioned voltages.)

These primary transmission lines deliver power to electrical substations. Substations are located strategically around population areas or industrial centers. The substations have transformers that reduce the voltage of the power delivered before further distribution. The electricity is then distributed to a local transformer at approximately 4160 V (4.16 kV) to 13 200 V (13.2 kV).

This voltage is fed into local transformers and reduced to voltages that would be directly used by equipment. Some sites receive three-phase power, while others receive only single-phase power.

Phasing

Introduction

Every power-generation station has some form of generator. A generator has an outer shell around a rotating element, called an armature. The armature has three isolated coils of wire wound together. This armature spins around the magnetic field supplied by the shell.

As the armature turns, it outputs electricity. The armature may be turned by water (e.g. a hydroelectric dam) or a steam turbine (e.g. a nuclear and fossil fuel power plant) or an engine (e.g. an automobile).

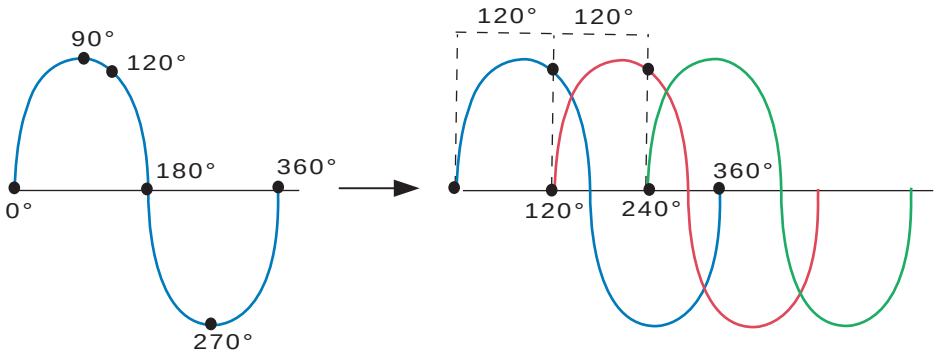
Generator Behavior

As the coils of wire spin, moving through the magnetic field, they capture some of that energy and cause the electrons in the coiled wires to move. The electrons first move in one direction. As the coil's location in the magnetic field changes, it causes the electrons to move in the other direction. This is alternating current (ac). If the electronic fluctuation in any one of the coils of wire were measured with an oscilloscope, a graphical depiction of this fluctuating action would look like a sine wave.

The frequency of the ac power sine wave may be 50 hertz (Hz) or 60 Hz.

As a result of using the three coils in power generation and distribution, ac power has three phases, each 120 degrees out-of-phase with the others (see Figure 7.7).

Figure 7.7
Phase relationships of three-phase power systems



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Single-Phase Power Distribution Systems

Some sites receive three-phase power, while others receive single-phase power. In the United States, voltages distributed to a given site may include:

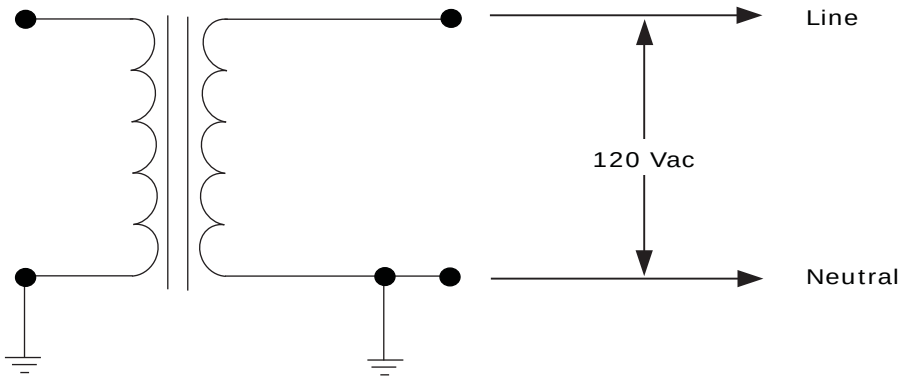
- 120 V single-phase.
- 120/240 V single-phase.

The ac power distribution system types also are referred to by the number of wires carrying the power. For example, a 120 V single-phase system uses two wires.

120 V Two-Wire Single-Phase System

One wire, called a line, carries 120 V of ac power, and the second wire is a neutral (grounded) conductor (see Figure 7.8). While this is a simple system, it is not commonly used in modern power distribution systems, because most locations need more than 120 V.

Figure 7.8
120 V two-wire single-phase system



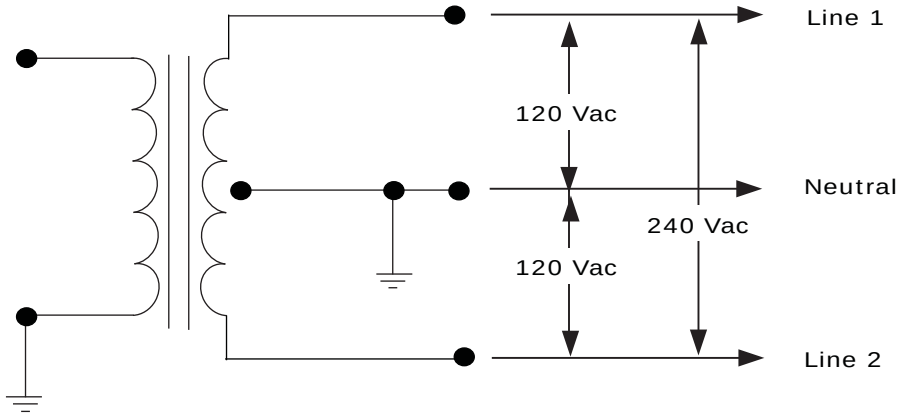
Vac = Volt alternating current

Single-Phase Power Distribution Systems, continued

120/240 V Three-Wire Single-Phase System

A 240 V single-phase system has three wires. The first carries 120 V, the second carries 120 V from the same phase, and the third is a neutral (grounded) conductor (see Figure 7.9). This system is used in almost all homes in <the United States>, where the needed load is relatively small. The two legs of power can be used together to power appliances. This system also is used in small commercial buildings with fewer power demands.

Figure 7.9
120/240 V three-wire single-phase system



Vac = Volt alternating current

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Three-Phase Power Distribution Systems

The most common three-phase systems are:

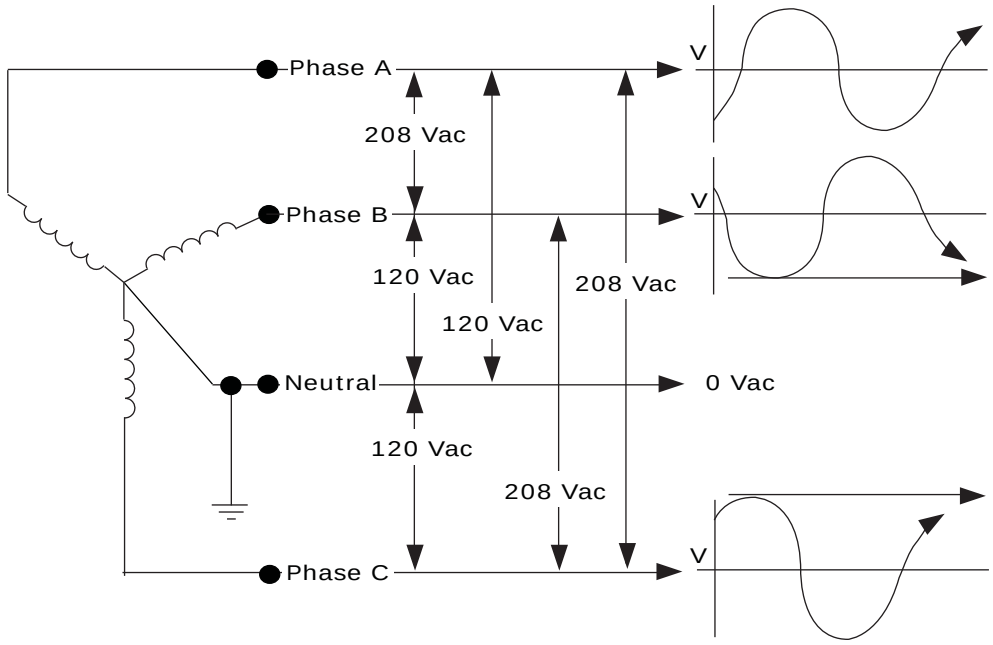
- 208Y/120 V three-phase.
- 240 V three-phase.
- 480Y/277 V three-phase.

Power comes into commercial buildings nearly always as three-phase. Ideally, all of the power for audiovisual (AV) equipment should come from only one of the phases. Interconnected equipment powered by different electrical phases can interact, causing noise.

208Y/120 V Three-Wire Three-Phase System

A 208Y/120 V three-phase power distribution system uses four wires, with 208 V available between any of the phases (A-B, B-C, and C-A) and 120 V available between any of the phase conductors (A, B, or C) and the neutral (grounded) conductor (see Figure 7.10). It is the most popular system used in commercial, institutional, and light industrial buildings. The system is called a wye transformer because it is in the shape of a Y.

Figure 7.10
208Y/120 V three-wire three-phase system



V = Volt
Vac = Volt alternating current

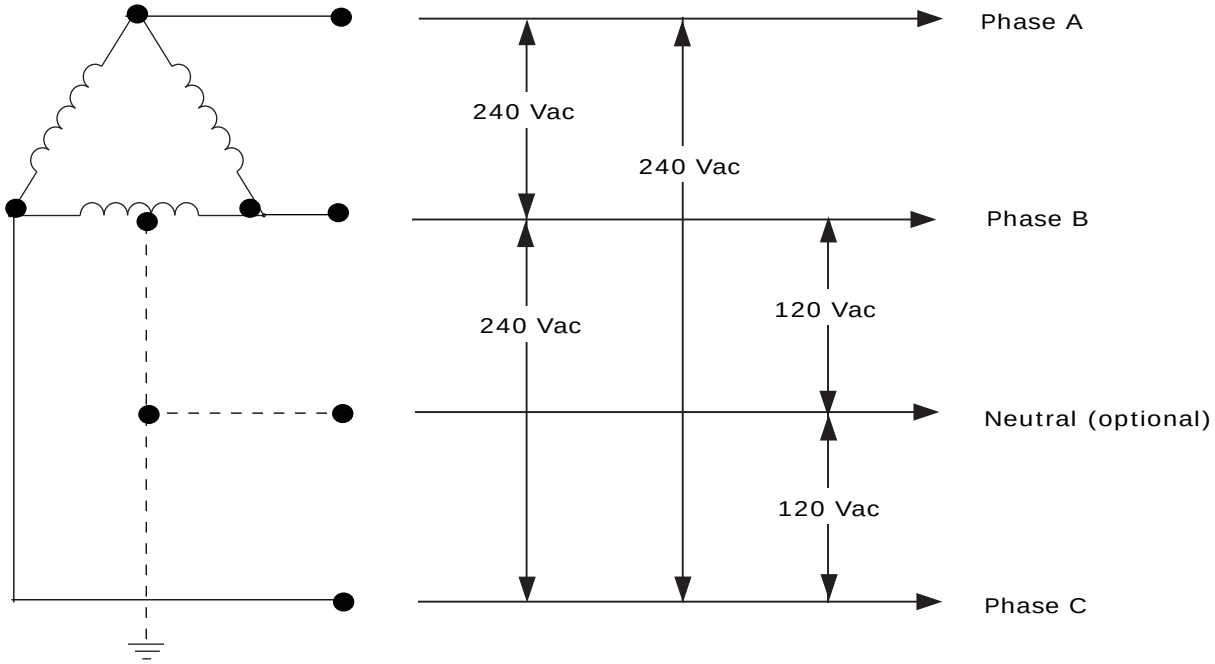
Three-Phase Power Distribution Systems, continued

240 V Three-Wire Three-Phase System

A 240 V three-phase system uses three wires and an optional fourth wire (see Figure 7.11). The power of 240 V is available between any two phase conductors (A-B, B-C, C-A). When an optional fourth wire for the neutral (grounded) conductor is added to one of the coils, it splits the power output in half. This provides 120 V between phase B and the neutral, and phase C and the neutral.

This system is found in commercial and industrial buildings with sizable power loads. It also is known as a delta transformer because it is shaped like a Greek letter Ä.

Figure 7.11
240 V three-wire three-phase system



Vac = Volt alternating current

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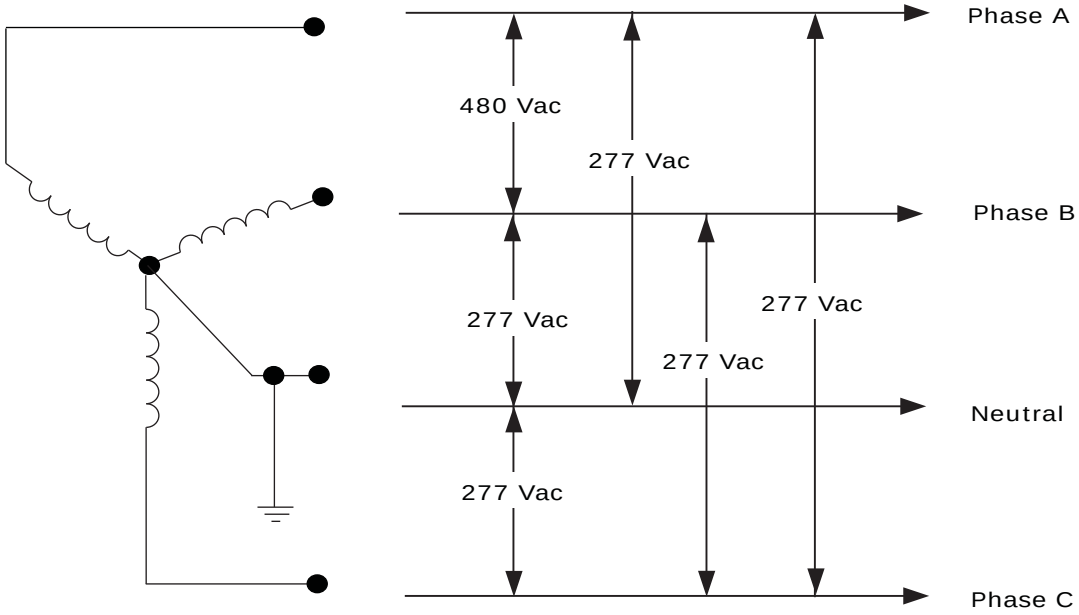
Three-Phase Power Distribution Systems, continued

480Y/277 V Four-Wire Three-Phase System

A 480Y/277 V three-phase power distribution system (Figure 7.12) uses four wires and is similar to the 208Y/120V system. The power of 480 V is available between any of the phase conductors (phase A-B, B-C and C-A). The power of 277 V is available between any of the phase conductors (phase A, B, or C) and the neutral (grounded) conductor.

This system is used in large commercial and industrial buildings.

Figure 7.12
480/277 V four-wire three-phase system



Vac = Volt alternating current

Installers should understand the reasons for making specific power assignment choices. Since electricians try to balance the current flow of the three phases, installers should understand that all electronics cannot be located on a single phase.

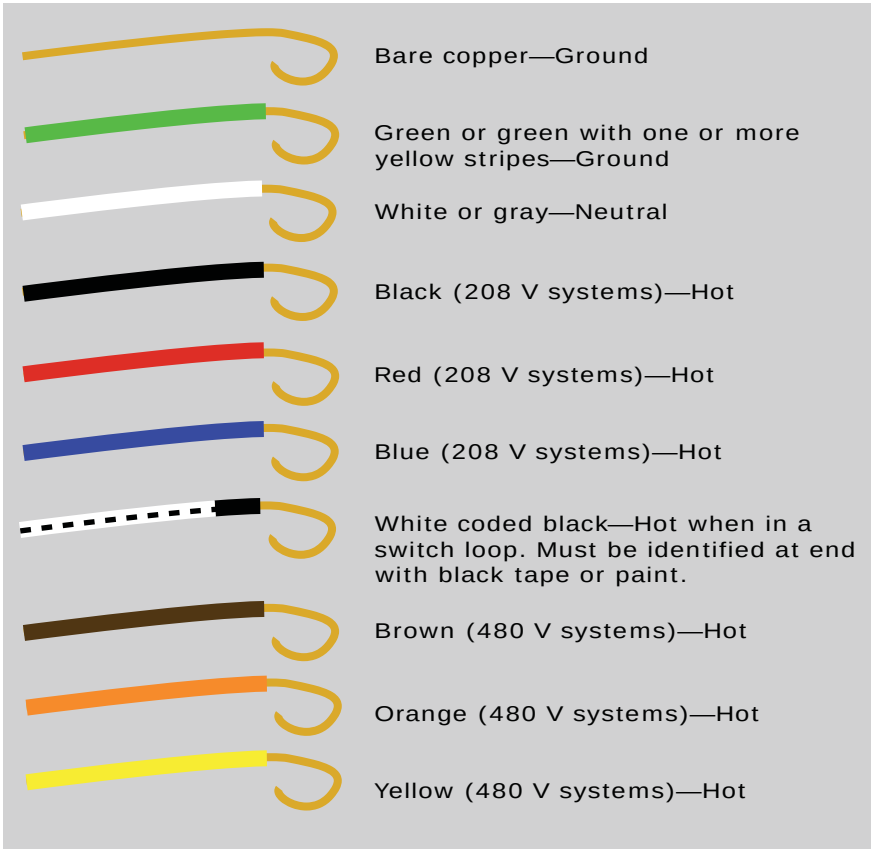
Phase and Neutral Conductors

In single or three-phase power, the wire that carries the current is the phase conductor. Electricians may call the phase conductor hot or refer to its wire color, black.

The neutral (grounded) conductor is common to the phases. It does not carry any current if the loads of all of the phases are equal, which makes it neutral. The neutral conductor is intentionally grounded. However, the grounding can take place at only two locations: the electrical service or a separately derived system. For this reason, the neutral (grounded) conductor must be kept insulated from the equipment grounding conductor at all other locations in the electrical system.

While the neutral (grounded) conductor may be connected to ground in the main electrical panel, it is not intended for use as an electrical equipment ground for the AV equipment. Electricians may call the neutral conductor the grounded conductor or refer to its wire color, white. See Figure 7.13 for more wire color codes.

Figure 7.13
NEC® Wire color codes



V = Volt

Phase and Neutral Conductors, continued

NOTES: The *National Electrical Code*® (*NEC*®) requires supplying branch circuits from more than one nominal voltage system for identification. This can be done by color coding, marking, taping, or tagging (NEC 210.5[C]). The previously mentioned color codes are Institute of Electrical and Electronics Engineers® (IEEE®) standards.

Wiring color codes used for electrical power are not the same as those used for electronics. Generally, in electronics wiring, red is hot and black is ground.

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Chapter 8
Grounding

This chapter provides various references that an audiovisual (AV) professional should consult before addressing a grounding project. Properly grounded facilities promote a safe environment for occupants and property. Grounding is a complex topic requiring research and discussion beyond the scope of this manual.

Table of Contents

Grounding 8-1

References 8-1

Grounding

Grounding is a complex topic requiring research and discussion beyond the scope of this manual.

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Chapter 9
Heating, Ventilating, and Air Conditioning (HVAC)

While the audiovisual (AV) designer is not responsible for designing the heating, ventilating, and air conditioning (HVAC) systems, having a basic working knowledge of the common components and systems will aid in their integration with the AV systems. This chapter provides the AV designer with the information necessary to address such things as heat loads and HVAC noise.

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Figure 9.1 Typical heating, ventilating, and air conditioning system 9-4

Overview

Heating, ventilating, and air conditioning (HVAC) systems are the physical systems that control the environmental (temperature and humidity) conditions of a workspace. Audiovisual (AV) designers are primarily concerned with the relationship between HVAC systems and the maintenance of temperature and humidity in the AV equipment as well as the associated noises created in presentation spaces.

AV designers are not responsible for, and in many cases are barred from, the design of HVAC systems. However, an AV designer should coordinate HVAC requirements with an HVAC designer, and make the HVAC designer aware of the AV system's impact on an HVAC system.

Heating, Ventilating, and Air Conditioning (HVAC) Distribution Systems

Introduction

HVAC distribution systems circulate conditioned air into a building's spaces. In the AV systems context, HVAC distribution protects the equipment from the effects of temperature and humidity.

Heating, Ventilating, and Air Conditioning (HVAC) Component Functions

All HVAC systems generally have the same basic components. A system consists of components that:

- Extract heat to and from the environment.
- Extract heat to and from the conditioned spaces.
- Move air throughout the conditioned spaces.

HVAC systems may have many different functions (see Figure 9.1). The following definitions describe some of the major components of common HVAC systems.

Chiller and Boilers

Chillers create chilled water for cooling the air in air handlers and other HVAC equipment. Boilers create hot water to warm the air.

Variable Air Volume (VAV) or Air Terminal Unit (ATU) Box

A variable air volume (VAV) box is a small damper box that controls the amount of conditioned air introduced into the conditioned space to control the temperature. Usually many VAV boxes are connected to a central air handling unit through a ductwork system. This unit is also known as an air terminal unit (ATU).

Ductwork

A ductwork system distributes air throughout the building. It is usually made of tubular or square sheet metal. Duct-board–type materials are commonly seen in residential applications due to their low cost and are not normally used in commercial applications. The ductwork provides a means of transporting conditioned air to diffusers or registers, which supply the air to the conditioned spaces.

Supply and Return Paths

A supply path is the distribution of ductwork that supplies the conditioned air to the space. A return path can consist of ductwork that directs the air either back to the air handling unit or to a return-air plenum.

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Heating, Ventilating, and Air Conditioning (HVAC) Component Functions, continued

Return-Air Plenum

Oftentimes the space above the ceiling in office-type environments is used as a return-air path for air to circulate back to the air handling system. This is called a return-air plenum. Any cabling and equipment used for AV systems must be plenum-rated to be permitted for use in an air plenum. The HVAC designer also must give special consideration to noise transmission control through the plenum cavity.

Split Systems

A split system is an HVAC system where the condenser (outside unit) and evaporator (inside unit) are in separate locations joined by refrigerant piping.

Air-Handling Units (AHUs)

An air handling unit (AHU) consists of fans, heating and cooling coils, filters, and other components through which the air is moved to be conditioned. An AHU is also known as the evaporator portion of a split system.

Fan Coils

A fan coil is an air-handling device where the amount of cooling (or heating) is controlled by the amount of chilled water passing through the unit's coils. The airflow is usually constant. Heating can be achieved through the use of hot water or electric strips.

Cooling Towers

Cooling towers are used for cooling water by the process of evaporation. As the water evaporates, heat is pulled from the water to the atmosphere, cooling the remaining water. This water is then circulated to the coils or tubes of HVAC equipment. Cooling towers are commonly used with water-cooled chillers.

Filtration Units

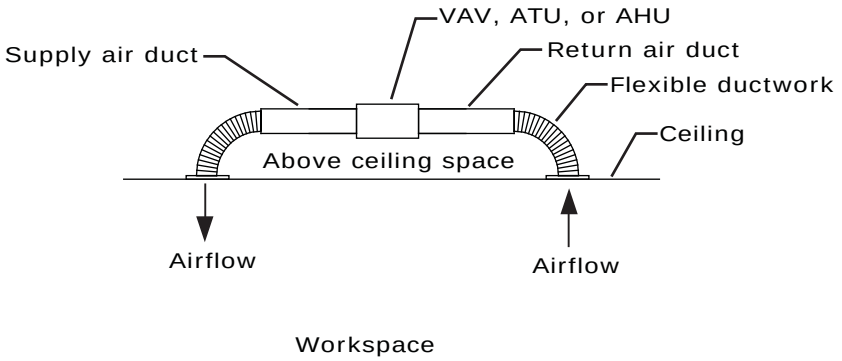
Various types of units are used for air filtering. The most common is a dry extended-surface filter. It is typically found in light commercial and residential HVAC units. This unit cleans the air by trapping particulate matter (dust). Other types of units include electrostatic units, which trap dust with static electricity, and viscous impingement units, which trap dust with adhesives.

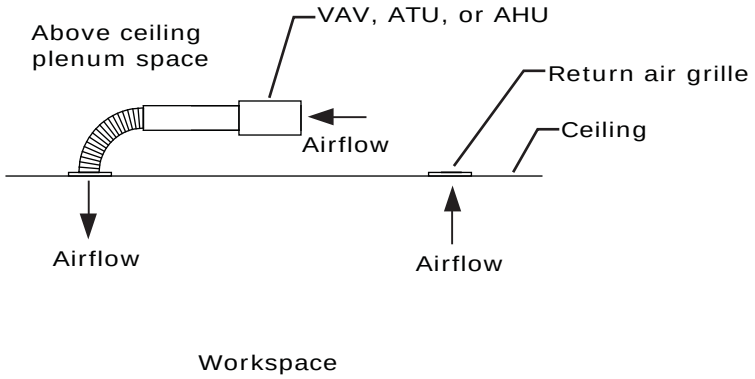
Heating, Ventilating, and Air Conditioning (HVAC) Component Functions, continued

Silencers

Silencers (also sound attenuators, sound traps, or mufflers) are most often small sections of ductwork designed to reduce noise. Noise reduction is achieved through baffles and insulation panels. Sounds that would normally travel down the ductwork are reduced by absorption into the silencer.

Figure 9.1
Typical heating, ventilating, and air conditioning system





AHU = Air-handling units
ATU = Air terminal unit
VAV = Variable air volume

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Positive and Negative Pressure

Individual room pressurization depends on the function of a space. To provide negative pressure would be to provide more return and/or exhaust air in the space to prevent contaminants, odors, and other air-born pathogens to escape from one space into the other occupied spaces (i.e., hospital isolation rooms). To provide positive pressure is to do the exact opposite; it keeps contaminants from entering a space (e.g., a clean hospital room). Negative pressure is also beneficial in spaces where dust contamination is undesirable (AV equipment).

The effect of positive and negative pressure is caused by the air's forcible transfer (through a fan) from one area to another. This creates a higher pressure on the outlet side of the fan than on the inlet side.

Providing more outside air than exhaust air in a building is desirable, especially in hot humid climates, to achieve positive pressurization of a building. This prevents indoor air quality (IAQ) problems associated with outside air infiltration that is not accounted for in the building conditioning design. If this occurs, the relative humidity of the building may rise and possibly cause moisture problems inside the conditioned spaces.

In the AV equipment context, by creating a negative pressure environment within the equipment, the air can be drawn with a relatively low velocity through the equipment, minimizing dust infiltration, which helps the AV equipment performance. With equipment fans facing inward, higher amounts of dust are pulled in with the air and deposited on the circuit boards. The same holds true for equipment rooms.

Heat Load

Heat load is the amount of heat generated by a combination of the human bodies and equipment in a space in addition to the radiant, conductive, and convective heat generated by a building's exterior environment.

Two types of heat the designer should be able to recognize are:

- Sensible heat
- Latent heat

Sensible heat is the heat produced by a rise in the air temperature. This is the heat produced by any electrical equipment and also by the sun's radiant energy.

Latent heat is heat produced by a change in the temperature of the air's water content. Human bodies produce an amount of latent heat that must be accounted for by an HVAC designer. The addition of latent heat to a space is not a critical concern in the AV systems context.

Heat Load, continued

Impact of Heat, Power, and Air Requirements from Audiovisual (AV) Equipment

An AV designer should understand the procedure for estimating the amount of heat generated by the AV equipment and presenting the findings to an engineer or architect for an appropriate HVAC system design.

An AV designer also should understand the causes of HVAC noises and consult with an HVAC designer about the methods of noise mitigation. If the amount of heat is excessive, the HVAC designer ideally creates a plan of removing the heat from within the room in cooperation with the AV designer.

Evacuation of Heat through Air Distribution Systems

The typical sources of heat within a room can be:

- Electronic equipment generating heat during their operation.
- Solar gain from sunlight entering through windows or skylights
- Light fixtures generating heat during normal operation
- People generating body heat.

The HVAC designer is concerned with all of these heat sources. The AV designer should be able to calculate the heat load of the AV equipment and provide this to the designer.

Estimating Heat Load and Distribution

All electronic equipment produces heat. The unit of heat or energy is joule (J [British thermal unit (Btu)]). By definition, 1 J is a unit of work or energy equal to the work done by a force of 1 newton (N) acting through a distance of 1 meter (m). One Btu is a measure of the quantity of heat approximately equal to 1,055 J.

HVAC designers normally do not deal with the energy units but rather with the energy transfer units. A unit of energy transfer is watt (W) or J per second (J/s or Btu per hour [Btuh]). One W generates 3.4129 Btuh (rounded off to 3.4 Btuh).

Any device that generates heat will have a heat load, although this number may vary depending on how the equipment is used (i.e. amplifiers create more heat with higher volume).

The capability of an HVAC system to heat or cool a room also is rated in W (Btuh). A HVAC system's capacity must equal or be greater than the room load to condition the space properly. As previously mentioned, an HVAC system uses ducts and diffusers to remove heat and distribute warm or cold air throughout the room.

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Heat Load, continued

The AV designer must understand how different devices generate different heat loads:

- Video monitors/projectors convert most of the input power into heat.
- Lights convert almost all of the power into heat.
- One person sitting at rest generates an amount of heat equivalent to a 100 W light bulb 340 Btu.
- Windows can pass substantial amounts of heat from outside the conditioned space.

The windows, lights, and human bodies should be considered by a mechanical engineer or architect. However, an AV designer should work with the engineer to ensure that they fully understand the AV system operation and use. Often, different lighting systems in a TV studio are not used at the same time to avoid using oversized or costly air conditioning system.

Duty Cycle Requirements and Impact on Audiovisual (AV) Equipment

The duty cycle of an audio signal is very important. It is the proportion of time the amplifier power is consumed during normal operation.

The duty cycle used by an amplifier depends on the type of a program source. For example, the duty cycle of:

- Pink noise is 50 percent.
- Background music is 20 percent.
- Continuous speech is 10 percent.
- Paging is 1 percent.

The higher the duty cycle for a specific program, the more heat is generated by the amplifier.

Calculating Relationship between Power and Heat

Heat is generated during the operation of electrical equipment when watts of electric power are absorbed by the load. In a resistive system, the power is calculated as voltage multiplied by amperage.

The volt-ampere (VA) value is the apparent power used by a system. This calculation takes into account the fact that all loads are not purely resistive. Some loads are inductive and do not act as resistors. Simply stated, while the electrical power required for a piece of equipment is expressed in W, it is not always equal to the heat load W. The difference is in the system's efficiency.

Heat Load, continued

Most amplifiers also give an efficiency rating that identifies how much of the power is translated into heat. If the efficiency rating of an amplifier is 65 percent, 65 percent of the power generates an audio signal, while the remaining 35 percent generates heat. In this example, the amplifier draws 7 amperes (A) at 120 V of alternating current (Vac). This roughly equals 840 W but not in terms of the heat load generated by the equipment. The amplifier with this duty cycle generates approximately 294 W (35 percent of 840 W) or 1000 Btuh of heat load.

The formula for determining the heat load of a power amplifier is:

$$W = \left(\frac{Rated\ output \times duty\ cycle \times 0.35}{Amplifier\ efficiency} + Quiescent\ \ power\ draw\ in\ W \right) = Btuh \times 3.4$$

These formula elements are often provided by the manufacturer, or more often a W (Btuh) load is provided at various power settings.

The following are some examples of heat load generated by AV components:

- Audio equalizer—30 W (100 Btuh)
- Teleconferencing unit—23 W (80 Btuh)
- 4 X 1 video switcher—10 W (35 Btuh)
- 800 W power amplifier—301 W (1025 Btuh waste heat) with music (20 percent duty cycle) into 4 ohm load
- Video projector 3600 American National Standards Institute (ANSI) lumens, extended graphics array (XGA)—405 W (1377 Btuh) in a standard mode/320 W (1088 Btuh) in a low-power mode/0.8 W (nominal Btuh) in a standby mode

Before calculating the heat load from the electrical specifications, an AV designer should consult the manufacturer's technical specifications for any heat load data. These tables are often provided by the manufacturer and take the specific manufacturers usage and efficiency of the equipment into account.

Maintaining the consistency of humidity and heat is important for the stability of electronics. An AV designer should coordinate the design requirements with the architect and HVAC designer to ensure adequate ventilation.

Design for Future Expansion

In calculating the heat loads of systems, the designer also should take into account any future expansion and provide this information to the HVAC engineer. Mechanical systems do not follow AV system upgrades unless an overheating problem becomes apparent.

Humidity Issues

Although AV equipment does not produce humidity, the designer must understand how humidity affects the equipment. A mechanical engineer should account for humidity control from the given design criteria for the building and its climate.

Room Control

AV systems should be kept at the temperature and humidity similar to that of a telecommunications equipment room (ER). Equipment should not be placed in a room that is accessible from the outside and should be kept at 18 to 24 degrees Celsius (°C [64 to 75 degrees Fahrenheit (°F)]) and 30 to 55 percent humidity.

Noise Criteria (NC) and Room Criteria (RC) Ratings

Background noise within a room can affect speech intelligibility, which creates additional challenges for AV designers. One common source of background noise is the building HVAC system. HVAC system components that can generate noise include:

- Fans—motor vibrations and air turbulence.
- Diffusers—passage of supply or return air through the diffuser vents. The air flow from a diffuser also can cause the swaying of a projection screen.
- Ducts—passage of air. The ductwork also can carry noise generated by other sources throughout the building.

Other sources of noise can include:

- Pumps.
- Chillers.
- Emergency generators.
- Fan coil units.
- VAV boxes.

NOTE: For more information about the effects of noise, refer to Chapter 11: Acoustics.

Vibration

Vibration is another source of noise. The AV designer, architect, and mechanical engineer should work together to ensure large mechanical units are not placed directly adjacent to the spaces that require a low-noise floor.

Mechanical vibration and noise created by vibration are often major complaints in buildings. The low rumble of a chiller or large fan can resonate throughout a building if it is not designed properly and given the proper vibration isolation. Low-frequency vibration also should be considered because it can affect the stability of display devices attached to the building structure.

Recommended Parts and Parameters for Vibration Isolation

Many components can be used to control vibration. Larger pieces of equipment are often provided with spring isolators, air mounts, or rubber padding. Piping systems also can be isolated with the use of flexible pipe connectors between sections of metal pipe to control vibrations traveling down the pipe walls. Ducts are isolated with either flexible canvas or rubber duct connections between metal sections. Although this does not prevent the traveling of noise down the air within the duct, these methods isolate vibrations in the body of the ductwork. Isolators, in conjunction with silencers, reduce noise and vibration propagation within the ductwork airstream.

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Audiovisual (AV) Equipment Air Distribution Issues

Assessing Proximity of Heating, Ventilating, and Air Conditioning (HVAC) Equipment to Audiovisual (AV) Equipment

A designer should understand the operation of HVAC system equipment and how it affects AV systems.

HVAC is usually the main source of noise that a designer will have to address. HVAC diffusion vents can generate a substantial amount of noise and unwanted airflow if they are not designed and balanced carefully for the space's function.

Location of Diffusers Relative to Audiovisual (AV) Equipment

A reflected ceiling plan is an especially important plan for AV designers since it depicts the features included within the ceiling. It includes AV components (e.g., loudspeakers) as well as other features that can interfere with the location and/or installation of AV components (e.g., HVAC ducts or diffusers or indirect lighting hanging from the ceiling).

AV designers must be aware of the locations and installation requirements of HVAC system components to create a compatible overall system design. For example, the designer should check the air duct placement in relation to any projector mounting location or any screen mounting location. A misplaced air vent with a high velocity of air may cause the shaking or waving of projection screens.

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Chapter 10
Structural Considerations

Audiovisual (AV) equipment must frequently be mounted onto the structural elements of a building. This chapter provides some recommendations to the AV designer but does not seek to be a structural engineering design guide and should not be used in lieu of a registered structural engineer.

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Overview

The mounting and suspension of audiovisual (AV) devices is a common and necessary practice in the installed AV industry. This chapter addresses the issues and concerns that AV designers must consider when specifying AV equipment and planning the integration and mounting of equipment to a building structure.

Most categories of AV equipment devices are mounted, suspended, hung, or attached to a building structure and include:

- Projection screens.
- Display devices and lifts.
- Loudspeakers.
- Cameras.
- Control devices.

A number of significant factors must be addressed in evaluating the mounting requirements of devices to a building structure. Many design factors and the evaluation of appropriate solutions are beyond the scope of AV designers' work.

The role of an AV designer is to identify the AV requirements for equipment placement. Possessing the knowledge of typical mounting requirements and approaches helps AV designers make feasible suggestions.

The best practice is to communicate the mounting requirements to an architect or a building structural engineer. Mounting specifications and details for elevated devices introduce significant safety factors that must be incorporated into designs by engineers who are responsible and liable for the mounting design.

This chapter offers a number of mounting considerations elements and factors that an AV designer should understand and incorporate into the conceptual design of AV device placement.

Audiovisual (AV) Equipment Load Issues

Introduction

Safety should be the top priority when mounting any AV components to a ceiling or wall structure. The designer should thoroughly understand the loading requirements of the equipment and be able to relay this information on to the designing architect or structural engineer.

Weight and Size Parameters of Audiovisual (AV) Equipment

Load Limits

Any equipment and the related mounting hardware intended for wall or overhead mounting is assigned a load limit. The load limit is the weight at which the mounted item will structurally fail. The mounting hardware and equipment must be designed to hold higher loads than the mounted object. The term safe working load (SWL) or a similar rating called the working load limit (WLL) determines the weight that must not be exceeded.

Another factor that pertains to the mounting equipment is a safety factor. The safety factor is a multiplier applied to the maximum carried by the mounting equipment and hardware. The safety factor is sometimes referred to as design factor, load factor, or safety ratio.

In general, a safety factor of five is often applied to the safe SWL rating of the mount. For example, a 45 kilogram (kg [100 pound (lb)]) projector and mount combination requires a structure capable of handling 225 kg (500 lb). This extra margin of safety is intended to compensate for losses in strength associated with the aging of components, unintended additional loading, and unexpected events.

Each individual part of the mounting assembly must have a compatible load factor. The weakest point in any assembly determines the maximum load of the entire assembly. For example, if one underrated bolt is used, the mounted structure can only be rated to that level.

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Weight and Size Parameters of Audiovisual (AV) Equipment, continued

Mounting Overview

Mounting is the practice of suspending or attaching components to the structure of a building. Some examples of the items that AV technicians mount are:

- Rear projection mirror assemblies.
- Plasma screens.
- Projectors.
- Televisions (TVs) and monitors.
- Equipment racks.
- Loudspeakers.
- Whiteboards.

Since this equipment typically does not have the mounting hardware included, installing a support system is necessary. Manufacturers make special hardware that fits with the equipment.

Mounting Preparation

An AV designer should follow the instructions and drawings of a structural engineer. If such items are not available, a mounting procedure should be drawn and given to an engineer for approval. Such procedure should define the specific parts that will be used and review the:

- Size and weight of the mounted object and its parts.
- Mounting location.
- Structure onto which the object will be mounted (and assess any potential problems).
- Structural designs of the room or building to ensure safety.
- Manufacturer guidelines and drawings.

A structural engineer should review all of the mounting plans and advise on any difficult situations that may have been encountered. Modifying another contractor's work constitutes an assumption of responsibility.

Weight and Size Parameters of Audiovisual (AV) Equipment, continued

Floor Mounting

Floor mounting is the simplest form of mounting because of the effect of gravity. Floor-mounted equipment may include:

- Projection pedestals.
- Rear projection mirror assemblies.
- Podiums.
- Equipment racks.
- Kiosks.

Floor mounting boosts the security from theft and mistreatment. A careful equipment alignment is necessary for a successful permanent assembly attachment.

Wall Mounting

Wall mounted equipment includes:

- Projection screens.
- Flat panel displays.
- Monitors.
- Video cameras.
- Loudspeakers.
- Small equipment racks.

One of the most important parts of the wall mounting process is blocking. Blocking is the support system or construction material typically added to the wall before the wall finish is applied. The general contractor may insert heavy wood into the wall assembly across three or more studs prior to the application of sheet rock or drywall. Once the finish is applied to the wall, the blocking is invisible to the eye. This can be done only with advance planning and coordination among the AV designer, the architect, and the builder.

NOTES: Wall mountings should not be used for heavy objects. Heavy objects should only be mounted vertically (overhead).

A stud should be located before mounting an object onto a drywall.

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Weight and Size Parameters of Audiovisual (AV) Equipment, continued

Overhead Mounting

Overhead mounted equipment includes:

- Projection screens.
- Projectors.
- Flat panel displays.
- Monitors.
- Loudspeakers.

Any time equipment is suspended or hung overhead, the means of weight support should be determined. The hardware should be mounted to the building structure and not to the ceiling assembly.

Slab Parameters and Coordination Issues

AV designers may need to coordinate with an architect or a structural engineer the structural floor penetration and mounting parameters of devices such as poke-thrus, floor boxes, floor ducts, conduits, and junction boxes.

For example, post-tension construction used in many modern commercial buildings can present safety hazards. These types of structures use metal cables embedded within the concrete slab to support the structure. Since these cables are under a large amount of tension, accidentally drilling through a cable can cause the cable to snap and eject from the slab.

When working in buildings that use post-tension construction, a portable x-ray machine must be used to determine the locations of the tension cables before drilling through any floor slab.

Recommended Mounting/Suspending Methods

The main concern for a designer or installer to consider with equipment mounting is whether the building structure (e.g., wall, ceiling) and the support system (e.g., mount, bracket, guywire) will hold the weight.

In a difficult or unusual structural situation, the AV designer should obtain professional engineering assistance before committing to a specific mounting scheme.

Installers are often required to permanently mount heavy devices, such as video monitors or loudspeakers. These devices are often mounted over the heads of audience members, creating a critical safety issue. Installers must understand which structures can support a system component and how to safely mount components to these structures.

A safe mounting of components requires that the installer understand and follow some basic mounting principles. For example:

- When two flat surfaces are mated together, one takes on the integrity of the other. To ensure the strongest bond, components must be mated flat and tight to increase the solidity of the bond.
- Weights should be attached close to the wall to reduce the effects of leverage.
- Mechanics and physics should be carefully considered, including assessing stresses, determining the load balances, and minimizing the effects of leverage created from an imbalance.
- Heavy components should be securely attached to structural components of a building. Structural components of a building are the portions of a building capable of and integral to supporting all other building materials. This includes support beams and columns. For example, ceiling mounts must be attached to the structure and not just to the ceiling.
- Wall mounts must have proper blocking to ensure that the wall section is strong enough to support the weight. Blocking is best installed before wall finishes.

NOTES: The mounts for heavy objects are typically installed early in the construction process so the installers can have easy access to the structural elements of the building.

When using black iron pipe, any threaded junction should have some means of locking (e.g., a set screw or an alignment hole with a through bolt). This will prevent the assembly from becoming unscrewed over time and use.

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Recommended Mounting / Suspending Methods, continued

Mount Malfunctions

Mounts are subject to destructive stress that can affect the strength of the mounting. A mounting can malfunction for many reasons, including:

- Sheer—The tendency of the mounting to tear or cut off from the structure. It is measured by how much weight is necessary to break the mounting from the wall.
- Tensile strength—The hardware's elasticity and to the tendency for the mount or structure to become stretched or extended, reducing strength (how much tension it can withstand before it physically stretches). Soft, inferior grade mounting hardware will stretch and distort when under stress and can cause an object to fall.
- Pull out—The amount of force needed to pull a fastener from the wall. This includes the strength of both the mount and the structure to which the mount is attached.
- Shock loading—A sudden additional load. Application of a proper safety factor in the overall design load is meant to overcome any typical or plausible shock loads.
- Placement of bolts—Bolts placed in the top of the mounting carry more stress than ones that are placed elsewhere. The placement should be done according to the manufacturer's instructions.
- Improper calculation of loads.

Building / Room Layout and Structural Concerns

The following is a list of concerns that should be addressed before any mounting is begun. The designer should:

- Compare the building to the latest set of drawings. All dimensions, including the ceiling height and the room shape, should be checked to ensure they match with the drawing specifications.
- Check the stairwells and door openings to ensure enough room for product installation and access.
- Inspect the walls and compare them to the room layout.
- Inspect the ceiling construction and determine the type and thickness of the ceiling for ease of access to the cabling.
- Determine the sprinklers' location before the installation.
- Check the air duct placement in relation to any projector or screen's mounting location. An air vent may cause the projecton screen to shake and wave.
- Inspect the wall construction. Double-studded walls are designed to prevent open channels. The isolation and fire ratings of wall and floor structures should be preserved.
- Determine the gauge of steel used for the wall construction and ensure that the metal stubs support the mounting hardware.

Recommended Mounting/Suspending Methods, continued

- Determine if laminated beams are used. They are wood beams made of smaller wood pieces assembled together by pressure and heat. An installer should never drill into the flat area of a laminated beam so the hole cuts through the glue lamination area. This can cause the beam to delaminate or split. A saddle clamp should be used to drill into the sides of the beam, centered on one of the laminated boards.
- Determine if the wood studs are cross bearing and what they would support.
- Determine the floor type (e.g., tiered, flat, computer, studio, or pan) and any related special specifications, as in the case of a TV studio floor.
- Inspect the building for heating, ventilating, and air-conditioning (HVAC) vibration and isolation that might affect the mounting and determine if the HVAC unit is on a concrete slab. Another associated concern is how often the system will be turning on and off. Vibrations can be disastrous to a projection installation.
- Determine if loudspeakers need to be isolated from the structure and perform an acoustic test prior to the installation. Loudspeakers should not be mounted onto movable or vibrating surfaces because such mounts may loosen over time.
- Determine the installation hardware based on the mounting surface type and depth (e.g., frame structure or wall interior).
- Determine cable needs and transport to the mounting point.
- Determine if the mount will need to swivel and, if so, the degree of rotation and the strength capacity.
- Coordinate the hardware to ensure it fits in with the facility's aesthetic design

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Seismic Parameters

Seismic Considerations

AV designers should be aware of seismic parameters and any additional mounting hardware requirements and installation procedures for the AV systems.

Mounting standards can be different depending on the location where the component is installed. Areas that are subject to extreme conditions (e.g., earthquakes, hurricanes, tornadoes, and flooding) may require additional mounting strength to ensure that the components are secure. For example, in an earthquake, a component may sway from side to side and create a dangerous condition. In areas subject to earthquakes, the mount may require a sway bar to secure the component.

Each equipment mount should be designed in a manner that will ensure the safety and security of persons and property.

Stabilizers

Stabilizers may be necessary for some equipment mounts. For example, if a ceiling-mounted video monitor requires a long mounting pipe, stabilization may be necessary to prevent the swaying of the device. Stabilizer arms can be installed to secure the mount at 45 degrees from the connection point and at 90 degree angles from each other.

Safety Cables

Safety cables also may be necessary for some installations. The safety cable helps to ensure that the equipment will not fall into the audience if the mount fails.

IMPORTANT: Equipment installers are responsible for injury or equipment damage caused by improper mounting.

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Chapter 11
Acoustics

The successful audiovisual (AV) system frequently interacts with, and is dependent, on the acoustics of the space. This chapter provides an overview of the most essential acoustical considerations to be aware of when designing AV systems.

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Overview

This chapter provides an overview of acoustics fundamentals for a professional audiovisual (AV) designer. Although AV technology evolves toward an ever-greater, all-digital, implementation, its final stage of delivery to the audience will remain through the analog world of acoustics. Acoustical concerns that often arise in the construction of an audiovisual enabled space include:

- Mechanical and electrical equipment noise reduction.
- Sound isolation and speech privacy.
- Environmental noise reduction.
- Reverberation and echo control.

This chapter provides a review of acoustic fundamentals that should form a basis of understanding for a design professional. The chapter will then explore how these fundamentals can be applied by an AV designer.

Mechanical and Electrical Equipment Noise

Background Noise and Heating, Ventilating, and Air Conditioning (HVAC) Noise Reduction

Background noise within a room can affect speech intelligibility, which creates additional challenges for AV designers. A common source of background noise are the heating, ventilation, and air conditioning (HVAC) systems within a building. HVAC noise can originate from any of the following:

- Fans
- Ducts
- Diffusers
- Mechanical room equipment (e.g., pumps and chillers)
- Terminal equipment in ceilings (e.g., fan/coil units and other distributed air handling devices)
- Outdoor mechanical equipment (e.g., cooling towers and ventilation fans)

These devices can create noise that is either airborne or structure-borne. Airborne noise is generated by equipment or air movement and may be controlled by a variety of means based on the mechanical system design, architectural means, or both. Structure-borne noise is typically generated by the equipment attached to the structure. It is either radiated as airborne noise from walls and ceilings in the AV space or it can cause AV equipment problems by transmitting vibration to projectors, loudspeakers, or microphones mounted to walls, ceilings, floors, and furniture.

Noise from HVAC equipment should not be overlooked by the AV designer. The AV designer should help to identify the required noise criteria (NC) for each room and work with the architect and mechanical and acoustical engineers to create rooms that meet the criteria.

NOTE: For detailed information about HVAC systems, see Chapter 9: Heating, Ventilating, and Air Conditioning.

Noise Criteria (NC) and Room Criteria (RC)

To specify or quantify the background noise levels from ventilation equipment or other sources in an occupied space, the rating system referred to as NC (or noise reference [NR] in countries other than the United States) is commonly used by the building industry. The criteria are described in Chapter 7: Sound and Vibration of *Handbook—Fundamentals*, published by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE).

A similar metric called room criteria (RC) also has been adopted by ASHRAE. This metric is helpful in quantifying the tonal characteristics of ventilation noise, such as rumble or hiss. Other acoustical metrics, such as the decibel adjusted for frequency (audio, weighting curve A [dBA]) are more often used for environmental sounds, such as a nearby roadway.

Noise Criteria (NC) and Room Criteria (RC), continued

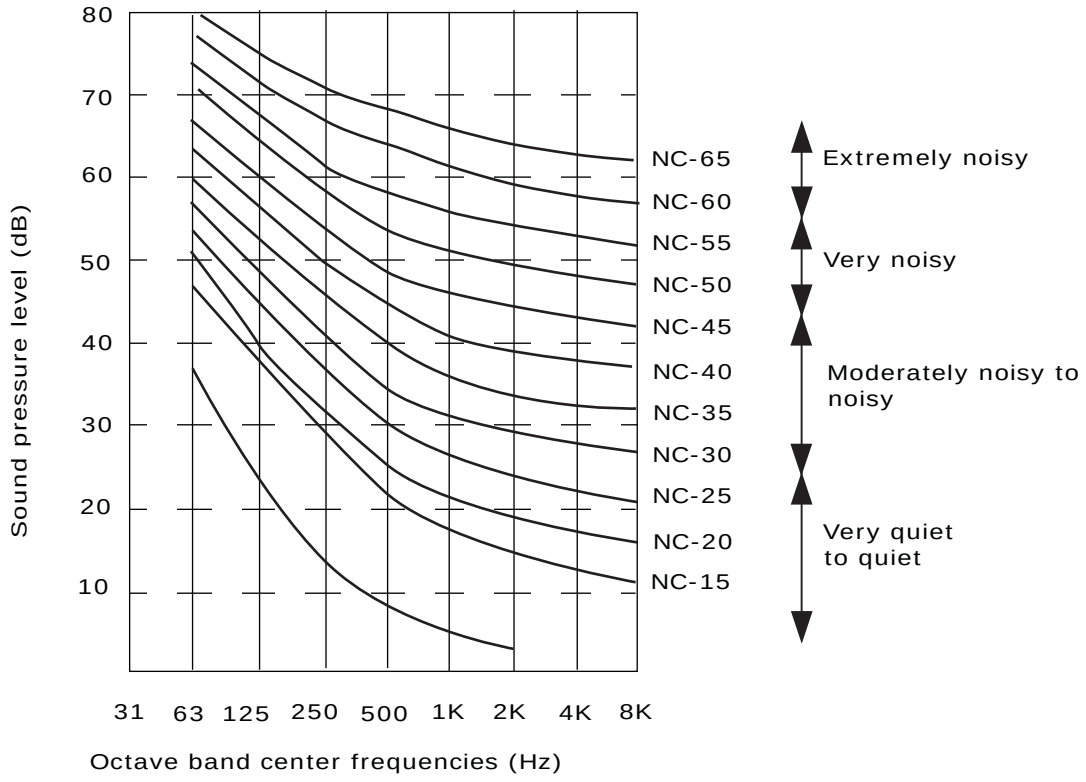
The RC method takes all of the components (i.e., walls, ceilings, diffusers, and others) in a room as a whole to determine the criteria levels for room design. This method is now the preferred method for rating HVAC system noise in a room.

RC curves are similar to NC curves but with lower frequency bands added. The RC method is not used to evaluate individual components like the NC method but to evaluate the overall system and environment. The RC method, therefore, takes background noise into account, noting its effect on speech intelligibility and sound quality.

NC and RC criteria are single-number ratings that represent a complete spectrum of sound pressure levels to meet a particular criterion. For example, to meet NC-35, the sound pressure levels in the room cannot exceed the levels in any octave band on the NC-35 curve. An octave is the interval between two discrete frequencies having a frequency ratio of two. For example, frequencies of 25 hertz (Hz) and 50 Hz are said to be separated by one octave.

The RC curves are more restrictive than the NC curves, particularly in the higher frequencies for the same numerical rating. Figure 11.1 shows the NC curves, while Figure 11.2 illustrates the RC curves. The criteria system currently recommended by ASHRAE is an RC Mark II rating system described in ASHRAE's *Handbook*.

Figure 11.1
Noise criteria

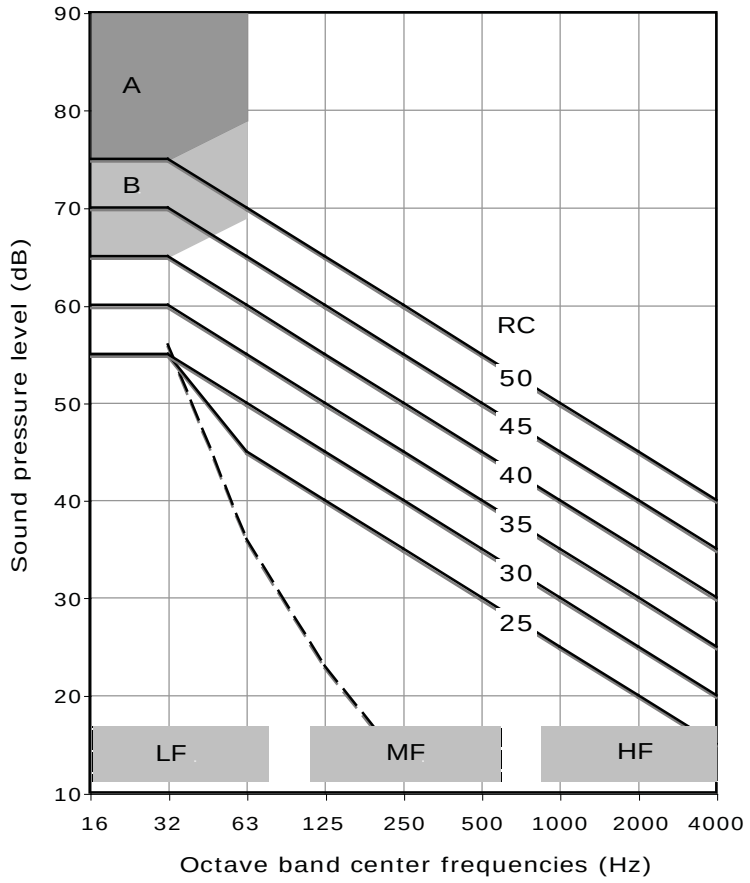


dB = Decibel
Hz = Hertz
NC = Noise criteria

Noise Criteria (NC) and Room Criteria (RC), continued

NOTE: In Figure 11.1, the noise levels are weighted, with the lower frequency sounds reaching NC levels at a higher volume, compared with the higher frequency sounds. For example, at 125 Hz, a 60 decibel (dB) sound will result in a reading of NC-45, while at 4 kilohertz (kHz), a 45 dB sound will result in an NC-45 reading. This is due to the perceived loudness levels of sound at various frequency levels.

Figure 11.2
Room criteria



A = A weighting
B = B weighting
dB = Decibel
HF = High frequency
Hz = Hertz
LF = Low frequency
MF = Medium frequency
RC = Room criteria

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Noise Criteria (NC) and Room Criteria (RC), continued

The primary way that these criteria are used is to establish maximum acceptable room noise levels for a particular space. These levels have implications for both the HVAC system design and the architectural design of the building.

Table 11.1 shows ASHRAE-recommended RC levels for various space types.

Table 11.1
Room criteria

Room Type	RC Level
Hotel meeting/banquet rooms	25–35
Conference rooms	25–35
Teleconference rooms	25 (max)
Open-plan offices	30–40
Drama theaters	25
Concert and recital halls (retaining an acoustician recommended)	< 30
Music teaching studios	25
Music practice rooms	30–35
General assembly religious facilities with critical music programs	25–35
Classrooms	25–30
Large lecture rooms	25–30
Libraries	30–40
Courtrooms with unamplified speech	25–35
Courtrooms with amplified speech	30–40
Large seating-capacity spaces with speech amplification	45–55

RC = Room criteria

These RC should be provided to the architect and mechanical engineers early in the design process as a basis for the design of acoustically sensitive spaces.

Reducing Heating, Ventilating, and Air Conditioning (HVAC) Noise

Although larger central building systems should be studied by an acoustics/vibration specialist, the AV designer should review the HVAC design for the following design issues that can affect the acoustical performance of the HVAC system:

- Air velocities in the ductwork serving AV spaces should be lower than in the typical duct runs. They should be limited to a velocity range from 91 meters per second (m/s [300 feet per second (ft/s)]) to 152 m/s (500 ft/s).
- Supply-air diffusers and return-air grilles should have manufacturer NC ratings below the room's NC rating.
- Dampers in ducts should be located well upstream of diffusers and grilles.
- Acoustically lined ductwork should be used to reduce the fan noise that can propagate inside ducts.
- Supply- and return-air ducts and outlets can reduce sound isolation between rooms if not properly configured to provide sufficient duct lengths between rooms.
- Variable air volume (VAV) boxes and fan/coil units should be located away from the AV-enabled rooms.
- AV-enabled rooms should be located away from mechanical equipment rooms
- In some cases (e.g., rooms adjacent to a busy street or next to a mechanical systems room), a move to another (quieter) location in the building may be appropriate to meet the desired RC.

Many other issues should be reviewed and analyzed. A qualified acoustical consultant is often required to properly evaluate HVAC systems and provide noise reducing recommendations.

Sound Isolation

Sound Isolation

Sound isolation is defined as the capacity of a structure to prevent an unwanted sound from transmitting from one space to another. AV systems, which can produce high sound pressure levels, often demand higher levels of sound isolation. Acoustically sensitive spaces with live microphones (e.g., videoconferencing rooms, theaters, and media production spaces located near sound-generating mechanical equipment) also require sound isolating constructions.

Sound Transmission Class (STC) and Noise Isolation Class (NIC)

Sound isolation is quantified by two numerical ratings, noise isolation class (NIC) and sound transmission class (STC). NIC is the field-measured noise reduction provided by a construction assembly, while STC is the sound isolation performance rating measured in a controlled laboratory.

STC is a numerical rating often provided in the product manufacturer's literature. This rating can help the AV designer to evaluate a product's suitability for the intended application.

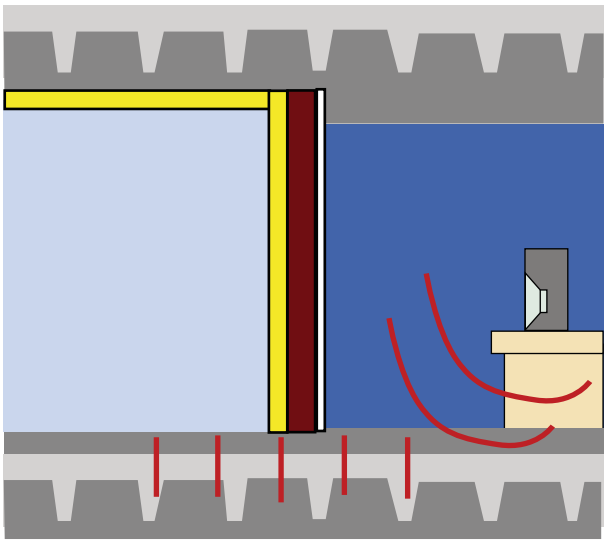
Sound Isolating Construction Assemblies

The most effective method of decreasing sound transmission from one space to another is with partitions and doors having high STC ratings. Acoustically sealed partitions with greater mass or larger insulated airspaces perform better than single-element lightweight constructions with high air infiltrations.

Sound Isolation, continued

Sound-isolation performance is compromised by the presence of flanking paths (e.g., above-ceiling ducts or mullions) at partition/window intersections. Flanking paths are additional paths of sound transmission around the construction being considered (see Figure 11.3).

Figure 11.3
Flanking paths



Common sources of noise leaks between, otherwise well-isolated, spaces are doors. Various door assemblies help to maintain a required level of sound isolation. Expensive laboratory-tested doors with STC ratings are available for applications where sound isolation is critical. Door requirements for recording rooms and other critical applications generally require a laboratory-certified STC 43 or greater.

A good performance also is achievable at a lower cost from nonrated solid-core wood doors that are acoustically gasketed. These are well suited for boardrooms or private offices and other spaces requiring a specific degree of sound isolation. Avoiding door constructions altogether between extremely sound-sensitive spaces (e.g., between a courtroom and a jury deliberation room) is often necessary. Sound lock vestibules are often recommended in such situations.

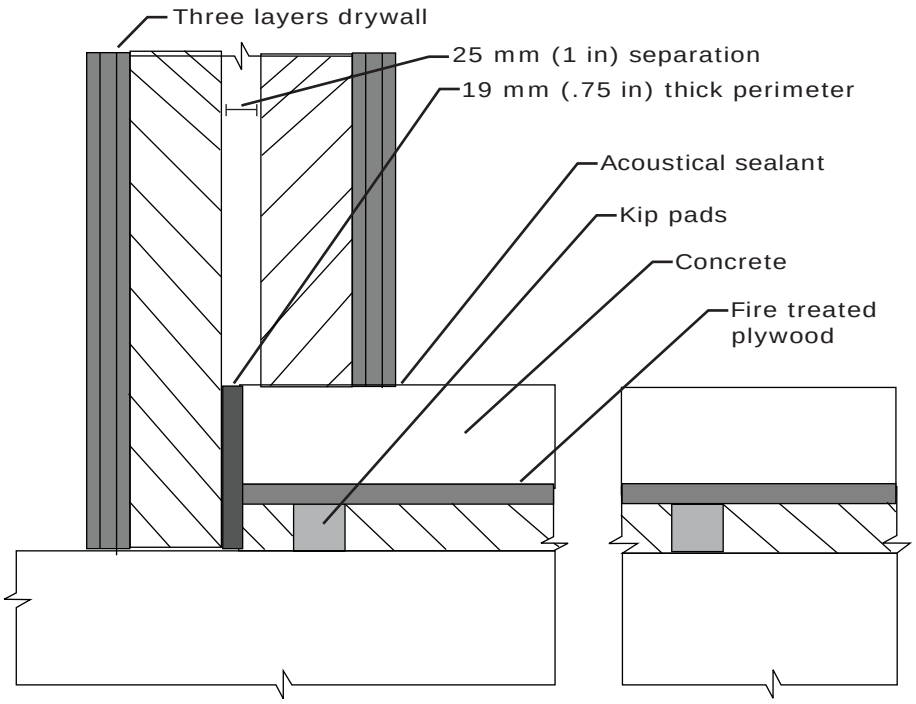
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Sound Isolation, continued

For spaces requiring high levels of sound isolation performance (e.g., recording studios), double-stud walls, floating floors, and resiliently hung ceilings may be required. This sound isolation method is often collectively referred to as a room-within-a-room.

The floating floors (see Figure 11.4) and resiliently hung ceilings not only prevent sound from transferring from space above and below, but also minimize the flanking of sound through the structural floor from the adjacent rooms.

Figure 11.4
Floating floor



in = Inch
mm = Millimeter

Environmental Noise Reduction

Before a project is constructed at a given site, it is advisable to determine environmental noise levels that may affect interior noise levels and isolation requirements for audiovisual usage. A long-term environmental noise study can test for average and single-event noise levels. The potential impact of roadways, highways, trains, busy urban areas and helicopter and airplane flight paths can be evaluated based upon the environmental noise study. Often these are required as a part of an environmental impact report.

Speech Privacy

The sound isolation performance of construction assemblies (e.g., partitions and doors) is only one of the several factors that determine the degree of speech privacy afforded between two spaces. The background noise level in the receiving space can play an equal or greater role in the resulting speech privacy.

Confidential speech privacy is achieved when speech, while detectible in an adjoining space, cannot be understood as distinguishable words or phrases. Confidential speech privacy occurs when the STC rating of a construction and the noise criteria of an adjoining space added together is greater than 80. For example, if the space adjoining the noise source has a background noise level of NC 30, the intervening partition should have an STC rating of 50.

Normal speech privacy levels are typically achieved when the sum of the two ratings is equal to 70 or more.

Masking Systems

The purpose of masking systems is to provide a constant and predictable level of background noise that will make nearby conversations less intelligible and unwanted intermittent noise less noticeable. In open plan offices with low background noise levels, speech privacy can be unsatisfactory. To remedy this situation, a masking system can be employed, using evenly spaced loudspeakers located above a suspended lay-in tile ceiling. A spectrally tuned amplified pink noise source fed to the loudspeakers can be programmed to raise and lower to match the activity level within the office over the course of the work week.

A sound masking system should provide a diffuse sound field that is spatially uniform and blends with the ventilation noise within the open office area. Loudspeakers are often aimed up towards the structural slab or horizontally to scatter and diffuse sound off the building structure.

Room Acoustics

Room acoustics is a study of sound reflections in a confined space and its effects on human perception. Various sound frequencies can be reinforced or attenuated based on the shape of a room and the types of surfaces in a room.

All surfaces reflect, absorb, or diffuse sound. These properties are frequency and surface material dependent and determine whether clear and intelligible sound would reach the listener. Room acoustics relates to the following phenomena:

- Direct or near-field sound
- Early reflections
- Echoes (late arriving reflections)
- Reverberation

Direct or Near-Field Sound

Sound that has not been colored by room reflections is referred to as being near-field or direct sound. Direct sound travels from the source to the listener in a straight-line path without interference from room reflections. The more direct the sound reaching the listener, the clearer it typically is.

Early Reflections

Early reflected sound is created by sound waves, which are reflected (bounced) off one or more surfaces between the source and the listener. These sound waves arrive at the listener's ears soon after the direct sound. Early reflections are similar to echoes but are not heard as distinct from the original source. Thus, they can actually be beneficial, providing a natural reinforcement of the sound. The wall behind or the ceiling above the performer or presenter may be made of acoustically reflective materials so that the generated sound is reflected to the audience. An orchestra shell is an application of this concept.

Echoes

Echoes are distinct, late arriving reflections from a single wall surface. Echoes should be avoided in an acoustical design. A common echo source in a performance space is the sound from the stage that reflects off the back opposite wall. This type of echo is often referred to as slap echo. Because of the long delay, it is heard as an entity distinct from the original sound. To avoid such echoes, the back wall should be treated with acoustically absorptive or sound diffusing materials.

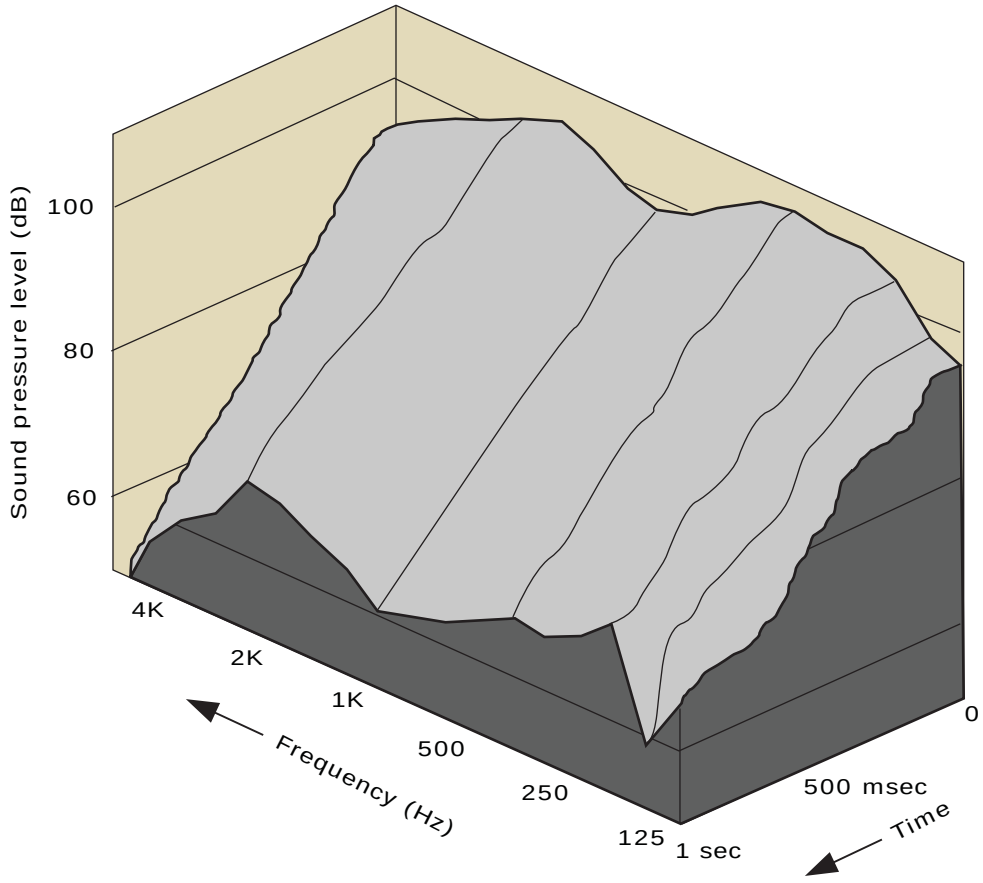
Reverberation

Reverberation is defined as the effect of sound scattering and steadily decaying in a room (see Figure 11.5). Reverberant sound bounces off multiple surfaces before reaching the listener, arriving at the listener's ears after the early-reflected sound.

Reverberant sound, or reverberation, is one factor that creates a room's sense of size and space. The amount of reverberant sound in a room determines how far the listener can be away from the sound source and still discern the sound.

Room size and surface treatments determine the amount of reverberation in a space. Hard surfaces such as untreated gypsum board and wood paneling contribute to sound reverberation. Conversely, soft surfaces, such as acoustical tile and fabric wrapped fiberglass panels, decrease sound reverberation.

Figure 11.5
Reverberation



dB = Decibel
Hz = Hertz
ms = Millisecond
s = Second

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Reverberation, continued

While reverberation and echoes can adversely affect speech intelligibility, a room with too much sound absorption can be perceived as acoustically unproductive. Therefore, an appropriate balance of sound absorption and managed sound reflection is necessary to achieve an acceptable acoustic environment.

Reverberation Time (RT60)

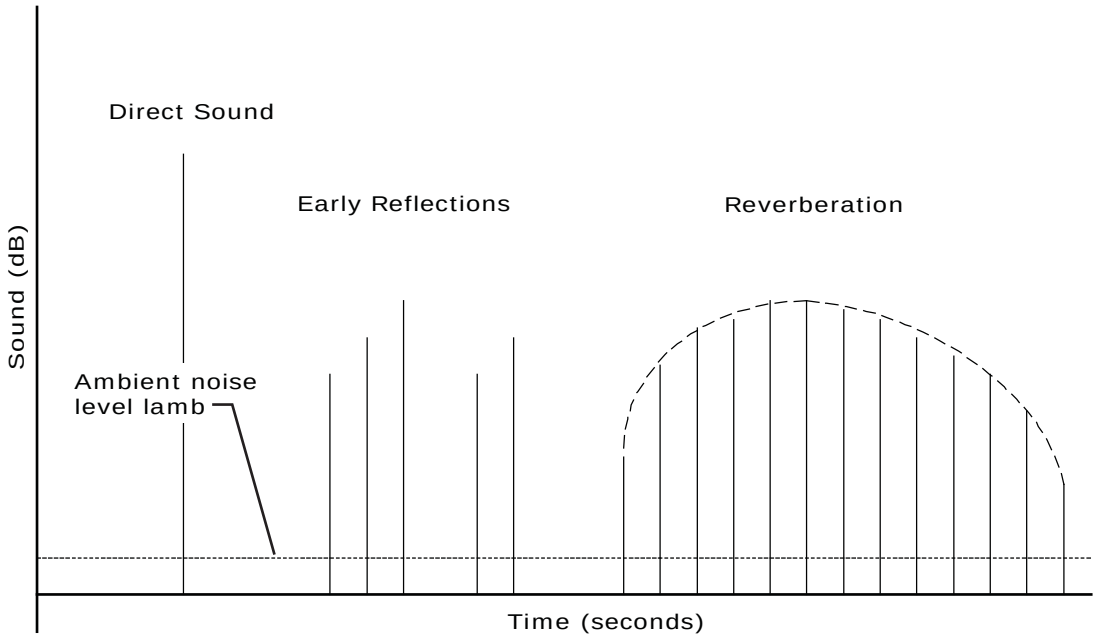
Reverberation time (RT60) is a metric that quantifies reverberation. Technically, RT60 is the time in seconds required for the sound within a room to attenuate 60 dB after its source is abruptly halted. The reverberation times of over two seconds are beneficial in concert halls because they help the blending of music. The reverberation times of less than one second should be considered in speech-oriented venues (e.g., lecture halls) because a reverberant sound field will mask the subtle details of speech. See Figure 11.6 for a comparison of sound levels against time.

Examples of typical RT60 values for various venues include the following ranges:

- 0.3–0.8 seconds for television (TV) studio
- 0.7–0.9 seconds auditorium for speech
- 0.5–1.0 seconds for recording studio
- 1.0–3.0 seconds for house of worship
- 0.5 seconds for average living room

The required reverberation time is dependant on the room volume. It would be acceptable, and possibly even required, for a room of greater volume to have a longer reverberation time.

Figure 11.6
Sound levels versus time



Absorption, Reflection, and Diffusion

To optimize room acoustics for the best performance of an AV system, AV designers must understand the acoustical effects of room surface materials.

When the sound from a source strikes a room surface such as a wall, ceiling, or floor, the following three phenomena occur in varying degrees, depending on the shape and type of the material:

- Absorption
- Reflection
- Diffusion

Absorption

Absorption is the ability of a material to soak up the sound energy and not reflect it back into a room. The metric unit for absorption is known as a sabin. One sabin is equal to 1 square foot (ft^2) of a perfect absorber (no sound reflected).

A room designer can calculate the reverberation time of a room by knowing the number of sabins provided by the room finish materials. Softer room finish materials (e.g., fabric wrapped fiberglass panels) have greater absorption capabilities than hard-surfaced material (e.g., wood paneling). A 50 millimeter (mm [2 inch (in)]) thick fabric-wrapped fiberglass panel has a greater sound absorption in the lower frequency ranges than a 25 mm (1 in) thick panel of the same type.

Reflection

Reflection is the phenomenon by which a sound wave is re-radiated or bounced off a surface. Hard surface materials (e.g., glass, wood, marble, or gypsum board) tend to reflect most of the sound energy that would strike it. If these surfaces are flat, the angle of incident is equal to the angle reflection.

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Absorption, Reflection, and Diffusion, continued

Diffusion

Diffusion differs from reflection. Diffusion is a phenomenon whereby sound strikes a surface and scatters in all directions. The ideal diffusing surface sends sound energy of all frequencies equally in all directions. Irregularly shaped and convex surfaces, commonly found in classic architecture, will increase a room's diffusion, in contrast to flat hard surfaces often seen in modern architecture.

Diffusing surfaces are generally preferred over flat reflecting surfaces, because diffusion tends to have less detrimental effects on the sound source, while still offering a sense of space and beneficial acoustic gain.

Diffusing materials are often more suitable for a room than sound absorption. Like absorption, diffusion can reduce echoes in a room but without the effect of losing valuable acoustic energy. In critical spaces such as recording studios and theaters, applying specially manufactured diffusers on wall and ceiling surfaces can achieve diffusion.

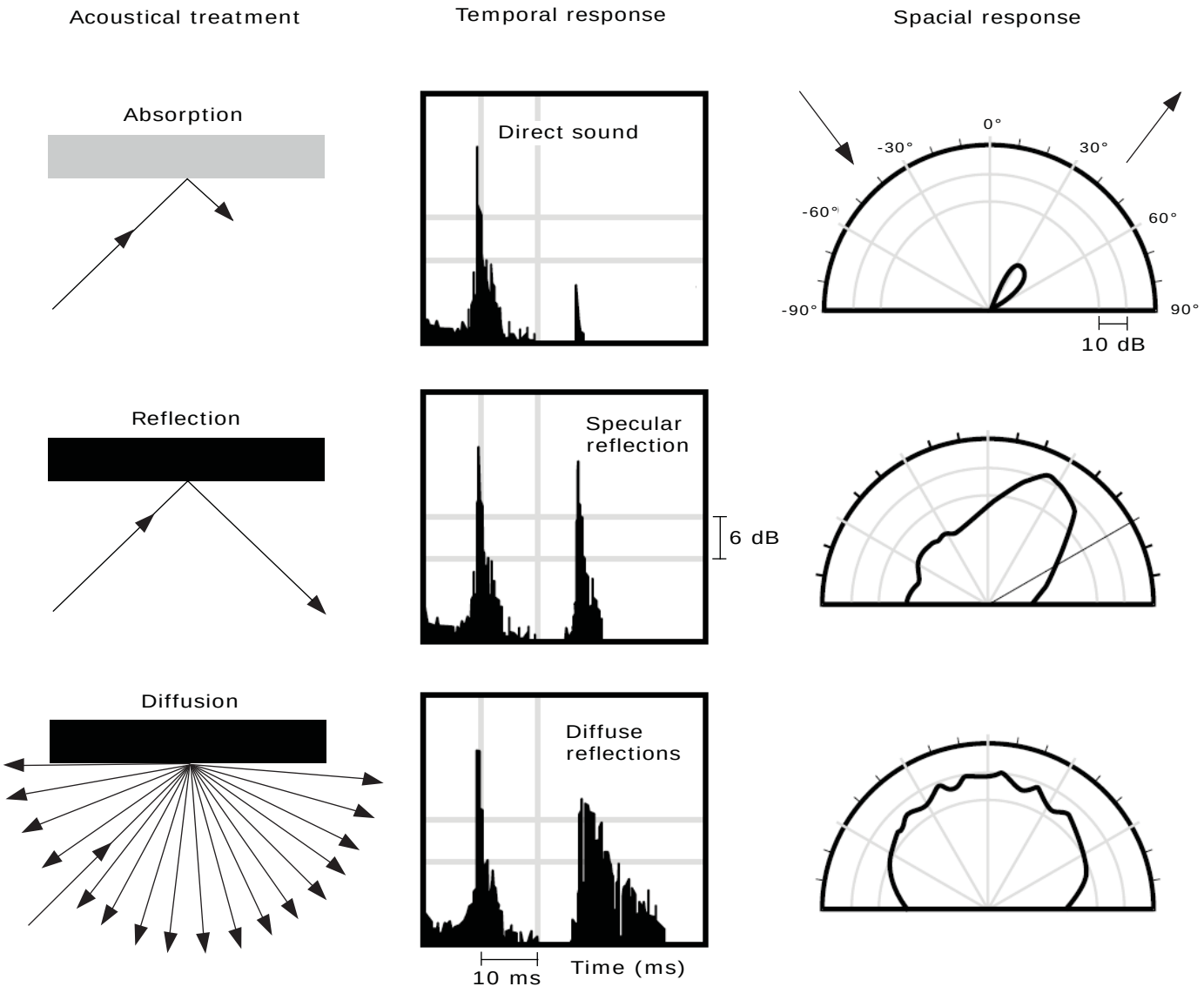
Diffusion reduces the sound energy (amplitude) by:

- Increasing the distribution of the direction of the sound—Instead of focusing in one direction, sending the sound off in many directions reduces the overall amplitude by distributing the amount of energy over a larger area.
- Distributing the sound energy in time—The sound waves from a specific source arrive at the listener at different times, resulting in a reduction of the sound amplitude.

Absorption, Reflection, and Diffusion, continued

For a comparison of all of the three phenomena, see Figure 11.7.

Figure 11.7
Absorption, reflection, and diffusion



db = Decibel
ms = Millisecond

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Noise Reduction Coefficient (NRC)

Reverberation and echoes can be minimized with a sound absorbing room finish material. A single-number rating used by the building industry to quantify the sound absorption of a material in the speech frequency range is the noise reduction coefficient (NRC).

The NRC of a material is the arithmetic mean of the sound absorption coefficients in the 250, 500, 1000, and 2000 Hz octave bands. A room surface material having an NRC rating of 1.0 is a virtually perfect absorber. Conversely, a finish material with an NRC rating of 0.1 would reflect back into the room nearly all of the sound.

Using room finish materials with high NRCs helps to absorb the sound waves that otherwise would be reflected and cause excessive reverberation. For example, a designer may specify a specific type of wall covering at the rear of a rectangular room to reduce the overall amount of reverberation.

The choice of building materials and their NRC ratings affect the amount of reverberation within a room. For example, specifying parallel walls composed of hard wood (low NRC rating) will result in long reverberation times, while specifying walls of softer materials placed at angles will reduce the sound reflections that result in reverberation.

Designers can control reverberation by managing how and where materials are mounted within a room. For example, mounting sound absorbing materials in specific locations can be an effective method of reducing reverberation.

The location of sound sources and sound-absorbing materials affects the amount of reverberation within a room. The designer must analyze the room configuration and determine the appropriate locations to install NRC materials.

The NRC of a material can be affected by how it is mounted within the room. For example, if the designer includes an air space between the acoustic treatment material and the wall, the effectiveness of the acoustic treatment will be increased.

Understanding the effect of acoustic treatments within a room is an important aspect of the room design. Controlling the amount of reverberation is important, since the sound reflections can reduce intelligibility of speech and other audio programs.

Speech Intelligibility

Speech intelligibility refers to the ability to hear and understand the spoken word clearly. The speech intelligibility within a room is a function of its background noise level, its reverberation, the strategic use of early reflections, and the sound level of the speaker's voice.

AV designers are often asked to design a speech reinforcement system if the room has a high ventilation background noise, is overly reverberant, or does not have sound reflectors placed to provide useful early reflections. The AV designer must understand the acoustic principles to design a sound system that will improve speech intelligibility.

To make speech intelligible, it is commonly amplified at least 15 dB above the background noise level. This relates to a signal-to-noise ratio (SNR) of 15 dB. Reverberation time of the room should be maintained below 1 second (s). For greater reverberation times, loudspeakers often need to be strategically placed in relation to the listener to improve intelligibility.

Several metrics quantify the level of speech intelligibility, including:

- Speech transmission index (STI).
- Percentage articulation loss of consonants (%ALcons).

STI is based on the premise that speech is an amplitude-modulated (AM) signal. Using a test system that can accurately measure the reduced amplitude modulation of the received signal compared to the source, the expected speech intelligibility of a space can be quantified. STI intelligibility values range from 0 (completely unintelligible) to 1 (perfect intelligibility). Local authorities may require a particular STI value in the design of fire and life safety systems.

%ALcons is defined as the percentage of articulation loss of consonants in speech. This number gives an estimated percent of loss in intelligibility. In most cases, 10 to 15 %ALcons is considered acceptable.

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Chapter 12
Lighting

Proper architectural lighting has a significant impact on audiovisual (AV) systems. While typically not tasked with the lighting design, the AV designer should have a good understanding of these fundamentals and how they impact designs. This chapter addresses the most common lighting fundamentals helpful to the AV designer.

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Overview

Lighting is essential to the success of modern visual presentation and conference facilities. Lighting quality is a primary consideration. It needs to be sufficient and suitable for the assortment of visual tasks performed in these spaces. Therefore, the audiovisual (AV) professional must have the basic knowledge about lighting.

This chapter covers the lighting terminology and technology and reviews lamps, ballasts, controls, and AV integration techniques. Common and specialized types of luminaires that provide successful lighting in presentation spaces are detailed.

Further, this chapter describes the parameters of basic design criteria. These criteria can assist in creating suitable lighting for the common AV and videoconference applications. The concept of layers of light and its use in the lighting design process are also presented.

Effective lighting is achieved only when the related controls are efficiently applied. Lighting controls provide the flexibility required by the changing variety of tasks. Presentation spaces with exterior or interior windows or skylights require the addition of shading devices and controls.

Daylight can provide a valuable and pleasant contribution of light to the space. High levels of daylight or direct sunlight, however, can create reflections and glare on visual displays as well as harsh shadows and hotspots seen by room occupants and videoconference or broadcast cameras. Using shading devices, which include window tinting, shades, blinds, curtains, louvers, and light baffles, solves this problem. This chapter explains the fundamentals of window treatment systems and controls.

Lighting Theory

Introduction

The fundamental goal of lighting is to facilitate clear verbal and nonverbal communication. Whether the lighting objective is to explain a marketing concept in a boardroom or convey a message to several thousand attendees, suitable lighting is necessary for enabling the viewer to see the presenter and any accompanying visual material clearly.

When video cameras are used, lighting must be selected, positioned and managed to ensure the highest quality recording achievable. A successful presentation space balances the needs of the participants with those of the camera. Effective architectural lighting design can simultaneously deliver visual comfort, facilitate group interaction, and produce high quality video images.

Principles of Illumination

Human and Camera Visual Requirements

The human visual system and video cameras both require light to operate. That is where the similarities end.

The human visual system is an image interpreter. The camera is merely an image detector. Video cameras have little tolerance for brightness variation across a single scene. While the human visual system can handle a brightness range of 1000:1, the camera can only simulate it over a range of 30:1.

On an elemental level, the human visual system consists of the eye and the brain. Together, they provide the following abilities that cameras cannot reproduce:

- Accommodation (the eye's ability to change the focus from one distance to another).
- Adaptation (the increase in the visual system's sensitivity as the light levels fall).
- Constancy (the visual system's ability to interpret the brightness, color, size, and shape of objects regardless of their lighting, distance, or orientation).
- Contrast sensitivity (the object's visibility depends on the combination of size and contrast).

Cameras are highly susceptible to high and low brightness extremes, quick movements, and other irregularities normally absorbed by the eye.

Lighting Distractions

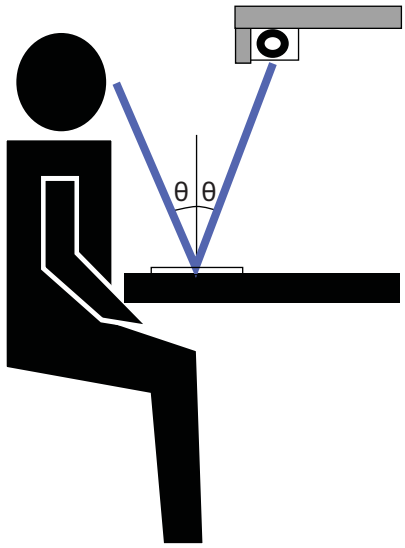
An important aspect of lighting in presentation spaces is the comfort of the participants. Lighting elements that should be avoided are the direct-source glare from high-angle fixtures and the light reflected off displays and computer screens (i.e., veiling reflections).

Principles of Illumination, continued

Glare and Veiling Reflections

Glare results when a bright luminous source in the visual field scatters unwanted light across the retina. Veiling reflections (see Figure 12.1) result when the light incident upon a gloss surface reflects directly into the eye of the observer, making the visualization of detail (e.g., written text) difficult or impossible.

Figure 12.1
Veiling reflection



NOTE: Figure 12.1 has been reproduced with the permission of the National Lighting Product Information Program, Lighting Research Center.

The human visual system is designed to cope with these distractions but they can be significantly reduced by properly positioning subjects and luminaires. See the References section for documents that can provide more information about the luminous environment.

Principles of Illumination, continued

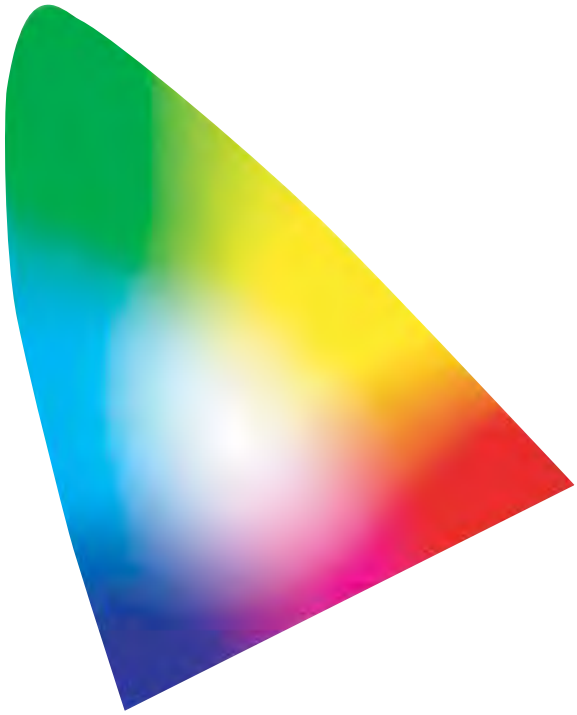
Light and Color

Mixing paint and ink colors reveals that yellow and blue make green, and mixing all paint colors usually creates black. Light works differently. Black is defined as the absence of light. When primary colors of light, red, blue, and green, are mixed and are present in equal proportions, white is the perceived color.

A chromaticity diagram, created by Commission Internationale d'Eclairage (CIE [International Commission on Illumination]) demonstrates how a colored light can be mixed together (see Figure 12.2).

NOTE: Black is not represented in the diagram.

Figure 12.2
Chromaticity diagram



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Principles of Illumination, continued

At the center of the human retina is a dense cluster of photo receptors called cones. Unlike rods, which can only perceive in grayscale, the mosaic of cones is divided into three separate types, each of which is sensitive to a different, but overlapping, range of colors. The primary colors in each range are red, green, and blue.

When the eye sees a field of green grass, the brain deciphers the grass as green because the grass absorbs the blue and red parts of the sunlight illuminating it. Only the correct green wavelength is reflected back for interpretation by the eye and the brain. If none of the light were absorbed, the grass would appear white. If all of the light were absorbed, it would appear black.

At very low light levels, the eye cannot perceive color, only the levels of gray. Therefore, seeing the field at night, with only starlight or dim moonlight, it appears gray because the human night vision is sensitive to grayscale more than to saturation or hue.

Daylight versus Electrically Produced (Fabricated) Light

Daylight is distinguished as a light source by its unique, changing spectra and distributions. It can increase occupant satisfaction and conserve energy if considerations such as view design, glare control, human factors, and integration of building systems are properly addressed. To avoid problems with glare and damage to materials, daylight effects should be considered in any space where daylight is admitted, even if it is not exploited as a light source.

To use daylight effectively, the following factors should be taken into account:

- Human factors, including physiology, perception, preferences, and behavior
- Effects of daylight on all materials, including furniture, artwork, and plants
- Controlled admission of direct sunlight
- Controlled admission of diffuse daylight
- Effects of local terrain, landscaping, and nearby buildings on the available light
- Integration of building systems, including the electric lighting, fenestration, interior geometry and finishes, manual and automatic control systems, and active climate control systems

Daylight sources include direct sunlight and skylight.

Principles of Illumination, continued

Direct Sunlight

Direct sunlight is based on the daily and seasonal movements of the sun with respect to a particular geographic location on the earth. These movements produce a predictable pattern of amount and direction of the available sunlight. Superimposed on this predictable pattern is a variation caused by the changes in weather, temperature, and air pollution.

Sunlight energy has a color temperature of approximately 6 500 degrees kelvin (K). On a clear day, the illuminance on the earth's surface by the sun may exceed 100 kilolux (klx [9 290 footcandles (fc)]). On cloudy days, the illuminance drops to less than 10 klx (929 fc). (For more information about these and other measurement units, please see the section Terms and Units of Measurement further in this chapter.)

Skylight

Skylight is the diffuse daylight created by the considerable amount of sunlight scattered by the earth's atmosphere. As sunlight passes through the atmosphere, a portion is scattered by dust, water vapor, and other suspended particles. The blue color of a clear sky and the reddish appearance of the rising or setting sun are common examples of this scattering effect. This scattering, acting in concert with clouds, produces sky luminance. The color temperature of this sky illuminance changes throughout the day.

Electrically generated (fabricated) light sources have been divided into two types, incandescent and luminescent. Fundamentally, the cause of light emission is the same—electronic transitions from higher to lower energy states. The mode of electron excitation and the resultant spectral distribution of the radiation are different, however. Incandescent solid substances emit a continuous spectrum, while gaseous discharges radiate mainly in discrete spectral lines.

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Energy Management and Sustainability

Today, lighting systems are designed for energy efficiency and sustainability. The importance of energy management has been increasing since the early 1970s, stimulated by the escalation of energy costs, the depletion of certain energy sources, and the concern for the protection of the environment.

The responsible use of energy has become a general public concern and, consequently, has motivated the development of new legislation, codes, and standards designed to establish minimum levels of energy efficiency. As a result, the way buildings are constructed, lighted, heated, and cooled is closely examined.

Criteria for new building design and existing building modifications have been developed to ensure that energy resources are efficiently used. Over the last decade, energy management has become a fundamental element of mainstream lighting design. The key elements of lighting design for energy efficiency are that the:

- Lighting needs of a space must be defined including adequate illuminance on the task surface, a proper balance of luminance between the task surface and surrounding surfaces, control of direct and reflected glare, and acceptable color rendering of task elements and surroundings.
- Compliance with energy codes and standards for lighting must be ensured.

The concept of sustainable (green) design has come to the forefront in the last 20 years. It is a concept that recognizes the human civilization is an integral part of the natural world and that nature must be preserved to ensure the survival of the human species. Sustainable design articulates this idea through developments that exemplify the principles of conservation.

Energy efficiency gained importance during the 1970s oil crisis. Recycling efforts in the United States from the 1970s onward became commonplace and captured the attention of the building industry.

The goal of sustainable design is to create high-performance buildings. In the 1980s, the sick building syndrome concept emerged and the concern for workers' health and productivity became an issue. The concern for toxic material emissions also became an issue. Early green designs usually focused on one issue at a time, mainly the energy efficiency or the use of recycled materials.

Green building architects in the 1980s and 1990s began to realize that the integration of all of the valuable factors would produce the best results and, in essence, high performance buildings.

Lighting Systems

Introduction

A lighting system is not unlike an AV system in that it is an integrated set of components that work together to meet the users' needs. The components of an AV system are the audio, video and control devices, the wiring between the devices, and the programming of the devices. The components of a lighting system are the lighting fixtures and control devices, the wiring between them, and the system programming.

Like AV systems, the lighting design and performance depend on the room characteristics, including the room shape, seating layout, and room finish type, color, and pattern.

Lighting systems fall into several categories related to the general or specific type of functions required for a space, as follows:

- Architectural lighting
- Videoconferencing lighting
- Theatrical lighting
- Broadcast lighting
- Entertainment lighting
- Other specialty lighting systems

Architectural lighting is a general term applicable to general commercial and institutional facilities and space types. In general, the lighting systems for corridors, offices, conference rooms and most public spaces are considered architectural lighting. Such lighting is usually integrated into the architecture and is intended to support both human tasks and act as an enhancement to the interior or exterior design of a space or a building.

Videoconferencing lighting systems are specialized lighting systems that are specific to a videoconferencing environment. These lighting systems are most commonly integrated into an architectural environment but also may be implemented in a broadcast type environment.

Theatrical lighting systems are specialized systems found in the spaces that have a stage area with live stage functions. This may be a performing arts theater, a hotel ballroom, house of worship, or other type of assembly area.

Broadcast lighting systems are found in broadcast studio environments where television (TV) programming is originated and recorded. These systems are generally considered under a discipline somewhat specialized and separate from architectural lighting.

Entertainment lighting systems are typically associated with entertainment facilities such as theme restaurants, theme parks, and amusement venues. The lighting and control systems are generally a mix of both theatrical and architectural lighting.

Other specialty lighting systems that may be associated with AV systems are medical and healthcare facilities and other special areas where both lighting for a particular task as well as an AV function may be required.

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Architectural Lighting

Most building lighting is referred to as architectural lighting. This is the lighting required for the performance of human visual tasks. Some lighting may be purely decorative or aesthetic in nature. In general, this term refers to the use of lighting fixtures intended for aesthetic integration into an interior design (e.g., where the lighting fixture's appearance is important or the resulting lighting is mostly for aesthetic purposes).

The relationship of AV and architectural lighting is commonly found in typical commercial and institutional buildings. Human tasks (e.g., reading, taking notes, or viewing objects) place specific demands on the lighting design. Meeting this demand, while respecting the space interior design, is an integral part of the design process.

Some rooms, including conference rooms, board rooms, training rooms, lecture halls, and auditoria, have AV requirements that place additional demands on the lighting design. These demands create issues beyond the basic human task needs in terms of the lighting system configuration.

The AV requirements generally revolve around display systems, projector and screen locations, the ability to view an image while maintaining an adequate contrast ratio in the image, and cameras that may be used for videoconferencing, overflow audiences, or video recording.

Layered Approach to Architectural Lighting Design

Contemplating an architectural lighting design requires the understanding of several basic lighting design concepts. Lighting systems are handled through a layered approach. Each layer of light is a unique lighting system addressing a specific need.

The common layers are:

- Ambient or general lighting layer.
- Task layer.
- Focal and accent layer.
- Decorative or traditional layer.

The typical layers that are used for AV spaces include the:

- Ambient layer.
- Note taking (task) layer.
- Focal layers:
  - Lighting for a presenter.
  - Lighting of participants for videoconference cameras.
  - Wash light for walls.
  - Accent lighting on marker boards and displays.
- Decorative layer.

Architectural Lighting, continued

Ambient or General Lighting

Ambient or general lighting is the primary lighting source in a space. It provides a relatively uniform lighting and the necessary illumination for the general uses of the space.

If it provides all of the lighting for the tasks in the space, this type of lighting is called general lighting. If additional layers are used for specific tasks and accent, it is referred to as ambient lighting.

Ambient lighting is commonly provided by recessed fluorescent fixtures, pendant-mounted indirect fixtures, or fluorescent cove lighting. Decorative chandeliers also can contribute to the ambient lighting.

Task Lighting

Task lighting is generally intended for lighting the horizontal work surfaces at task locations (e.g., desks, tables, and counter tops). It also provides nonuniform room lighting that can be used to create a dramatic effect.

In common usage, the term task applies to small areas of lighting for a particular person or use. For example, a lamp on a library table is referred to as task light for reading.

In the AV industry, task lighting is important for both the end users and the AV operators in a space. Students in a training facility may need task lighting at their desks for reading or performing some detailed manual task. The instructor may require task lighting on a lectern to read the notes while lecturing. Likewise, an AV operator may need task lighting to see the audio console or other system controls.

The task lighting design requires determining the amount of light required for a specific task. Additionally, the impact of this lighting on AV functions must be considered (e.g., avoiding excessive light on a projection screen or glare from task lighting in a camera's field of view).

Focal Lighting and Accent Lighting

Focal lighting in an AV space includes the lighting for camera use. Primarily, it is the vertical illumination of a presenter in a distance learning situation or participants in a videoconference application. This lighting is provided by the fixtures designed specifically for creating sufficient vertical illumination on the people and room surfaces in a camera's field of view.

Generally, accent lighting provides specific lighting of marker boards and wall surfaces used for displaying the presentation material. Accent lighting also provides specific lighting for display areas where items will be viewed either as part of a local presentation or on camera. It also is used to accentuate artwork or other decorative architectural elements. Accent lighting is primarily provided by wall wash lighting and other nonhorizontal surface illumination (adjustable spotlights).

Accent lighting can be used to create a dramatic effect. Such effects are achieved by adjusting the contrast between the brightness created by focal lighting and ambient lighting.

The control of individual focal and accent lighting elements is critical. Separate zones should be provided for each element to achieve appropriate adjustment to room contrasts.

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Architectural Lighting, continued

Decorative Lighting

In general, decorative lighting consists of luminaires required by a specific architectural or interior design style, period, and motif.

Decorative lighting normally exists to aesthetically enhance an object or an area in a room. It also could simply consist of luminaires installed purely as aesthetic objects. The AV designer should be aware of these types of fixtures and evaluate their impact on the AV functions required in a space.

Decorative lighting can contribute to ambient illumination. In some designs, decorative lighting is used as ambient lighting.

Decorative lighting should be zoned and controlled independently so it can be dimmed or turned off separately from the room lighting elements. As with general lighting, avoiding problems with degradation of projected images or of images viewed by a video camera is important.

The design and location of decorative fixtures requires coordination with the design team including the lighting designer, interior designer, and the architect.

Videoconference Lighting

The lighting for a videoconference room must fulfill a few contrary conditions.

To achieve the maximum contrast on the video screens, direct light falling on the screens must be minimized. Cameras, however, require a high level of illumination. A uniform wash of vertical light on the participants is needed. Additionally, lighting a white board or live board should be such to keep glare off the display screens or monitors.

Lighting affects the display screen contrast. Lighting requirements vary depending on the use of front projection, rear projection, or a standard monitor.

The light within a camera's field of view should be uniform so that the camera auto-iris does not make constant adjustments.

The lighting in a conference room should be supplied by fluorescent fixtures. An appropriate design consists of the layers of light using different fixture types.

The basic lighting criteria include placing the fixtures to illuminate the participants' faces for the cameras, which is typically referred to as key light. This lighting also contributes to the general room lighting.

The lighting should strike participants' faces from the angle of 45 degrees or more to avoid harsh facial shadowing. To soften the shadows on the participants, fill light is required and provided usually by the ambient lighting. Fill light also is provided by the light reflected off the room surfaces or furnishings. A table is often the largest element near the participants that provides an opportunity for reflected light.

Videoconference Lighting, continued

The surfaces behind and to the sides of the participants should be lighted. Background light falls on the vertical surfaces. It separates the foreground (the participants' faces) from the background, adding depth to the scene as it is transmitted to the remote site. The foreground and background luminance should be balanced and kept relatively uniform to achieve a minimal contrast. The contrast should range from 3:1 to 1:1. The optimum final balance between foreground and background luminance is set using a dimming system to program the contrast.

The design should limit the amount of light that falls on the display screen. Front projection screens tolerate less ambient light. The should be kept below 53 lux (lx [5 footcandles (fc)]) for front projection screens, 161 lx (15 fc) for rear projection screens, and 215 lx (20 fc) for direct view monitors. The lighting levels in the display area in front of the projection screen should be no greater than 430 lx (40 fc).

Light Path Obstructions

The design of a videoconference space may include elements that interfere with the desired distribution of light. These obstructions can be architectural elements and, often, some of the lighting fixtures. The fixtures provide part of the required lighting but, due to their location, can create unwanted shadows and glare to the camera. Two common challenging types are chandeliers and pendant-mounted indirect fixtures.

Chandeliers are generally placed in the center of a room and are part of the decorative layer. Influencing the fixture selection is desirable. A chandelier with diffuse lighting elements placed close to the ceiling can minimize the potential glare to the camera.

Pendant fixtures can be a good source of vertical illumination needed for the participants. However, they should be carefully placed to avoid shadowing. The fixture should be the type with minimal surface brightness and be kept out of the camera's direct view.

Pendant indirect fixtures provide a high level of ambient illumination. In rooms with front projection screens, this can cause screen washout. The use of rear screen projection, plasma, or other direct-view displays is recommended when indirect lighting is used, particularly in rooms that require high light levels. Controls play an important role in these applications because they provide the ability to dim or turn off the indirect light when it is not required.

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Theatrical Lighting

Theatrical lighting is specialty oriented solely for performing arts facilities. As a result, this type of lighting design approach often is not appropriate for architectural spaces such as conference rooms, boardrooms, and classrooms.

Theatrical lighting design is a separate discipline that is best left to the professionals specializing in such type of lighting. A high level of design coordination is required when AV systems are installed in the spaces with theatrical lighting systems.

The two basic types of theaters are:

- Live production theaters.
- Motion picture viewing theaters.

Some theater spaces provide both functions. These include performing arts facilities and large houses of worship.

Live production can be further classified as:

- Legitimate theaters.
- Community theaters.
- School theaters.

Lighting requirements for the marquee, lobby, and foyer are similar for these theater types. Transitional lighting should be provided to accommodate visual adaptation as patrons proceed from the brightly lighted marquee and street area to the lobby, the foyer, and the auditorium. The lighting requirements for the auditorium depend on the type of space.

In lobbies, accent lighting is used to highlight the signage, concession, and retail sales areas. Poster panels may contain their own lighting systems or be video displays using digital signage.

The ceiling luminaires are often decorative with designs that retain architectural elements and brightness patterns that both attract attention and influence the flow of traffic. Additional considerations are easy maintenance and energy use.

The foyer lighting provides a low level and subdued illumination by large, low-brightness, elements such as coves. Accent lighting on statuaries, paintings, posters, and plants are important for creating a theater atmosphere. The foyer light must not spill into the auditorium. Lobbies and foyers also can be used as public gathering places and as places of assembly for civic and business events. The likelihood of these events occurring should be considered in planning the lighting system.

Theatrical Lighting, continued

Live Production Theaters

The most common live production theaters are the:

- Traditional proscenium theaters.
- Open stage or thrust theaters.

Indoor and outdoor live production theatres exist in many varieties such as amphitheaters, music tents, arenas, and open stages. The proscenium-type theatre is typically composed of a seating area (auditorium) and a stage area. It may serve not only as a theatre, but as an assembly and lecture hall, a study room, and a concert area.

The lighting in the seating area should provide adequate general illumination and diffuse, comfortable, illumination. Because the seating area often accommodates a variety of activities, a different illuminance method is necessary. This method, called house lighting, should be on a lighting control system, preferably operated from several stations such as the stage lighting control board, the projection booth, and a staff entrance.

Lighting equipment for the seating area may include general downlight luminaires, coves, wall sconces, and curtain and mural lights. Selected lighting system circuits can be used for cleaning and rehearsals. Panic switches independent of dimmers and switches should be provided to allow selected lights in the house in case of emergency. In accordance with local codes, emergency lighting must be provided.

For the lighting of the stage area, an appreciation of the dramatic potential of lighting begins with an understanding of its four basic functions:

- Visibility—This is the most basic function of lighting in the theatre. For the audience to hear and understand in the theatre, they must be able to see.
- Motivation—Motivation or naturalism is the term given to the expression of time and place.
- Composition—Composition is revealed artistically through light and shadow. Warm and cool light gives plasticity and composition to the visual effect. The concept of production presented by the playwright and implemented by the director determines the designer's approach.
- Mood—Mood or atmosphere as created by the total visual effect and brings the stage into focus with the meaning of the play.

The final visual effect is provided by equipment that has been chosen by the designer because it supplies the desired output of light in terms of intensity, form, color, and movement.

The controllable properties of light as they apply to the theatre include intensity, form, color, and movement. The control exercised by the designer over these properties has a direct bearing on the success of the performers in achieving the intended response from the audience.

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Theatrical Lighting, continued

Intensity

Intensity control is achieved with various types of luminaires, lamps, mounting positions, color media, and dimmers. Precise and consistent dimmer control is essential for establishing and maintaining various intensity levels. Vertical illuminance of 2000 lx (186 fc) or higher is required to highlight selected performances.

Form

The form or distribution of light calls for a variety of luminaire types and mounting positions. The angle of light relative to the object and the viewer creates dimensionality, which in turn is a function of the fixture type, location, focus, and dimmer balance. Luminance ratios on the stage should not exceed 100:1.

Color

In lighting design, color is used to accent, enhance, distort, and motivate the scene. Color is controlled by lamp selection, dimmers, and filters that can be placed in front of each source. Incandescent lamps in particular become much more yellow as they are dimmed. A tonal quality can be obtained by the additive mixture of two or more sources. The color rendering index (CRI) of light sources used in theatre should not be less than 80.

Movement

Movement consists of a change in one or all light properties. Movement is usually accomplished by both dimming individual luminaires and by luminaire movement. Additionally, manually operated follow spots are commonly used.

To accommodate the number of luminaires, an adequate number of power outlets at various locations and accommodating control equipment should be provided so the stage lighting designer can create lighting for all stage performances. The necessary structural provisions must be made to allow placement of the lighting equipment and access for their installation, operation, and maintenance.

The two basic locations for lighting equipment are:

- In front of the proscenium opening, including the auditorium ceiling, side walls of auditorium and proscenium, balcony front, follow-spot booth, and edge of the stage apron.
- Behind the proscenium opening, including pipes for attaching side lights, overhead cyclorama or top lights, and stage electrics above the stage.

Also employed are cyclorama pit or base lights as well as special locations in free spaces at the side or rear of the stage, including ones that are floor mounted, hanging, or set beneath the stage area.

Theatrical Lighting, continued

Motion Picture Theaters

The chief objectives of auditorium lighting in the motion picture theatre are to:

- Create a pleasing and distinctive environment with comfortable viewing conditions.
- Retain brightness and color contrasts inherent in the motion picture.
- Create adequate visibility for safe circulation at all times.

The need to eliminate stray light on the screen dictates controlled lighting for the front section of the auditorium. Downlighting is an effective method for this purpose. In general, diffusing elements (e.g, coves) allow too much light to fall on the screen if they provide adequate illumination in the seating area. Diffusing wall brackets, semidirect luminaires, and luminous elements are generally too bright to be used for supplying illumination during a motion picture presentation.

Preset scene control systems provide suitable settings of light levels and appropriate fades for preshow, presentation, intermission, postshow, and emergency. The control system can be integrated into the projection system for automatic operation.

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Broadcast Lighting

For broadcast and closed-circuit television (CCTV), the lighting system design and luminaire choices are based on the type of production. The size and complexity of the system vary on production needs, from elementary training facilities to professional facilities.

TV design requires information concerning types of productions (e.g., variety shows, dramas, news, soap operas, panel shows) that will be produced for network or local broadcasting or for closed-circuit or syndication release. In addition, the budget affects the degree of complexity.

TV broadcast lighting requires planning and flexibility due to continuous dramatic action on the set. Several scenes are arranged for several cameras and continuous switching from one camera to the next. Consequently, the lighting for each scene is preset for cameras positioned at different angles, and the lighting in one set should not interfere with adjoining sets.

The quantity and quality of the lighting needed for TV production depend on the absolute spectral sensitivity of the camera and the properties of the objects in the scenes. The actual illuminance levels for TV vary from under 1000 lx (93 fc) to several thousand lux (several hundred footcandles) depending on the type of camera. A limiting factor for any camera is the contrast range that the camera can accommodate.

In addition, the spectral response characteristics of cameras are critical to color reproduction. Best practice has shown that the light sources used for TV should have very broad spectral power distributions. The gains of the red, blue, and green channels of a camera can be adjusted to operate with nearly any broad spectrum light source. However, the wide variation in the spectral characteristics of the light sources used to illuminate a scene can cause unpredictable changes in color reproduction.

For TV lighting, different types of luminaires are used to produce qualities of light that fall within the following three basic categories:

- Key light is illumination with defined margins. Its output produces defined but soft-edged shadows and highlights. (A typical luminaire is the Fresnel spotlight.)
- Soft-edged light, sometimes referred to as fill light, is diffuse illumination with indefinite margins. Its output produces poorly defined shadows. It softens and fills the shadows produced by key light. (A typical luminaire is the soft light.)
- Hard-edged light is illumination that produces sharply defined, geometrically precise, shadows. (A typical luminaire is the ellipsoidal spotlight.)

The basic types of luminaires used in TV production have various optical characteristics. Most luminaires contain provisions for color filters or diffusion materials. Some special luminaires or accessory devices have the ability to remotely control aiming, focus, or color.

Broadcast Lighting, continued

Incandescent filament lamps have long been used for color studio lighting because of their continuous spectra, low cost, and availability in a wide range of sizes with approximately the same correlated color temperature. Incandescent filament lamps with the correlated color temperatures between 2 900 and 3 200 kelvin (K) are currently used. These lamps are favored because their housing equipment is generally less bulky and lighter in weight, and the smaller filament allows for better optical control of the light beam. Color filters also are easy to use with these luminaires. Where filament lamps are used, current best practice indicates the correlated color temperature of all lamps used in a scene should be within a 300 K range for consistent camera colors.

New developments in fluorescent and high-intensity discharge (HID) light sources are now providing greater flexibility for mixing sources. In particular, discharge lamps are now manufactured with much better and, in some cases, continuous spectral power distributions. Some sports arenas have successfully mixed 75 percent HID and 25 percent incandescent sources.

Metal halide HID lamps are used to light such areas as stadiums and arenas, providing the illuminance and color quality suitable for televised performances. They also have the capability of providing the daylight fill for TV productions.

Fluorescent lamps with a variety of spectral power distributions, often on special dimming systems, may light cycloramas in TV studios. Fluorescent lamps also are used as TV base lights. Both fluorescent and HID lamps for use in TV require high-frequency ballasts to overcome the flicker effect inherent in these lamps when operated on 60 hertz (Hz) of power.

The design of a lighting control system for TV is based on the artistic and technical needs of projected productions. Design parameters are expressed in terms of power capability, number of lighting outlets, dimmer bank capacity, interconnection system, and lighting control facilities.

A lighting control system must provide the designers with total flexibility of control over all of the luminaires lighting the set. Therefore, adequate dimmers, circuits, and control equipment must be used to establish the required number of lighting channels, to assemble those channels into cues, and to switch and fade from one cue to another, thus achieving the desired lighting changes.

Lighting control systems for the theatre and TV differ slightly. Theatre lighting control systems make extensive use of memory, require accurately timed faders, and must be capable of complex simultaneous operations. TV lighting control systems generally require less memory and fewer operational features and benefit from automated dimmer channels.

For more on lighting for theater and broadcast TV, refer to the sources in the References section.

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Entertainment Lighting

A combination of architectural lighting and theatrical lighting effects are used in many spaces today. This includes themed restaurants, entertainment facilities, and amusement parks. The lighting in these areas is integrated with other elements including AV and special effects.

Control systems are fundamental to the operation of the lighting. The architectural lighting can be controlled with a scene preset system while the theatrical lighting elements are controlled with a theatrical control system. These systems are coordinated by an AV control system or, for complex requirements, by a show controller.

Show controllers are specialized computer memory systems. They are programmed to record all of the aspects of lighting operation and effects. The show controller then plays back the program on an automated basis or when manually activated.

The lighting generally consists of a combination of architectural lighting fixtures and theatrical fixtures including moving lights, color changing lighting, light-emitting diode (LED) lighting, and other specialty lighting.

Terms and Units of Measurement

The two basic kinds of light perceived by the human eye are the:

- Light that arrives directly from a light source such as fire, the sun, or an electric lamp.
- Light that is reflected off a surface such as room walls, grass, trees, or the earth's atmosphere

The basic units of measure for lighting are defined below. The most commonly used fundamental units are used to describe the level of light emitted from a light source and light reflected from a surface.

Illuminance

Illuminance is the light level incident on a surface or plane from a source or sources. It is expressed in lux (lx [lumens per square meter]), which is the preferred unit of measure), or fc (lumens per square foot).

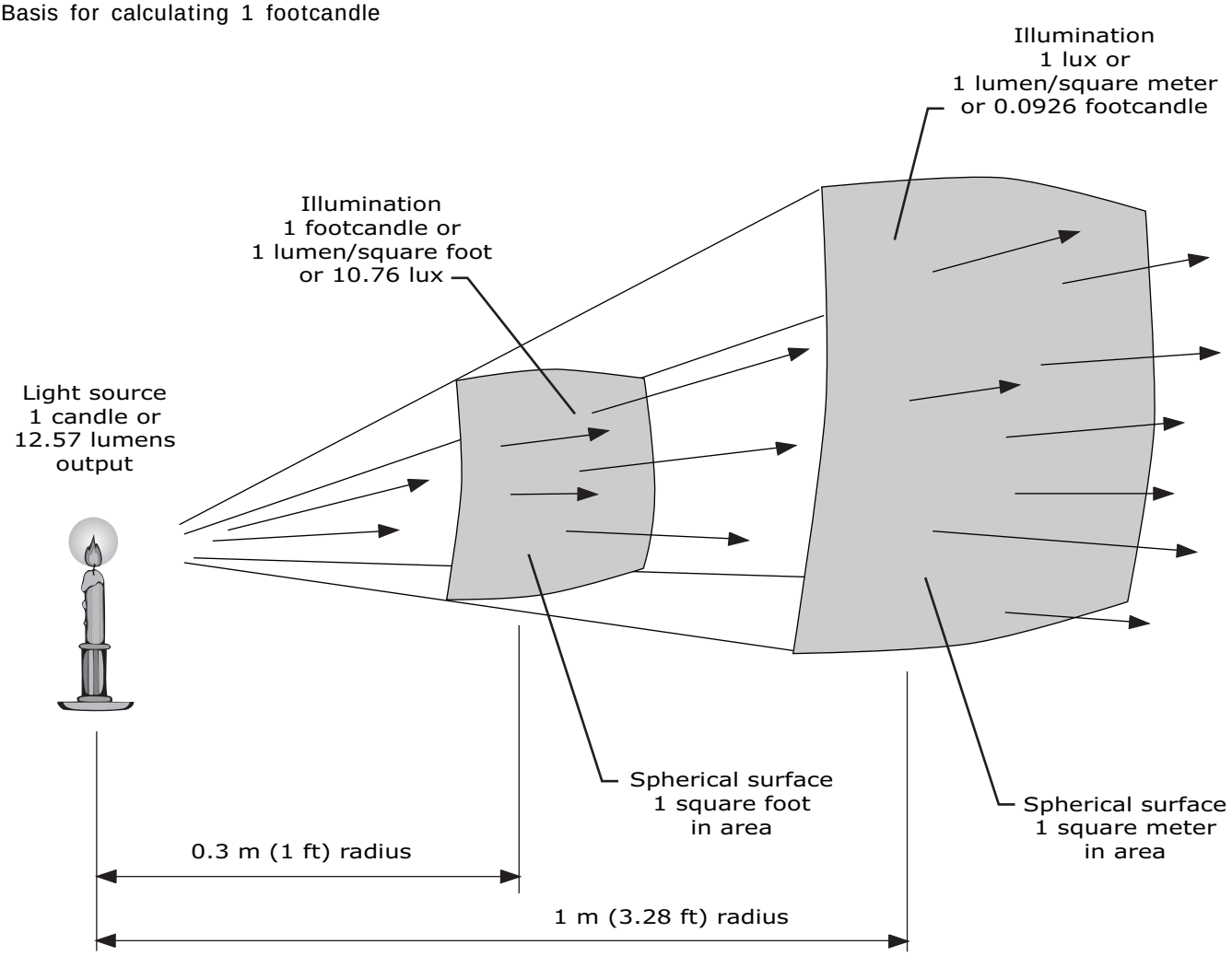
Footcandles and Lux

The terms fc and lux are used to describe illuminance, or the direct illumination striking a surface. Illuminance can be measured with a light meter. It is only a measurement of a lamp or light source, and not the light after is has been reflected off of a surface.

Terms and Units of Measurement, continued

An fc is specified as the amount of light that is equivalent to one lumen per square foot (10.76 lumens per square meter or 10.76 lx). Figure 12.3 shows the elements of 1 fc calculation.

Figure 12.3
Basis for calculating 1 footcandle



ft = Foot
lux = Luminance flux
m = Meter

Lux is a contraction of the words luminance and flux. A single lux (lx) is equivalent to one lumen per square meter and 0.093 fc.

NOTE: Exact conversions between lux and fc should be used when reporting measurements, but when both are given as criteria, a simple conversion factor of 10 is often used instead of 10.76.

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Terms and Units of Measurement, continued

Luminance, Footlamberts, and Nits

Luminance is the luminous intensity from a surface in a particular direction. Luminance may be considered the light reflected from a surface. It is expressed as candelas per square meter, or nits. The original imperial unit is footlamberts (fl) which represents lumens per square foot.

Candela

Candelas are used to describe the intensity of light leaving a lamp or luminaire in a given direction to measure the quantity of light from a source. The total light output of a source is measured in lumens. The standard candle produces 12.57 lumens or one lumen per square foot for a 1 ft radius sphere surrounding the candle. A 4 ft fluorescent lamp may produce 3000 lumens.

A standard 60 watt (W) incandescent light bulb produces about 900 lumens. Luminance units of measure are based on the candela, which represents the light output from a standardized source. A candela is defined as the luminous intensity of one-sixtieth of a square centimeter of fused thoria heated at 2,046 K.

Light Reflectance Value (LRV)

Light reflectance value (LRV) is a measurement often applied to paint and other room finishes indicating the percentage of light reflected from a particular surface independent of the color. LRV ranges from 0 to 100, with the higher numbers indicating lighter finishes and the lower numbers indicating darker finishes.

Luminance Ratio and Contrast

Luminance ratio or contrast refers to the mathematical ratio of the lightest area to the darkest area of a visual field of view. Lighting designers often use the term luminance ratio when discussing room environments and mostly nonelectronic illuminated surfaces. AV designers use the term contrast mostly to describe video projectors and displays. The fundamental definitions, however, are the same.

NOTE: See Chapter 15: Video Components, for more information.

Exitance

Exitance is the measure of light reflecting off a surface in all directions and is measured in fc. Exitance is determined by multiplying the illuminance onto a surface by the reflectance of that surface.

Terms and Units of Measurement, continued

Luminaires, Lamps, and Fixtures

Luminaire refers to a complete lighting assembly including the housing, reflectors, and lamps. The lamps are the bulbs or active elements that actually emit the light in a luminaire. An installed luminaire is referred to as a light fixture.

Color

Color communicates additional information and beautifies the human vision. Light is color. A light source radiates light at various wavelengths. The specific combination determines the source color temperature and CRI.

To appear white, a light source must have either all visible wavelengths or the primary colors red, green, and blue.

Color Temperature

Color temperature (or correlated color temperature [CCT]) is a measure of the color appearance of a light source. Measured on the K scale, so-called warm light sources have a more yellowish appearance and have a lower CCT (2 000-3 000 K) while cool sources tend to appear more white or bluish and measure above 4 000 K.

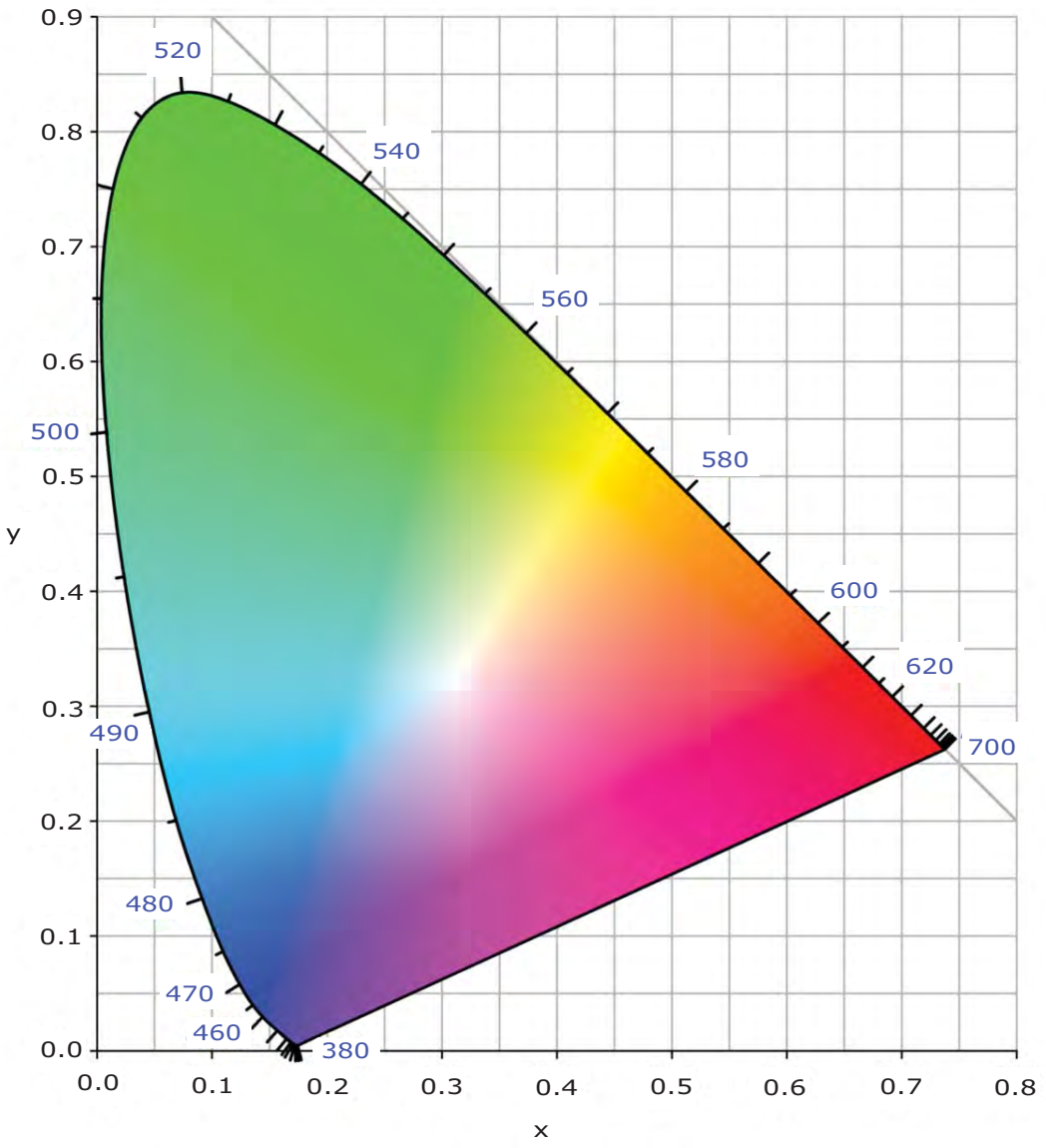
The color temperature of a light source is determined by the overall color content of the emitted light and the perceived color of an object is affected by the source's color temperature. In addition, cameras do not have the adaptability of the human eyes so the color temperature of light sources in camera use is particularly important.

Figure 12.4 indicates the color content of various color temperatures noted by the curve near the middle that identifies the various levels of white light in Kelvin (K). The numbers around the edge of the colored area represent the wavelength of the indicated color in nanometers (nm).

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Terms and Units of Measurement, continued

Figure 12.4
International Commission on Illumination curve



Color Rendering Index (CRI)

CRI measures the quality of white light and is a measure of the effect a light source has on the perceived color of objects relative to the illuminated by a reference light source. The higher the CRI is, the better the source color quality.

CRI is applied to light sources and is measured on the scale from 1 to 100, where 100 is the most accurate color rendering, while 80 or above is considered fair.

Terms and Units of Measurement, continued

Efficiency Terminology

Luminaire efficiency measures the ratio of total lumens emitted by the lamps within a fixture to the total lumens that exit from the fixture. It is expressed as a percentage.

Efficacy is a ratio of the light output from a source per unit of power input. Lamp efficacy is measured in lumens per watt.

Potential lighting system energy efficiency is expressed in terms of lighting power density (LPD) or, sometimes, unit power density (UPD). It is measured in Watts per square foot (W/f^2) or Watts per square meter (W/m^2).

The true measure of energy efficiency or use is measured in kilowatt hours (kWh) per year.

Vision System

Perception is both physical and psychological. Many factors effect perception, including:

- Adaptation, which is the human eye's ability to adjust to light and dark.

  The iris and the eye's internal chemistry work together to allow seeing over a wide range of scene illumination by adjusting to varying light levels.

  The iris regulates the amount of light entering the eye. Iris reactions are limited to about 500:1. The eye's internal chemistry also changes to allow for greater sensitivity at low light levels. This allows total visual range of 1 000 000:1 taken 1 000:1 at a time. Eye sensitivity decreases with age.
- Glare, which triggers many psychological and physiological reactions.

  Glare is caused by objects in the field of view that are very bright relative to the average scene illumination. When the eye adjusts to the bright sunlight, it looses the ability to see detail in darker areas.
- Discomfort glare, which is a glare sufficiently extreme to cause the sensation of discomfort or pain.
- Contrast, and the patterns of brightness. The visibility of an object is not determined by its absolute brightness, but by its contrast with its surroundings. Increasing the contrast generally increases the visibility. Too much or too little contrast is unsettling. Balanced conditions in a scene with a full range of brightness are desired. Gentle highlights and gradual shadows are visually interesting, comfortable, and inviting.
- Mood and subconscious reactions to light. Indirect lighting creates a relaxed atmosphere. Warm colors and light sources create a cozy, homelike atmosphere. Direct light creates an intense atmosphere. Lighting gives a sense of time. Warm colored light along with low light levels and shadows reminds the viewer of the morning or evening light. On the other hand, cool colored light with high light levels and absence of shadows gives more of a mid-day appearance.

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Lighting Controls

Introduction

AV and videoconference spaces require flexibility in the lighting levels and distributions. Lighting controls are necessary to achieve the range of lighting criteria. Lighting controls include both switching and dimming capabilities to provide the needed flexibility.

Lighting controls allow users to easily adjust the lighting for particular functions. This ensures the lighting is appropriate for presentations, single presenters, group meetings, or special functions. Additionally, controls allow composing the lighting in a space to create a specific look or mood, reproduce functional lighting schemes repeatedly, achieve highlight and balance between the various lighting elements and save energy, which is an important consideration in any space today.

The most important factor for videoconference applications is that lighting controls provide for the adjustment of luminance ratios to create ideal lighting levels for the camera.

Integrating the AV system and lighting controls provides increased coordination of the lighting and video systems. This allows the AV system to initiate the correct lighting in communication with the lighting control system.

The two basic elements of an effective lighting control system are:

- Separating the various lighting elements into individually controllable groups (zones).
- Providing the ability to select preset scenes.

NOTE: Preset lighting controls in AV and videoconference spaces is a fundamental requirement.

Lighting Zones

A lighting zone is a group of lighting luminaires controlled together. Zones are established for each basic lighting function.

The zones recommended for AV spaces include:

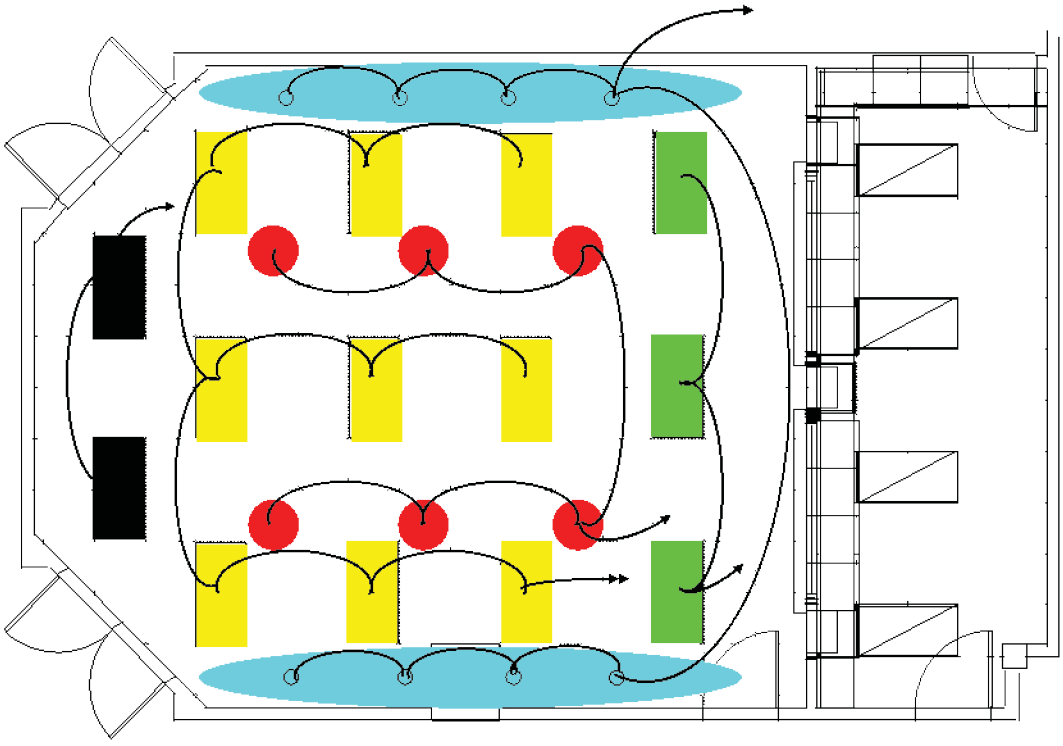
- Ambient or general illumination.
- Videoconference task lighting, if applicable.
- Lighting of vertical and perimeter surfaces.
- Front display lighting (any lighting fixtures located in front of the projection screen or monitor).
- Task lighting on desks and tables.
- Accent and display lighting.
- Decorative lighting.

Additional zones may be required for special elements such as a document camera or lighting of display boards, marker boards or demonstration equipment.

Lighting Zones, continued

Figure 12.5 illustrates how lighting fixture groups may be tied together for zoned control.

Figure 12.5
Lighting diagram depicting zones



The arched lines indicate power connections to various light fixtures. Each group is color-coded to show which fixtures are wired together.

In the above system, there are five zones:

- Front (green)
- Rear (black)
- Seating area fluorescent (yellow)
- Seating area downlights (red)
- Side wall wash (highlighted in light blue)

Each zone is home-run to a dimming or switch system allowing separate control of each zone.

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Lighting Scenes

Successful lighting control in a videoconferencing environment is accomplished by preset scenes. A preset scene is established and preprogrammed for each of the functions of the space. Each preset scene includes all of the zones in a space. The appropriate scene is selected using of a control station that has pushbuttons for each of the preprogrammed scenes. These controls also can be programmed in conjunction with the AV control system. Typical scenes for a presentation room might be:

- Setup—all zones at full level.
- Presentation—front zone off near projection screens and lights dimmed over seating area but bright enough for note-taking.
- AV—front zone off near projection screens and seating area lights very low.
- Videoconference—Videoconference fixtures full, other lighting set to levels appropriate for the camera.
- All off—all lights off.

Fluorescent Dimming

Fluorescent lighting is the primary source of lighting recommended for all commercial applications. Providing flexible control for this lighting source is critical. The dimming of fluorescent lighting requires the use of electronic dimming ballasts and fluorescent dimmers.

The dimming ballasts provide control over a wide range of light output. An advantage of fluorescent lighting is that, unlike incandescent sources, no color shift is produced by dimming. This color consistency ensures that the color is not adversely affected by changing the lighting levels in a video application camera use.

Lighting Control Types

A wide variety of lighting control products that provide multi-zone preset scene control is now available, including controls designed for new construction and retrofit projects.

Manual wallbox dimmers and switches are suitable for small meeting and conference rooms where no integration is planned. Most of these dimmers do not work well for use in professional AV spaces or for videoconference applications. They provide simple on/off and dimming control and work where lighting levels do not need to be preset to multiple scenes. In addition, they are not easily integrated with an AV control system. However, some recent styles are now beginning to incorporate infrared (IR) control and preset capabilities.

Small Rooms

Spaces that are 5 m (15 ft) x 6 m (20 ft) and smaller typically have a maximum of three or four zones of lighting. There are two cost effective solutions for controls. Individual wall box dimmers that have preset capabilities can be used for new applications. Wireless dimming control systems designed for retrofit applications can be incorporated at a reasonable cost without major changes to a building's wiring.

Medium Rooms

Spaces that are larger than 5 m (15 ft) x 6 m (20 ft) will typically have anywhere from 4 to 8 zones of lighting. Included in this category are large classrooms, training rooms, boardrooms and multipurpose rooms. These rooms require scene preset capabilities and should be operated from multiple locations within the room.

Integration of Window Treatments

Lighting control is not limited to the electric lighting fixtures. Controlling daylight is equally important. Automated shades and drapes should be incorporated into AV and videoconference spaces to control the daylight entering the room through windows. The lighting control system should control these window treatments as an additional lighting element. Coordination with the specifier and supplier of the window treatments is the key to a successful application of properly controlled shades and drapes.

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Integrating Lighting Control with Audiovisual (AV) Control

Lighting controls have to integrate with the AV control system. Integration with other building systems or, in some cases, theatrical lighting systems also may be necessary.

Control systems typically use RS-232 or Ethernet communication to connect to AV and other building systems. Both RS-232 and Ethernet communication allows the AV control system to access any of the functions that the lighting control system is capable of providing. The typical functions used are:

- Selecting preset scenes.
- Providing raise/lower override of individual lighting zones.

These interfaces provide integration of one room, multiple rooms or entire facilities.

Digital multiplex (DMX) 512 is the theatrical dimming system control protocol used mainly with theatrical stage lighting consoles and theatrical lighting instruments. Some architectural systems use this protocol for communication.

As theatrical fixtures are finding uses in architectural applications, the need for any lighting system to operate with control signals in the DMX512 format is increasing.

Dimming systems must be able to receive and send DMX512 signals. Receiving DMX512 means any dimmer or lighting instrument can listen to DMX commands and will respond appropriately. The most common application is the use of a stage dimmer console to drive architectural dimmer panels. Sending DMX512 involves the ability of any architectural lighting control system to send DMX commands to operate theatrical dimmers, moving lights, and other special fixtures, such as LED and fiber optic lighting.

Light Switches

Light switches are the basic form of lighting control. They provide a convenient way of manually turning the lights on and off. In most commercial buildings, switches give the ability to control the lighting in the occupied spaces.

Although quite common today, in the 1960s and early 1970s, buildings were built without many switches. Lighting was left on all the time or large contactors were used to turning on/off entire buildings or floors of buildings.

Energy concerns and codes require switches to be used in all commercial buildings. The simplest form of lighting control in the AV environment is to use multiple switches to turn on/off lighting where needed. These switches do not provide the optimum control and cannot be integrated into the AV control system.

Occupant Sensors

Occupant sensors are the common form of motion detector used for interior lighting. An occupant sensor is basically an automatic switch. Its primary role is to sense the presence of a person occupying a room and turn the lighting off when no one is present. The use of occupant sensors is growing and energy codes are requiring their use in commercial and residential applications.

Many varieties are available and can sometimes be located in place of the regular wall switches. Ceiling-mounted varieties that connect to the switching or dimming system to control all the lighting in a room also are available. Ceiling-mounted sensors provide a more effective function since they view a wider area with less obstruction.

Dimmers

In most applications, whether residential or commercial, the sole capability of switching the lights is not enough. The levels between on and off are also needed. Dimmers provide this capability.

The basic dimmer replaces the standard switch to control the intensity of an individual lighting zone and provide a wide range of other functions. Such functions include full-range dimming of primarily incandescent and fluorescent light sources, ability to remember preset light levels, slow fade of lights between on and off, and operation from wireless IR or radio frequency (RF) remote controls.

Control Systems

Beyond the standalone dimmers and switches are lighting control systems. A system is the interconnection of many dimmers and switches in a unified centrally-controlled network.

Dimmers and switches can be distributed or mounted together in a panel. The panels are normally mounted in electrical closets or other service areas. Panels are either dimmer panels or switching/relay panels. Combined panels with both dimmers and relays are also available. The panels also can incorporate the required electrical distribution circuit breakers.

A wide variety of panel sizes are available for any size project. Dimmers in the panels are generally rated for small loads (500 to 1 000 W) or larger loads in 20 ampere (A) circuit increments. Switching relays also are rated for 20 A circuit loads.

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Control Systems, continued

Operation of these systems is accomplished with appropriate control stations, programming controls and processors. The controls are on a digital network connecting both dimming/ switching panels and control elements. A vast array of lighting control system types is available, including:

- Preset control systems.
- Central dimming systems.
- Assignment control systems.
- Energy management controls.

Choosing the controls that would compliment the lighting design and provide the functions needed for the project is critical.

Preset Control Systems

Preset control systems allow for several zones of lighting to be controlled simultaneously. All zones are programmed to provide multiple scenes. Each of these scenes can be recalled with the touch of a button located on a control station. Preset systems are valuable in multifunction commercial spaces such as conference rooms and ballrooms.

Central Dimming Systems

Central dimming systems are the most powerful in the dimming control group. They consist of several remote dimming/switching panels. Local room control stations provide the control of lighting for the user. Computer based software programs provide the overall system operation and programming. These systems are easily customized, offering many combinations of manual, preset, and time clock controls. They can incorporate occupant sensors, photosensors, and emergency power functions.

Control Systems, continued

Assignment Control Systems

Assignment control systems allow several systems in partitioned rooms to be patched together through a flexible master control. Hotel function rooms and convention center meeting rooms are the most common applications. The assignment control station allows assigning independent control to separate rooms or single-point control to any open multi-room space leaving additional spaces isolated with their own control stations.

Energy Management Controls

Energy management controls are another type of system in common use. The various types of control strategies include switching controls that can be remotely operated by the central system, such as:

- Time control that provides for programmable schedules of times when lighting is on, off, or at various preset levels.
- Occupant/motion sensor control.
- Photosensor control—Daylight sensors provide continuous variable control of lighting in response to daylight. Light levels are changed smoothly as daylight changes. It is primarily used with interior lighting, where a smooth transition of changes in light level is important.

Emergency Lighting

Commercial buildings are required to have some form of emergency lighting. This lighting is required by codes and is designed and qualified by the electrical engineer.

The primary purpose of this type of lighting is to provide sufficient light for a safe exit out of the building when the normal electrical supply fails. It must operate for a specified minimum period time, typically 90 minutes. The source of power can be an emergency generator or battery/inverter system. Two other methods are emergency ballasts mounted within fixtures and standalone emergency packs with integral lights.

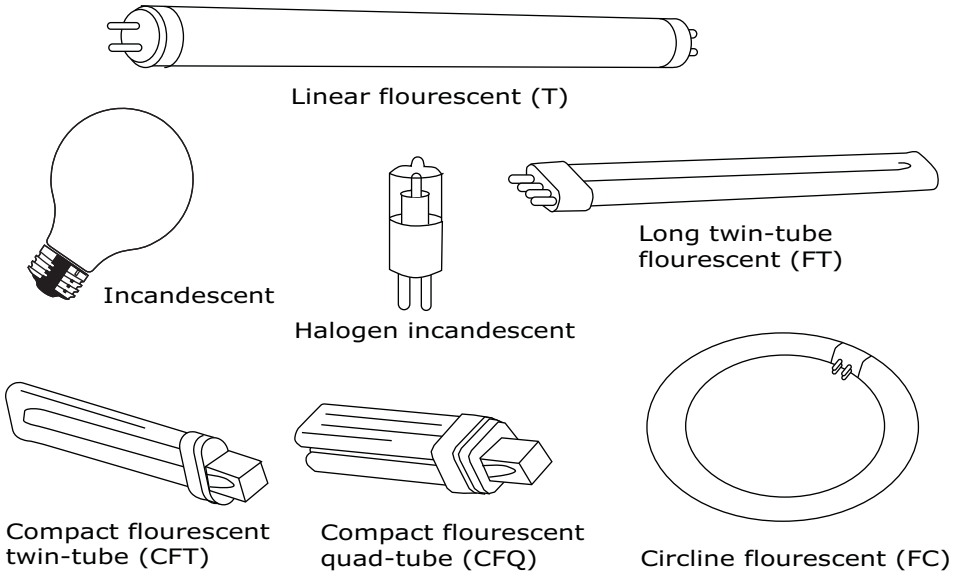
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Lighting Equipment

Light Sources

Many different types of light sources (see Figure 12.6) are found in visual display, presentation, and videoconference environments. Most interior commercial applications primarily use fluorescent lighting fixtures. For decorative and some accent uses, light fixtures with incandescent, and low-voltage lamps are incorporated. Many applications also have windows or skylights and can use natural daylight if controlled appropriately.

Figure 12.6
Light sources



NOTE: Figure 12.6 has been reproduced with the permission of the National Lighting Product Information Program, Lighting Research Center.

Light Sources, continued

Some characteristics of the sources affect the success of a lighting design. The following paragraphs briefly describe the key characteristics.

The color temperature of a lamp alters the color perception of any objects or images viewed under it but the eyes may not detect these subtle variations. A white sheet of paper observed under different white light sources with various color temperatures will seem to be white. The eyes often cannot detect this difference because the brain makes corrections for the discrepancy and, as a result, the eyes perceive the light as white. Depending on the application and uses of an environment, the color temperature of lighting fixtures may become extremely important.

If video cameras are used, all lighting fixtures should have the same color temperature and it should be a standard TV white (around 3 200 K). It also can become a factor when images with true and accurate color are evaluated or displayed.

In some critical viewing environments even the color temperature of the produced light is of concern. The color temperature of the light source used to light the environment should be the same as that of the image being viewed. This allows the eye to perceive color accurately. If the viewing environment lighting is very warm in color (i.e. incandescent lighting at around 3000 K), the TV pictures set for 6 500 K will appear excessively blue in color. Changing the environment to a 6 500 K light will allow the viewer to perceive colors accurately.

Types of Lamps

The electric lamp replaced gas lamps in the late 1800s and early 1900s. In the early 1900s the first electric lamp was the carbon-arc lamp, demonstrated in 1801 by Sir Humphrey Davy, but electric lights became popular only after the incandescent lamp was developed independently by Sir Joseph Swan in England and Thomas Edison in the United States. Edison patented his invention in 1879 and subsequently made the invention the commercial success that it is today.

This century has seen a huge increase in the number of available light sources in the marketplace, starting with improvements in the Edison lamp, then the introduction of mercury vapor lamps in the 1930s, followed closely by fluorescent lamps at the 1939 World Fair. Tungsten-halogen lamps were introduced in the 1950s, while metal halide and high pressure sodium (HPS) lamps were introduced in the 1960s. The introduction of electrodeless lamps in the 1990s indicates that the industry is dynamic and that the introduction of new light sources is expected to continue at the present rate well into the future.

The following paragraphs describe some of the various light sources available today. The wide selection of light sources on the market allows making several different choices for a given lighting application.

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Types of Lamps, continued

Fluorescent Lamps

The fluorescent lamp is a low-pressure gas discharge source in which light is produced predominantly by fluorescent powders activated by ultraviolet (UV) energy generated by a mercury arc. The lamp, usually in the form of a long tubular bulb with electrodes sealed into each end, contains mercury vapor at low pressure with a small amount of inert gas for starting. The inner walls of the bulb are coated with fluorescent powders commonly called phosphors. When the proper voltage is applied, the current flowing between the electrodes through the mercury vapor produces an arc. This discharge generates some visible radiation but mostly invisible UV radiation. The UV in turn excites the phosphors to emit light.

Fluorescent lamps must be operated in a series with a current-limiting device, commonly called ballast. The ballast provides the required starting and operating lamp voltages. In the applications requiring variable light levels, dimmable versions of the ballasts are used.

Linear fluorescent lamps are commonly made with straight, tubular bulbs of various diameters. The bulb is historically designated by a letter indicating the shape, followed by a number indicating the maximum diameter in eighths of an inch. Hence, T-8 indicates a tubular bulb 8/8 or 1 inches (in [25 millimeters (mm)]) in diameter.

Fluorescent lamps also come in shapes other than straight tubes. U-shaped tubes are formed by bending the tubes in half. They are commonly used in 0.61 m (2 ft) square luminaires. Circular (circline) lamps are tubes bent in a circle with the two ends adjacent to each other. Smaller diameter, single-ended, compact fluorescent lamps consisting of multiple shaped tubes joined together to form a continuous arc path are increasingly used. They are designed to approach the size of the incandescent lamp.

The color of the light produced by a fluorescent lamp depends on the blend of phosphors used to coat the wall of the tube. Many different white and colored fluorescent lamps are available, each having its own color characteristics.

Popular fluorescent lamps use three highly efficient phosphors. These triphosphor lamps can be obtained with high color rendering, improved lumen maintenance, and good efficacy with correlated color temperatures between 2500 and 6000 K. Common commercial types have correlated color temperatures of 3000, 3500, and 4100 K.

A variety of lamp types that radiate in particular wavelength regions for specific purposes, such as plant growth, merchandise enhancement, and medical therapy is available. Colored lamps (e.g., blue, green, and gold are obtained by phosphor selection and filtration through pigments.

Types of Lamps, continued

Incandescent Lamps

The incandescent lamp is the original electric light source and is still widely used today in residential, theatrical, and commercial applications. Commercially, it is used for primarily accent and decorative lighting applications. The characteristics of incandescent lamps provide warmth, sparkle, and controllability that can not be easily duplicated with other sources. Thus, use of incandescent sources in specialty applications are expected to be used into the future.

The tungsten-halogen lamp is used as an incandescent light source since it has many required properties. In the incandescent lamp, only a small percentage of the total radiation from a tungsten filament is in the visible region of the spectrum. The efficacy of light production depends on the temperature of the filament. The higher the temperature of the filament, the greater the portion of the radiated energy that falls in the visible region, and, thus the greater the luminous efficacy. For this reason, the design of a lamp should keep the filament temperature as high as is consistent with a satisfactory lifecycle.

A direct interrelationship exists between the lifecycle, efficacy, color temperature, and voltage of a lamp. Varying the voltage applied to an incandescent filament lamp changes the filament resistance, temperature, current, power, light output, efficacy, and lifecycle. These characteristics cannot be changed without affecting the others.

Dimming of Incandescent and Tungsten-Halogen Lamps

Today, dimmers have a dual purpose:

- Energy conservation
- Aesthetic lighting effects

Incandescent lamps can be dimmed simply by lowering the voltage across the lamp filament. When the voltage is lowered, less power is dissipated and less light is produced with a lower color temperature. An added benefit is an increase in the life of an incandescent lamp. For example, when an incandescent lamp is operated at 80 percent rated voltage using a dimmer, its life is increased by a factor of nearly 20. In a tungsten-halogen lamp, the life of the filament depends on voltage just as with standard incandescent filament lamps.

Today, most dimmers are electronic, using thyristor and transistor circuits that have low power dissipation. Modern dimmers are efficient and reduce power as the source is dimmed. Thyristors operate as high-speed switches that rapidly turn the voltage to the lamp on and off. This switching can cause electromagnetic interference (EMI) with other electrical or AV equipment as well as audible buzzing in the lamp filament.

Magnetic coils known as chokes are usually used as filters to reduce these effects. With many wall-box dimmers, however, lamp buzzing cannot be completely eliminated because a larger choke than the space allows is needed. For these cases, remotely mounted, properly sized lamp debuzzing coils or additional chokes are recommended.

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Types of Lamps, continued

Tungsten-Halogen Lamps

Tungsten-halogen lamps improve on the regular incandescent sources in several ways. Their advantages over regular incandescent lamps include compactness, whiter light (higher color temperature), and longer life at a given light output. The construction and principle of operation of incandescent filament and tungsten-halogen lamps are similar; however, the halogen regenerative cycle enables a tungsten-halogen lamp to provide the advantages.

Halogen lamps are available in both line voltage and low-voltage designs. The line voltage products are available as single ended, double ended, and parabolic reflectors (PARs). The low-voltage types are generally capsules or small reflector types. For specialty applications, other voltage ratings (e.g., 84 volt [V] and 200 V) also are available.

Low-voltage halogen lamps operate in the voltage range from 5 to 30 V. This voltage is supplied through a step-down magnetic or electronic transformer. The advantages of low-voltage lamps are greater resistance to vibration and shock because of their larger diameter filament wire, a more compact filament that allows better beam control and higher efficacy than line voltage lamps.

Tungsten-halogen lamps are designed for higher efficacy and longer life than normal incandescent lamps of the same wattage. For example, the 500 W incandescent lamp is rated for 1000 hours, while the 500 W tungsten-halogen lamp is rated for 2000 hours.

In general lighting applications, luminaires for tungsten-halogen lamps should have a lens or cover glass that, in addition to providing the required safety protection in case of lamp breakage, filters out most of the UV radiation generated by the filament.

Reflector lamps are popular types of both incandescent and tungsten-halogen lamps. Reflector lamps include those made in standard and special bulb shapes and have a reflective coating applied directly to part of the bulb surface. The following reflector lamps are readily available:

- Bowl reflector lamps
- Neck reflector lamps
- Reflector spot and reflector flood lamps with R-type bulbs (certain sizes of reflector lamps are available with heat-resisting glass bulbs)
- Ellipsoidal reflector (ER) lamps, which allow substantially improved efficiency in deep, well-shielded, downlights

PAR spot and PAR flood lamps use PAR bulbs, typically constructed from two molded glass parts, the reflector and the lens. Multifaceted pressed glass reflector lamps with low-voltage tungsten-halogen capsules and infrared-transmitting dichroic reflectors, known as MR-11 and MR-16, have been adapted from projection lamp designs for display and accent lighting applications.

Types of Lamps, continued

High-Intensity Discharge (HID) Lamps

HID lamps include the groups of lamps commonly known as:

- Mercury.
- Metal halide.
- High-pressure sodium.

These lamps are used in many exterior and some interior applications. Common outdoor uses are parking lot lighting, streetlights, and security lighting. Other exterior applications include sports fields, stadiums, and other outdoor arenas. Interior applications are limited to high ceiling applications like gymnasiums, warehouses, large retail stores, and large building atriums.

Low-wattage HID lamps also are applied in retail display applications. HID lamps are generally not found in general office, lecture hall, meeting room, or conference room applications due to the functional and color issues with these lamps.

The light-producing element of these lamp types is a wall-stabilized arc discharge contained within a refractory envelope (i.e., arc tube). This arc tube is enclosed within a glass bulb. The arc tube also contains metals or halide compounds of metals that, when evaporated into the arc discharge, produce characteristic lines of radiant light energy.

Each type of HID lamp produces light related to the type of metal that is contained in the arc. Mercury vapor lamps produce light by exciting mercury atoms; high-pressure sodium lamps produce light by exciting sodium atoms; and metal halide lamps produce light by exciting several different atoms and molecules, primarily sodium, scandium, thulium, holmium, and dysprosium.

The outer bulb absorbs the majority of UV energy radiated by the arc tube while allowing light to pass through. The outer glass bulb can be coated with a diffusing material to reduce the source brightness of the lamp. In mercury vapor and metal halide lamps, this diffusing coating can be a color-correcting phosphor that uses UV energy radiated by the arc tube to improve the lamp's overall color rendering properties.

If the outer bulb is broken and the arc tube continues to operate, the lamp emits a significant amount of UV energy. The exposure of more than 15 minutes can produce severe erythemal effects (skin reddening) or eye damage. Self-extinguishing lamps automatically turn the lamp off when the bulb is broken.

Low-wattage (below 175 W) metal halide lamps come in many varieties for different applications, such as displays, recessed lighting, and track lighting. They produce brilliant white light in a small arc capsule enclosed in a small outer jacket.

HID lamps do not immediately produce full light when turned on. With mercury lamps, normal operating values are reached after a warm-up period of several minutes, during which the voltage rises until the arc attains a stabilization vapor pressure. The mercury is then entirely evaporated.

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Types of Lamps, continued

If the arc is extinguished, the lamp does not relight until it is cooled sufficiently to lower the vapor pressure to a point where the arc will restrike with the available voltage. The time from the initial starting to the full light output at ordinary room temperatures without an enclosing lighting unit and the restriking time vary between 3 and 7 minutes, depending on the lamp type.

A metal halide lamp also does not reach full light output immediately but must warm up over a period of several minutes (time to reach full light output is longer for higher lamp wattages). During this phase, the color of the discharge changes as the metal halides warm up, evaporate, and incorporate into the arc. Upon full warm up, the lamp color and electrical characteristics stabilize.

Since a metal halide arc tube is smaller than that of a mercury lamp of equivalent wattage, it operates at a higher temperature. Hence, the time to cool down is longer and the time to reignite is longer. The hot restrike time in a conventional metal halide lamp can be 15 minutes or longer.

The high-pressure sodium lamp, once started, warms to full light output in approximately 10 minutes, during which time the color changes. The operating pressure of a high-pressure sodium lamp is lower than that of a mercury lamp and the restrike time is shorter. It usually restrikes in less than 1 minute and warms up in 3 to 4 minutes.

The light output of all HID lamps varies to some degree with cyclic changes of the line voltage. This flicker depends on the lamp type and the ballast circuit. Flicker can be an important consideration for HID lamps. In many lighting applications the stroboscopic effect from HID sources is not a problem. It can, however, be annoying to spectators in games such as tennis or Ping-Pong. Operators of rotating machinery can find it distracting. To minimize the stroboscopic effect, systems with a flicker index of 0.1 or less are suggested, or luminaires can be wired alternately on different phases of a three-phase system.

HID lamps require a current-limiting device, usually in the form of a transformer or ballast. Although HID lamps are optimized to operate at full power, some level reduction and energy savings can be obtained through dimming. Some light sources are more suitable for dimming than others. The slow warm-up and hot restrike delay, which are characteristic of HID sources, also apply to dimming. HID lamps respond to changes in dimmer settings much more slowly than incandescent or fluorescent sources; delays between minimum and maximum light outputs vary 3 to 10 minutes. However, instantaneous dimming is available over a limited range for some lamps.

HID lamps should be started at full power and the dimming should be delayed until the lamp is fully warmed up. Properly designed dimming systems ensure this process.

In addition to speed, the range of response is not comparable to that of incandescent or fluorescent dimming; however, in most cases the lamp efficacy and color are reasonably good quality down to 50 percent dimming or less. HID lamps are therefore not well suited to dramatic lighting or theatrical effects. Their use is satisfactory for many energy management applications. In these applications, the slow response of HID lamps provides additional system stability and minimal occupant distraction.

Types of Lamps, continued

Light-Emitting Diodes (LEDs)

LEDs have been used for years as pilot lights and indicator lights on much of the AV equipment used today. Common applications are traffic signals, message signs, commercial advertising signs, and exit signs. Lately they are used in color graphical commercial advertising signs and large scale outdoor full color video displays. Higher intensity LEDs are designed primarily for automotive exterior lighting, such as tail lights and turn signals.

Other high-luminance lighting designs are now incorporating LEDs. They are used for various accent lighting applications, particularly where color or changing colors are required. Some theatrical applications are ideal for LEDs. As this type of light becomes more efficient, it is beginning to find its way into more traditional architectural applications.

The efficiency of LEDs is currently slightly better than that of incandescent lights. Research and future developments are likely to improve the efficiency of LEDs in a way that would enable them to compete with the fluorescent lighting. Another advantage is their long life. LEDs are rated between 50 000 and 100 000 hours of operation depending on how they are used.

LEDs may be dimmed to 0.05 percent of the maximum using appropriate drivers (transformers) and dimming components.

Efforts have been undertaken to develop LED devices that produce white light. One method is to combine red, green, and blue LED chips in the same package to produce white light. LED devices have been combined with photoluminescent phosphors similar to fluorescent lamps. The short-wavelength energy from the indium gallium nitride (InGaN) LED device induces fluorescence in the phosphor that is encapsulated in the epoxy surrounding the LED chip. The photoluminescent phosphor emits a broad spectral distribution, which in combination with the spectrum of a blue LED produces a blue-white color.

Luminaires (Light Fixtures)

The more accurate name for a light fixture is luminaire. A luminaire is a device to produce, control, and distribute light. It is a complete lighting unit consisting of the following components:

- One or more lamps
- Optical devices designed to distribute the light
- Sockets for positioning, protecting, and connecting the lamps to a supply of electric power
- Mechanical components required to support or attach the luminaire

This section provides information on the most common types of luminaires, their use, and a general understanding about their application.

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Luminaires (Light Fixtures), continued

Luminaires are designed and manufactured for all common types of electric lamps. Luminaires are commonly available for the following types of lamps:

- Incandescent filament including tungsten-halogen
- Fluorescent
- HID including metal halide, high-pressure sodium, and mercury

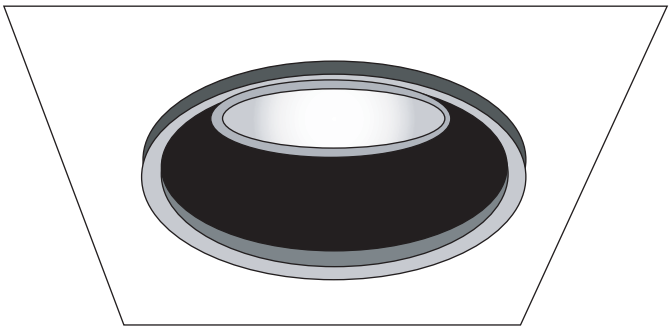
The size, materials, thermal properties, photometric performance, and power requirements of a luminaire depend on the type of lamp used. For example, lamps that produce a large amount of IR radiation (heat) require luminaires that are vented for convection, and fluorescent lamps that are sensitive to environmental temperature must be protected from low air temperatures.

Direct Fixtures

Recessed Downlights

Recessed downlights (see Figure 12.7) are general-purpose luminaires designed to provide general or ambient lighting in a space. They are recessed into the ceiling and designed to produce illuminance on a floor or workplane. Certain types have concentrated luminous intensity distributions designed for spaces with computer video display terminals (VDTs). It is often necessary to augment these luminaires with other types that raise the wall luminance and add the vertical illuminance to the space. Recessed downlights can be grouped by size.

Figure 12.7
Recessed lighting



Luminaires (Light Fixtures), continued

The two basic types of recessed downlights are:

- Incandescent, compact fluorescent, and metal-halide lamp downlights, which usually have modest apertures and can exhibit very low luminance at high viewing angles.
- Fluorescent lamp troffers, which use large fluorescent lamps and are usually used with a suspended tile ceiling system with sizes ranging from 152 mm (6 in) by 1219 mm (48 in) to 310 cm^2 (48 in^2).

Ceiling-Surface–Mounted Luminaires

Ceiling-surface–mounted luminaires can provide general or ambient lighting. In addition, some of the light can be emitted upward to produce a higher ceiling luminance than recessed or surface-mounted downlights. Examples include fluorescent troffers, compact fluorescent downlights, incandescent and tungsten-halogen downlights for task lighting on kitchen counter tops, and wraparound lens luminaires.

Wall-Wash Luminaires

Wall-wash luminaires are used to produce a distribution of illuminance/luminance on a wall that, though not necessarily uniform, changes gradually from high values at the top of the wall to lower values down the wall. Many wall-wash luminaires are designed to achieve an illuminance ratio from the top to the bottom of the wall of 10:1 or less. Wall-wash luminaires can be recessed or surface mounted. These can be grouped by size.

The two basic types of wall washers are:

- Linear fluorescent wall washers usually have a reflector that allows them to be placed close to the wall, and are available recessed or surface-mounted.
- Other wall washers, including compact fluorescent, incandescent, halogen, or compact metal halide lamp luminaires, are smaller units that, if recessed, have a modest aperture and therefore can appear like other downlights in the space. They also can be surface mounted.

Videoconference Luminaires

Videoconference luminaires are a combination of a recessed fluorescent troffer with light distribution characteristics similar to the linear wall-wash luminaires. They provide an asymmetrical distribution of light. This puts most of the light in the direction of participants in a videoconference. Little or no light is directed towards the camera or any video display.

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Luminaires (Light Fixtures), continued

Accent Luminaires

Accent luminaires are either ornamental or designed to produce patterns of light that are ornamental. They can be ceiling recessed, surface mounted, or wall mounted. Ceiling-mounted accent luminaires use incandescent, tungsten-halogen, compact fluorescent, or low-wattage metal halide lamps. The lamps are adjustable or fixed.

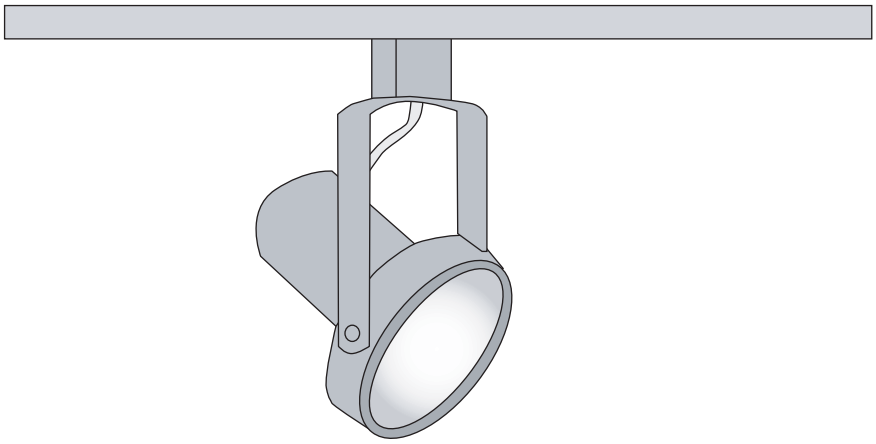
Sconces and other wall-mounted accent luminaires use incandescent, tungsten-halogen, or compact fluorescent lamps. Since they are often mounted low, they are often in the field of view, and therefore the designer should be aware of the potential for glare. Translucent shields, which vary in size or shape, are often used for lighting hallways, stairways, doorways, and mirrors.

Wall-mounted luminaires with opaque shielding completely conceal the source from normal viewing angles and are strongly directional in light distribution. Downlight luminaires are often mounted on a wall for accent and display lighting, whereas uplight luminaires can be used for general, indirect lighting. The extent to which wall-mounted luminaires protrude from a wall is often subject to code restrictions such as disability access regulations.

Track-Mounted Luminaires

Track (see Figure 12.8) refers to a system that includes luminaires and a track or rail that is designed to both provide mounting and deliver electric power. Track is generally made of linear extruded aluminum, containing copper wires to form a continuous electrical raceway. Some varieties can be joined or cut, and others set into a variety of patterns with connectors. Track is available in line or low-voltage, with remote transformers available for the low-voltage equipment.

Figure 12.8
Track light



Luminaires (Light Fixtures), continued

Track can be mounted at or near the ceiling surface, recessed into the ceiling with special housing or clips, or mounted on stems in high-ceiling areas. It also can be used horizontally or vertically on walls. Mechanical considerations may limit certain mounting arrangements, particularly for wall-mounted installations. Track can be hardwired at one end or at any point along its length. Flexibility can be added with a cord-and-plug assembly to supply power rather than with hardwiring.

A variety of adjustable track-mounted luminaires are available for attachment at any point along the track. These luminaires come in many shapes and styles, housing a large assortment of lamps, including line and low-voltage. In addition, a number of luminaires are designed to create special effects for decorative applications. Track luminaires use incandescent, tungsten-halogen, compact fluorescent, metal halide, or high-pressure sodium lamps.

Indirect Luminaires

Indirect luminaires are designed to provide general or ambient lighting by illuminating the ceiling with compact fluorescent, metal halide, or even high-pressure sodium lamps. They contain reflectors that help produce a wide distribution so that they can be mounted close to the ceiling. Pendants or cable usually suspends them, but some types are post-mounted from the floor.

Linear indirect luminaires are designed to use linear or compact fluorescent lamps to provide general or ambient lighting by illuminating the ceiling. Reflectors are used to produce wide distributions and permit short suspension distance. Linear indirect luminaires can be suspended from the ceiling by pendants or cable or, in the case of modest spans, mounted by their ends. They also can be mounted on the walls to form a perimeter lighting system.

Suspended linear indirect luminaires usually have a luminous intensity distribution that is symmetric about the lamps' axis, whereas wall-mounted linear indirect luminaires typically have an asymmetric distribution.

Linear direct-indirect luminaires are similar to the suspended indirect but provide some downward directed light. Variations are available for changing the proportion of upward and downward light.

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Luminaires (Light Fixtures), continued

Cove Luminaires

Cove luminaires are designed for placement in an architectural cove or have the shape that when mounted on the wall produces a cove and its lighting effect. The simplest form of this luminaire is a fluorescent lamp strip, providing ballast and lamp sockets. More elaborate forms provide reflectors to control near-wall and ceiling luminance.

Low-Voltage Lighting

Low-voltage lights are used as small spot lights to light specific elements within a room. The lamps used within these types of lights are designated as MR-16. These types of lights use a remote transformer that steps down the voltage to the appropriate level. Special dimmers are usually required to control these types of lights.

NOTE: Since the lighting design within a room can add substantially to the audience perception of the quality of the AV presentation, AV designers should pay special attention to creating a professional and flexible lighting plan.

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Chapter 13
Interior Design

The environment in which an audiovisual (AV) system is installed is an important factor in the system's success. Many architectural parameters must be closely coordinated throughout the course of a design to ensure a system performs as intended. This chapter addresses the most important interior design considerations for the AV designer.

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Overview

Introduction

The material contained in this chapter is intended for systems designers already familiar with the concepts and standard practices of audiovisual (AV) design integration. This chapter discusses the interior design principles associated with AV technologies, including space planning, room finishes, human factors and ergonomics, furniture layout, and AV device integration.

The intent of this chapter is to address space planning as it relates to rooms and facilities with communications as a primary function.

When designing a space for communication a greater importance is placed upon the interaction between presenters, participants, and the presentation material. Presentation capabilities can be greatly impacted by space planning and interior design. For example, ceiling height and image size require coordination and one can significantly impact the other during design.

Ergonomics

Ergonomics is defined as a group of factors or qualities in the design of a workplace or the equipment used by people at work that contribute to comfort, safety, efficiency, and ease of use. Ergonomics also is called human factors engineering.

The ergonomics of a space should be considered so that people can interact with the space and equipment in a natural, healthy, comfortable, and efficient manner.

AV systems designers should understand how a person interacts with the space and design of a room that takes these issues into account.

Several international standards have been adopted for the ergonomic design of spaces and communication systems including, but not limited to, International Standards Organization (ISO) standards:

- ISO 11064, *Ergonomic Design of Control Centers*
- ISO 9241, *Ergonomic Requirements for Office Work with Visual Display Terminals*
- ISO 9921, *Ergonomics—Assessment of Speech Communications*

Space Planning for Presentation

Introduction

The emergence of new technologies and new ergonomic standards and an increase in public awareness regarding workplace health have impacted space layout and furniture design. The human factors involved in presentation and viewing must be considered in the facilities design of presentation spaces. The space air quality, lighting quality, sound quality, and size and shape require consideration to properly optimize for AV communication.

Adjacency and proximity of AV support spaces (e.g., control rooms, projection rooms, interpretation booths, breakout rooms, telecommunications rooms (TRs), and electrical rooms) in relation to primary presentation spaces also should be considered as part of space planning.

Room Environment

The provision of an appropriate working environment is essential for spaces that must accommodate auditory or visual tasks. Environment variables that should be addressed are air quality, lighting quality, sound quality, and size and shape of the space.

Air quality and temperature play an important part in keeping participants alert.

NOTE: Refer to Chapter 9: Heating, Ventilating, and Air Conditioning (HVAC), for more information.

Lighting quality should be sufficient and suitable for all visual tasks.

NOTE: Refer to Chapter 12: Lighting, for more information.

Sound quality should be designed based on the auditory needs of the space. Where speech communication is important, ambient noise levels (e.g., HVAC noise, equipment noise, buzz from fluorescent lights, paper shuffling) need to be considered.

NOTE: Refer to Chapter 11: Acoustics, for appropriate ambient noise levels of different communications spaces. Additional sound quality requirements for sound intrusion into critical listening spaces and speech privacy also should be considered.

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Floors

Floor space greatly impacts the effectiveness of communications. The size, shape, slope, finish, and layout of the floor space should all be considered in initial space planning sessions.

The size of the floor space should take into consideration any audience seating requirements, ingress and egress requirements, presenter space requirements, and communications equipment space requirements. Support spaces also may be required, including equipment closets, control rooms, green rooms, prefunction or lobby spaces, projection rooms, light/sound locks, and storage closets.

When sizing a space, a room width should not be sized greater than twice the room length or a room length greater than twice the room width. Presentation spaces that significantly exceed a 2:1 aspect ratio may present additional design challenges.

For certain presentation spaces, the floor may be elevated for better audience viewing of the presenter and the presentation. Rooms such as auditoria, lecture halls, recital spaces, and movie theaters can benefit from a tiered or sloped floor. Special considerations must be made to accommodate local disability access requirements in tiered or sloped floor spaces.

The material used in floor finishes impacts the acoustics of the room.

NOTE: Refer to Chapter 11: Acoustics, for more information on appropriate acoustic treatments for various presentation spaces.

Light reflectivity of the flooring can impact video conferencing and broadcast environments where the floor will be within the viewing area of a camera. Bold or busy floor colors and detailed patterns can be difficult for cameras to interpret.

Several AV devices may be located in the floor. Raised floor and access floor systems may be used as part of the communications system infrastructure.

NOTE: Refer to Chapter 5: Infrastructure, for more information.

Floor poke-thrus, monuments, and recessed floor boxes may be provided beneath tables, podiums, and throughout presentation spaces. The sizes of these devices vary considerably. Certain floor boxes may require separate firestopping and structural requirements based upon the size of the floor opening or location.

Additional communication devices may be located within the floor space, including technology podiums, microphone stands, floor-standing loudspeakers, projection screens, whiteboards, poster boards, and cable management.

Seating Area

The design of seating area within a presentation space is intended to provide an optimal viewing and listening experience while maintaining a comfortable and safe environment for all participants.

Designing the seating area involves evaluating multiple parameters simultaneously. These include image size, sightlines, seat size, work surface requirements, and row and aisle spacing—all based on task requirements.

Viewing Area

As a part of the seating area design process, the optimum viewing area must be determined in conjunction with the room shape, seating capacity and purpose. This is an iterative process that works with each of these variables simultaneously.

The optimum viewing area is determined by the video display size, location, and orientation within the room. The size of the display is proportional to the farthest viewer in the room and either dimension can be the starting point in laying out a room.

The acceptable distance that the farthest viewer can be from the center of the display is based on the height (H) of the image. A factor of 6 is typically used for tasks that require some detail but do not include reading of small fonts (less than 14 points at 100 percent zoom in a typical 1024 × 768 image). In this case, the farthest viewer should be no more than 6 times the height of the image from the center of the display, as in the following formula:

$$\text{Farthest viewer distance} = 6 \times H$$

Conversely, the image should be at least one sixth of the farthest viewer distance:

$$\text{Minimum image H} = \text{Farthest viewer distance} / 6$$

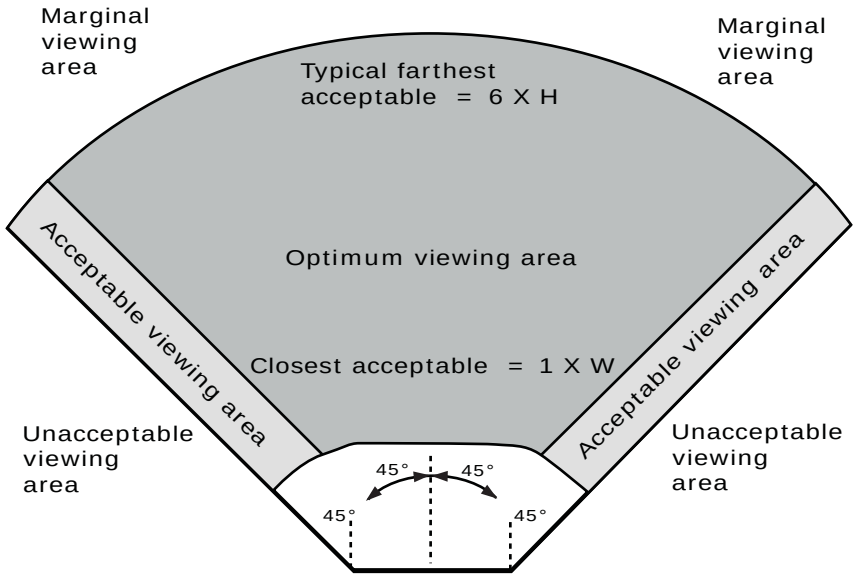
For tasks requiring more detail and smaller font reading, a factor of 4 may be used instead of 6, increasing the minimum screen height and decreasing the farthest viewer distance. For video applications that do not require perception of text or detailed images, a factor of up to 8 may be used, which allows for a smaller image size or longer viewing distances.

In addition to the farthest viewer limitations, limits to the off-axis viewing of an image also are present. The optimum viewing angle is considered to be 45 degrees horizontally to each side of the center axis of the display. The less optimum, but still acceptable, viewing angles include 45 degrees horizontally to an axis at the left and right edges of the display.

Seating Area, continued

These parameters work together to establish the optimum and acceptable viewing area, as indicated in Figure 13.1.

Figure 13.1
Optimum and acceptable viewing areas



H = Height
W = Width

Seating Layout

Seating area must ensure adequate space for comfortable ingress and egress of the room. The specific dimensions of these spaces are often defined by local authorities, but the guidelines for fixed or movable tables and chairs are:

- Back aisle—0.9 meters (m [3 feet (ft)]) to 1.2 m (4 ft) clear (behind chairs)
- Side aisle—0.9 m (3 ft) minimum
- Between tables—1.2 m (4 ft) minimum
- Center aisle—1.2 m (4 ft) minimum

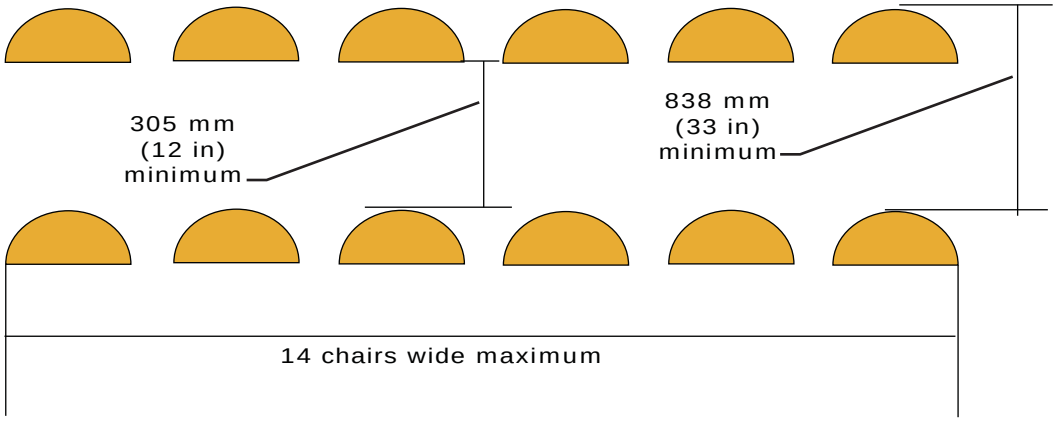
Workspace also may be required. The dimensions of the workspace area for each seat are based on the task requirements. For example, if the task requires the use of notebook computers or information within a binder, adequate space should be allocated for each seat for these tasks.

Seating Area, continued

The guidelines for movable seating and tables are different from permanently installed seating. Typically, the AV systems designer should provide for 1.2 m (4 ft) between tables and 0.9 m (3 ft) between a table and the side aisle.

Figure 13.2 identifies guidelines for the setup of movable chairs. The seating plan for these types of movable seats must comply with the local authority having jurisdiction (AHJ). For rows wider than 14 chairs, the auditorium seating guidelines should be used.

Figure 13.2
Typical requirements for portable chair setup



in = Inch
mm = Millimeter

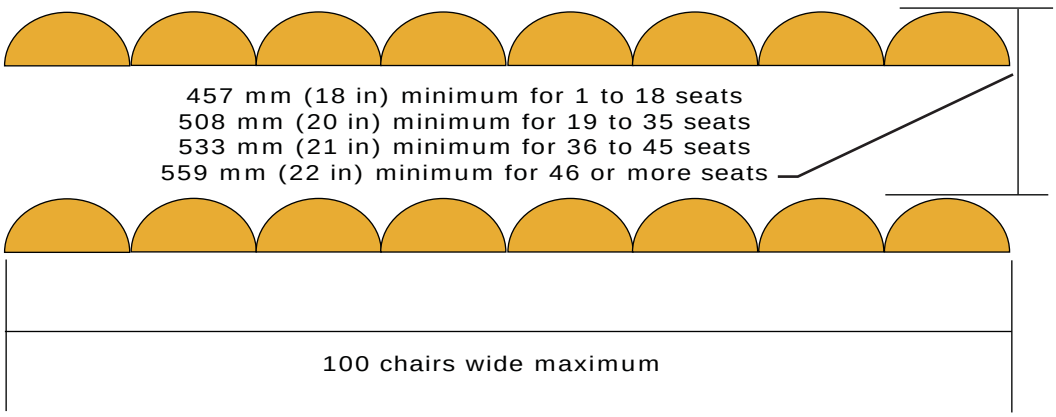
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Seating Area, continued

Permanently installed auditorium-style seating called continental or fixed seating (as shown in Figure 13.3) must conform to the AHJ.

The example assumes that an aisle is provided at each end of the row to allow audience exit paths. If the row-to-row depth is increased, then the number of seats in the row can also be increased.

Figure 13.3
Typical requirements for auditorium-style setup



in = Inch
mm = Millimeter

Considerations for permanently installed auditorium-style seating should include the following parameters:

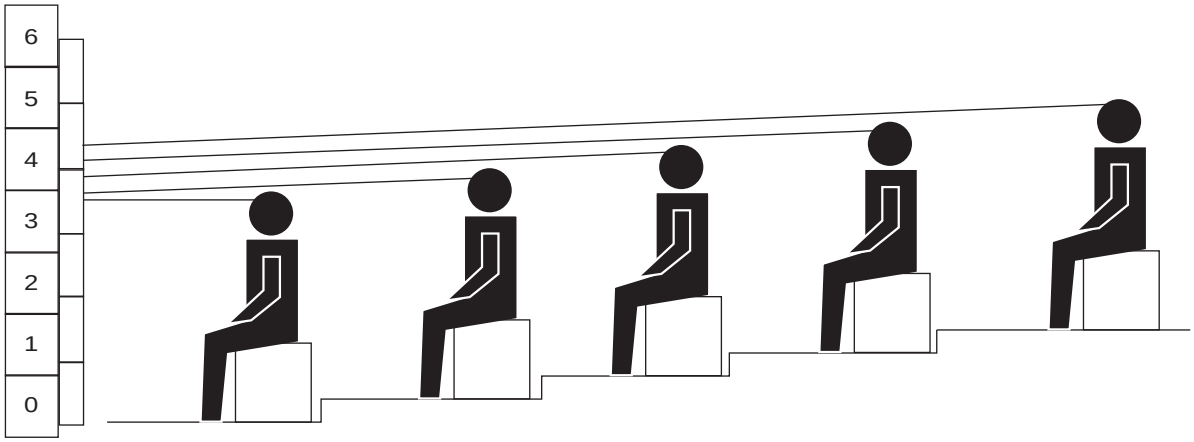
- Rows should be spaced not less than 762 millimeters (mm [30 in]) back-to-back with 914 mm (36 in) to 1016 mm (40 in) unless required otherwise by a code.
- Seats should not be less than 483 mm (19 in) side-to-side, with 508 mm (20 in) preferred. For pseudo-staggered seating, seats can be 483 mm (19 in), 508 mm (20 in), and 533 mm (21 in).
- The seat should provide a natural posture for viewing. Vertical and horizontal positions should not lead to an uncomfortable head position.
- Comfort in horizontal line of sight (LoS) seating areas beyond 15 degrees off center image axis may be improved by angled or curved row seating.

Seating Area, continued

Sightlines

AV sightlines (see Figure 13.4) dictate the seating layouts of a communications space. A sightline study determines the most appropriate seating layout for a clear field of view including the lowest visible point on the display wall, nearest viewers' LoS, farthest viewers' LoS, distortion of image from off-axis seat locations, and other ergonomic factors for a preferred field of vision and viewing comfort tolerances.

Figure 13.4
Sightlines



In Figure 13.4, lines are drawn from the eye level of each seated row passing just over the heads of the viewers in the next row. The scale on the left represents the front wall where an image would be displayed. The highest hit point of the lines drawn to the front wall should be the lowest point for the bottom of the image.

The sightline parameters that designers should consider when conducting a sightline analysis include:

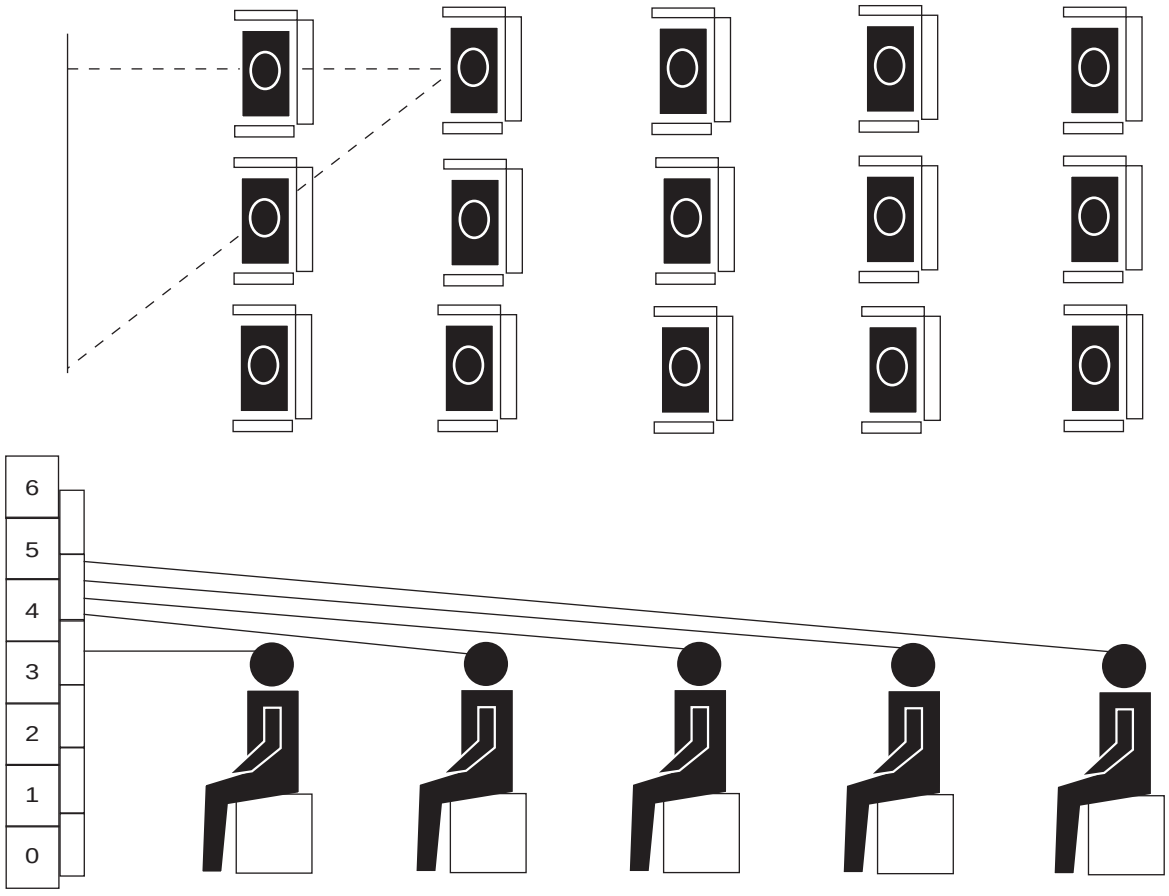
- Average seated head height of 1.2 m (4 ft)
- Average seated eye height of 1.1 m (3.5 ft)

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Seating Area, continued

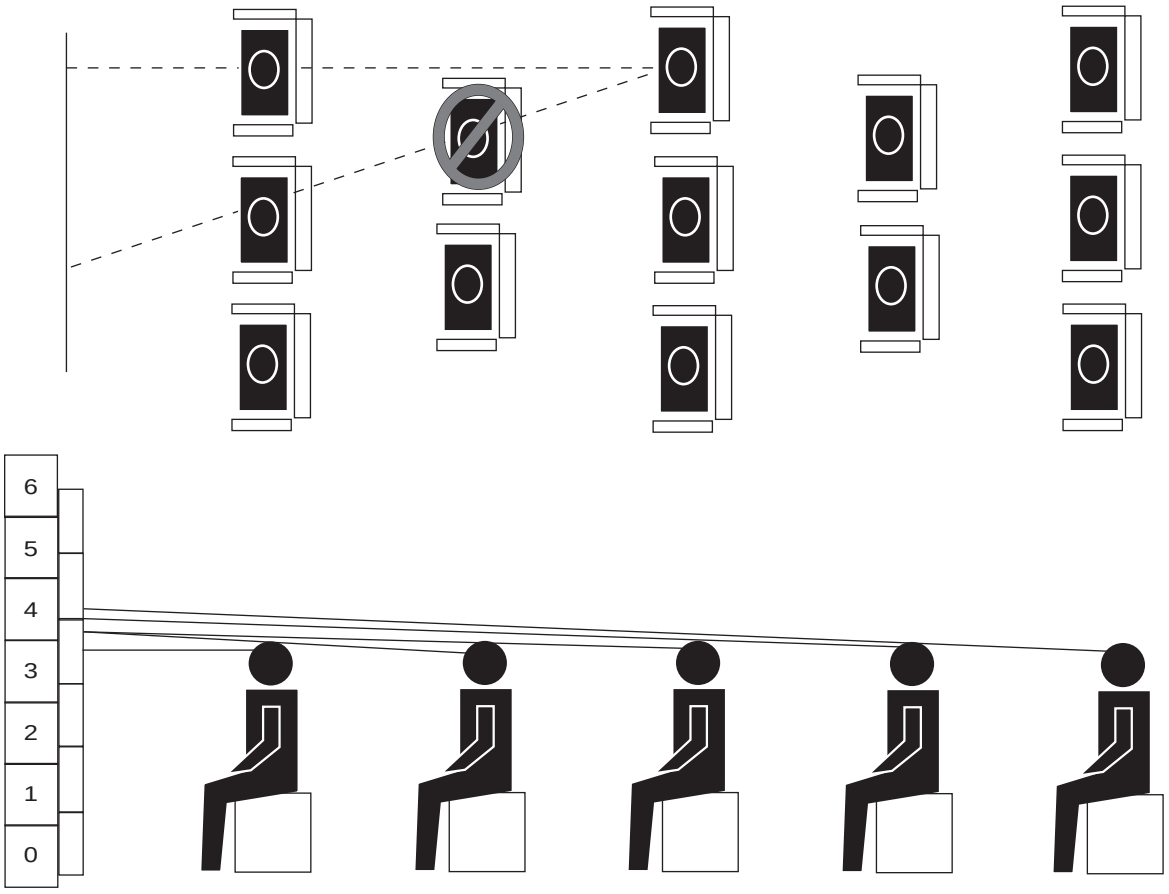
One way to improve sightlines in a presentation space is to provide a sloped or tiered seating layout. The AV systems designer can experiment with alternative seating arrangements to create the best viewing environment for the audience. Seating can be aligned or staggered, floors can be flat, sloped or tiered (see Figures 13.5, 13.6, 13.7, and 13.8), and the distance between seats can be varied.

Figure 13.5
Flat floor—seats aligned



Seating Area, continued

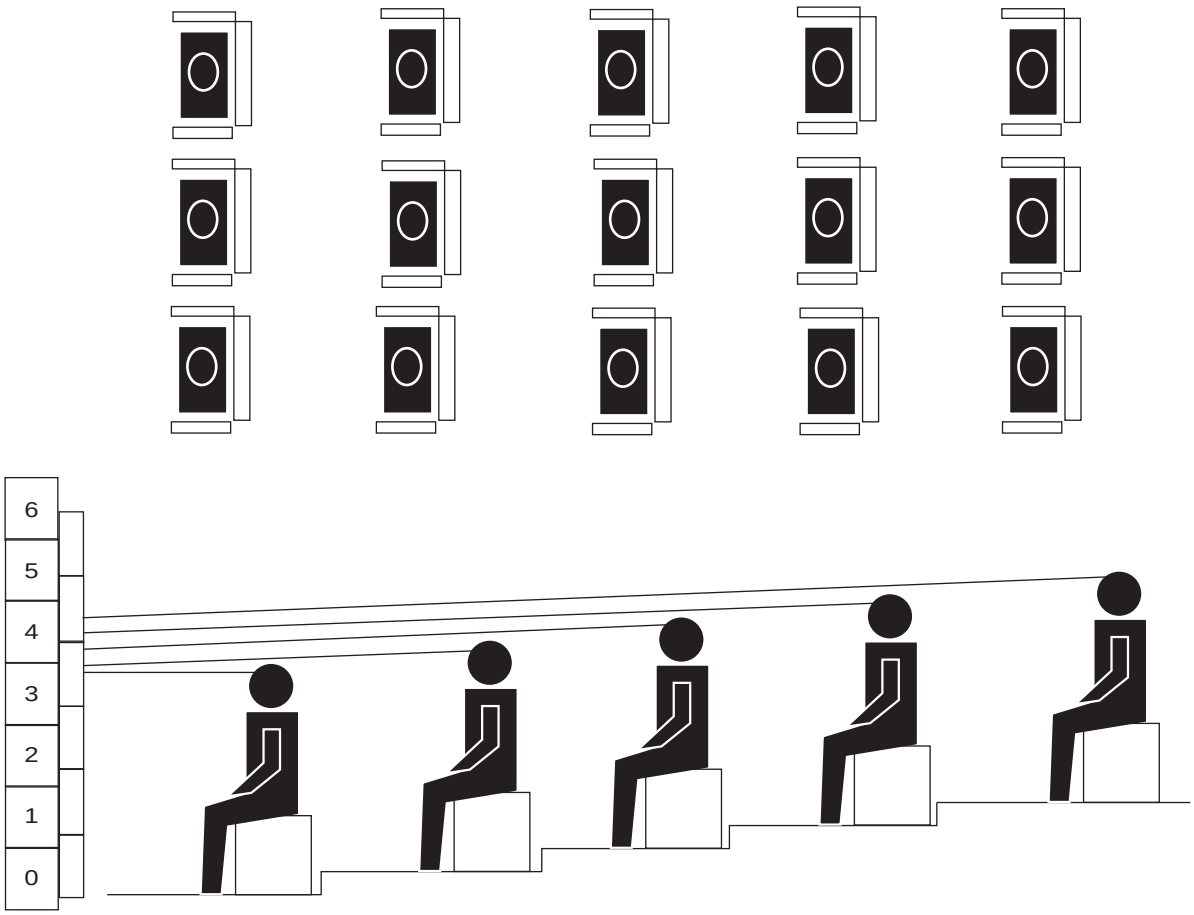
Figure 13.6
Flat floor—seats staggered



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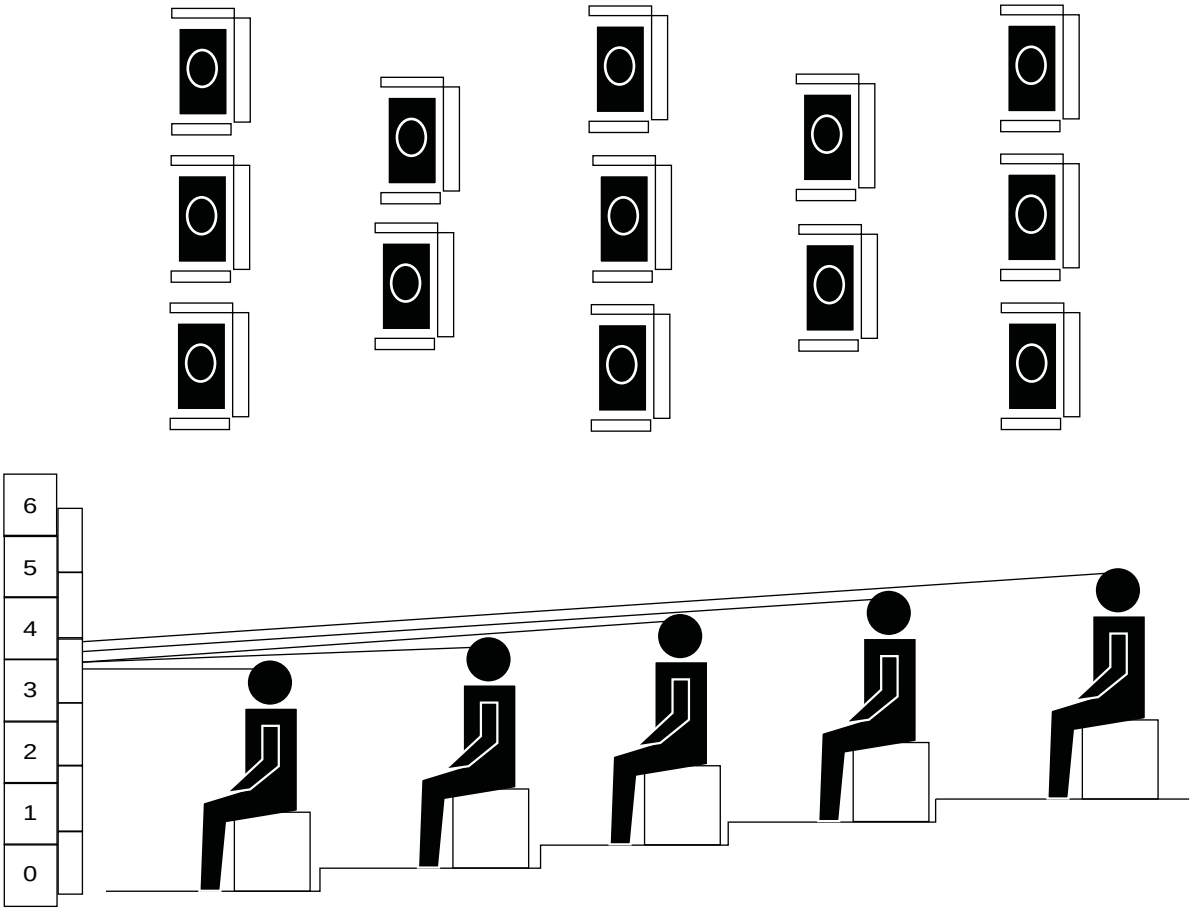
Seating Area, continued

Figure 13.7
Tiered floor—seats aligned



Seating Area, continued

Figure 13.8
Tiered floor—seats staggered



Typical sightline techniques include single-row vision and double-row vision seating layouts. In single row vision, the vertical sightline of a viewer passes over the heads of the persons in the first row ahead, as illustrated in Figures 13.5 and 13.7.

In double-row vision, the vertical sightline passes between the heads of the persons in the first row ahead and over the heads of the persons in the second row ahead, as illustrated in Figures 13.6 and 13.8.

Ceilings

The ceiling height, color, material, lighting layout, and lighting zoning require special consideration when designing a communications space. Likewise, other systems incorporated into the ceiling plenum such as structure, HVAC ductwork, lighting fixtures, and sprinkler heads impact the location of communications systems in the space.

In presentation spaces, audience size, sightlines, and image height requirements should dictate the minimum ceiling height.

NOTE: Larger rooms require higher ceilings to accommodate appropriate image sizes.

Ceiling finishes greatly affect the acoustics of a space. AV devices can generally be installed in any ceiling finish including hard lid, ceiling tile, exposed ceiling, fabric panel systems, and a number of specialized ceiling finishes.

NOTE: Refer to Chapter 11: Acoustics, for suitable room acoustics.

Dark ceiling colors absorb light and are often used with exposed or unfinished ceiling, front and rear projection rooms, control rooms, and movie theaters to reduce unwanted ambient light. Lighter ceiling colors are typically preferred in most other presentation spaces. Ceiling finishes for video conference and video broadcast rooms should avoid high gloss finishes or bold colors that may interfere with camera image capture.

Several building systems are located in ceiling space and require coordination with the AV systems. Lighting layouts often conflict with ceiling-mounted projection systems and placement of ceiling mounted loudspeakers. Pendant fixtures located in the center of a presentation space can interfere with light projection paths and image sightlines.

Some lighting fixtures may throw unwanted light or create image glare on communication displays.

NOTE: Refer to Chapter 12: Lighting, for detailed information on lighting criteria for communications spaces.

Several AV devices may be located in a ceiling, including loudspeakers, projection screens, displays, motorized lifts, antennae, transmitters, sensors, infrastructure, cabling, and other similar components. These AV devices can be provided in a variety of finishes to match a ceiling décor.

AV designers have to work around sprinkler heads that are installed in the ceiling of a room. The location of the sprinkler system often interferes with an AV system design. For example, a sprinkler head may interfere with the location in which the projector should be mounted or may be in the projector's LoS. In new buildings under construction, the AV designer should coordinate AV needs with the architect so that, if possible, the architect can keep the specific areas free of obstructions.

Walls

Color, reflectivity, texture, and surface have an impact on AV system design.

Wall color and texture play an especially important role in rooms with video conferencing and video recording. Bold or busy wall colors and patterns create distracting backgrounds for video conferencing. Detailed patterns with contrasting colors and thin lines are difficult for cameras and codecs to interpret. Also, colors that resemble skin tones tend to wash out participants captured by the video conference camera.

Dark wall colors have a tendency to absorb light. Dark colors are often used in front and rear projection rooms, control rooms, and movie theaters to absorb unwanted ambient light. Lighter wall colors are typically preferred in most other presentation spaces.

People typically do not like working in windowless environments. As such, many communication rooms incorporate windows and glass to provide an ergonomic, comfortable space. Window treatments including sun shades, blackout shades, light baffles, or drape may be required for light control and acoustic room treatment.

The wall surface determines much of the acoustics in a space. Typically most wall surfaces are acoustically reflective. Reflective wall surfaces such as glass, drywall, wood paneling, and stone can create highly reverberant spaces. Parallel reflective wall surfaces also can create unwanted flutter echoes.

Reverberant rooms cause minor problems for participants in the room (mainly fatigue and reduced speech intelligibility) because of the human mind's ability to concentrate on the original source. However, communication systems such as audio conferencing, video conferencing, and speech reinforcement are greatly impacted by room reverberation and reflections as the systems cannot easily delineate the original source from the reverberant sound.

Wall surfaces that are acoustically absorptive include acoustic paneling, heavy drapes, and fabric wrapped panels. These surfaces can be used on parallel walls and highly reflective walls to help reduce unwanted acoustic reflections and reverberation.

Several AV devices are located on walls such as loudspeakers, projection screens, control switches, button panels, input/output wall plates, antennae, flat panel displays, and video conference units. Back boxes, structural backing, and conduit may be required.

NOTE: Refer to Chapter 5: Infrastructure, for more information.

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Millwork and Furniture

Special considerations should be made for millwork and furniture incorporating AV equipment. This includes cabinets, tables, dais, benches, podiums, credenzas, niches, and a variety of other custom furniture work.

Millwork is defined as ready-made and custom fit woodwork such as installed cabinetry, credenzas, shelving, doors, and baseboards. Furniture includes movable items, such as lecterns, technology carts tables, chairs, and whiteboards.

Millwork and furniture incorporating AV systems should be located to provide easy accessibility for a presenter or operator. This position is generally near the front of the room, but it may be an area to the side or back of the room for specialized operator areas.

Millwork and furniture color, texture, and material affect performance of AV systems. High gloss or polished work surfaces can reflect task lighting into persons' eyes or back into a camera lens. Dark surfaces can absorb task lighting and display poorly in video conference and broadcast sessions. Hard surfaces (e.g., marble and stainless steel) create challenges for cable management and custom AV integration.

Hard furniture surfaces also impact the acoustics of the room and can lead to longer reverb times and flutter echoes.

NOTE: Refer to Chapter 11: Acoustics, for recommended criteria of presentation spaces.

Millwork with AV equipment requires proper sizing, ventilation, access, and cable management. The finish of components installed into millwork should be properly coordinated with the architect and owner. Finishes for visible AV plates and devices should match furniture finishes whenever possible.

Audiovisual (AV) Planning

Introduction

A variety of AV components integrate into millwork and furniture in presentation spaces. Interior design requirements regarding ergonomics, installation, and finishes of these AV components require additional coordination and design.

In addition, a variety of AV support spaces including equipment rooms (dedicated to both AV and mixed main and intermediate telecommunications rooms), control rooms and operations centers, front and rear projection rooms, and other storage and archival spaces.

Standards and codes have been adopted for ensuring that a building is accessible by disabled persons. The standards include:

- Requirements for providing systems to assist the hearing impaired.
- Space planning requirements for accessibility of the visually impaired.
- Wheelchair accessibility to all rooms and systems.
- Equal access to all services within the building.

The local standards and codes impact communications systems layouts, space planning, equipment locations, and digital signage and can dictate certain interior design criteria.

Audiovisual (AV) Systems in Millwork

AV equipment is frequently incorporated in conjunction with data and power for laptop connectivity. Coordination is required between multiple trades including electrical contractor/consultant, telecommunications contractor/consultant, furniture vendor, architects, interior designers, and owners.

Typical AV equipment found in tables, benches, and dais include microphones, loudspeakers, personal displays, graphical or button controlled user interfaces, switching electronics, connectivity for laptops, document cameras, and other devices. AV integration may require custom cutouts in the table. Tolerances for cutouts can be as stringent as 0.8 mm (1/32 in). Problems stemming from this issue are best circumvented if the furniture vendor provides the necessary cutouts, cable paths, and access doors to accommodate AV installations. However, this is not always possible due to the schedule of table installation or procurement of AV devices.

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Audiovisual (AV) Systems in Millwork, continued

AV equipment under work surfaces should be located to avoid persons' legs and chair arms and meet the disability access requirements. Appropriate table workspace should be provided for laptops, papers, and binders based on room use and coordinated with all of the AV equipment including microphones and table boxes.

Table boxes should provide easy viewing of all connectors from a standing position. Personal displays should be positioned directly in front of the viewer with sizes typically ranging from 381 mm (15 in) to 483 mm (19 in).

Movable and segmented tables require an extra level of coordination. Power, data, and AV cabling should be protected for table transport. Connections between table segments should be limited, easily identifiable, and properly protected from excess strain that might occur during table arrangement. System connections to movable tables can be provided at floor boxes, floor monuments, or wall plates. The number and types of connection points should be easily identifiable by reducing the number of connection points and color-coding connectors and providing intuitive connectivity using suitable cable management practices.

AV equipment can be housed in a dais, credenzas, cabinetry, and technology carts. Custom equipment racks for installation in millwork can be provided in these locations. The millwork design must accommodate the following:

- Adequate depth for equipment rack and cable management—Preferred depth of 559 mm (22 in) to 762 mm (30 in) with the minimum depth of 483 mm (19 in) for 406 mm (16 in) deep equipment rack and 76 mm (3 in) of cable management.
- Adequate ventilation for equipment rack heat load—Ventilation can be passive or active.
- Adequate height for all AV equipment—Equipment racks can be placed side-by-side to provide additional space; all components should be placed according to the local disability access requirements.
- Adequate front and rear access for service and maintenance of AV components—Millwork without rear access can be provided with slide-out and rotating equipment racks.
- Adequate room for the presenter and the casework compliant with all local disability access requirements

Audiovisual (AV) Support Spaces

AV support spaces are typically:

- Equipment rooms (ERs).
- Control rooms.
- Projection rooms (front and rear).
- Mixing locations.

Audiovisual (AV) Control Rooms

A control room, if required, must be designed to meet the needs of both equipment and personnel. The room layout (see Figure 13.9) should address ergonomic design issues to meet the needs of the technicians working within the room. Equipment rack access should meet the 914 mm (36 in) clearance per standard telecommunications requirements.

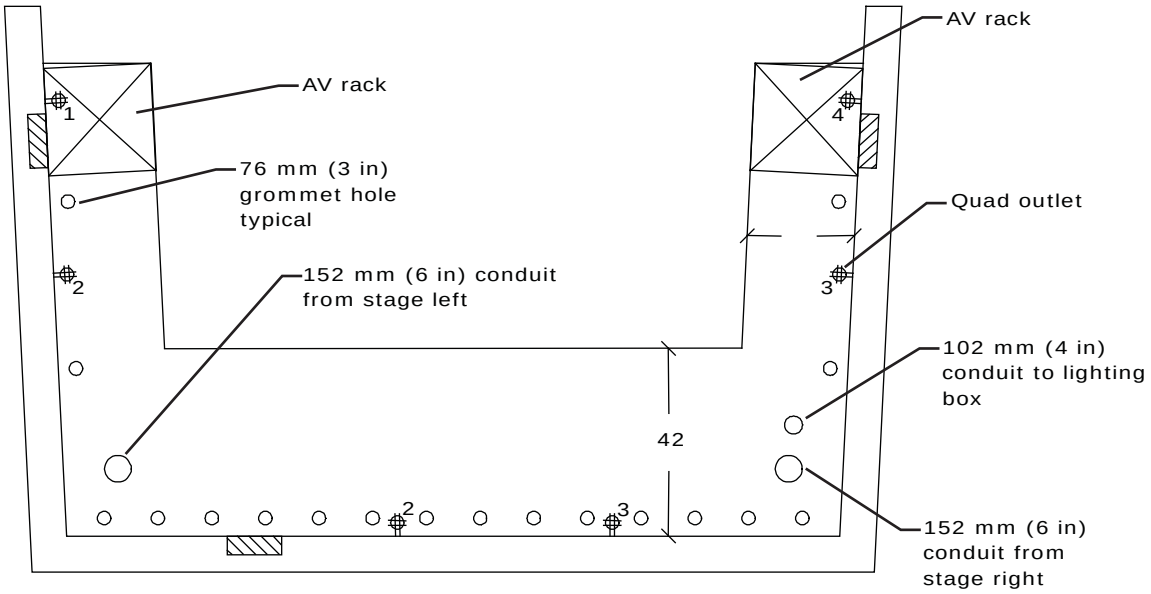
Designers should ensure sufficient space for current needs and future expansion and also ensure sufficient space for operators.

The design of a control room should specify:

- Equipment layout.
- Operators' orientation and equipment access.
- Built-in furniture requirements.
- Infrastructure details (electrical, structural, and mechanical).

Audiovisual (AV) Support Spaces, continued

Figure 13.9
Control room layout plan



= Circuit number for mix booth
AV = Audiovisual
in = Inch
mm = Millimeter

NOTES: Grommet's center should be 102 mm (4 in) from the nearest wall

All outlets on technical power 457 mm (18 in) above finished floor.

AV rack quad outlet should be mounted next to terminal panel.

Audiovisual (AV) Support Spaces, continued

Front Projection Rooms and Projection Booths

The design of a front projection room (see Figure 13.10) typically addresses:

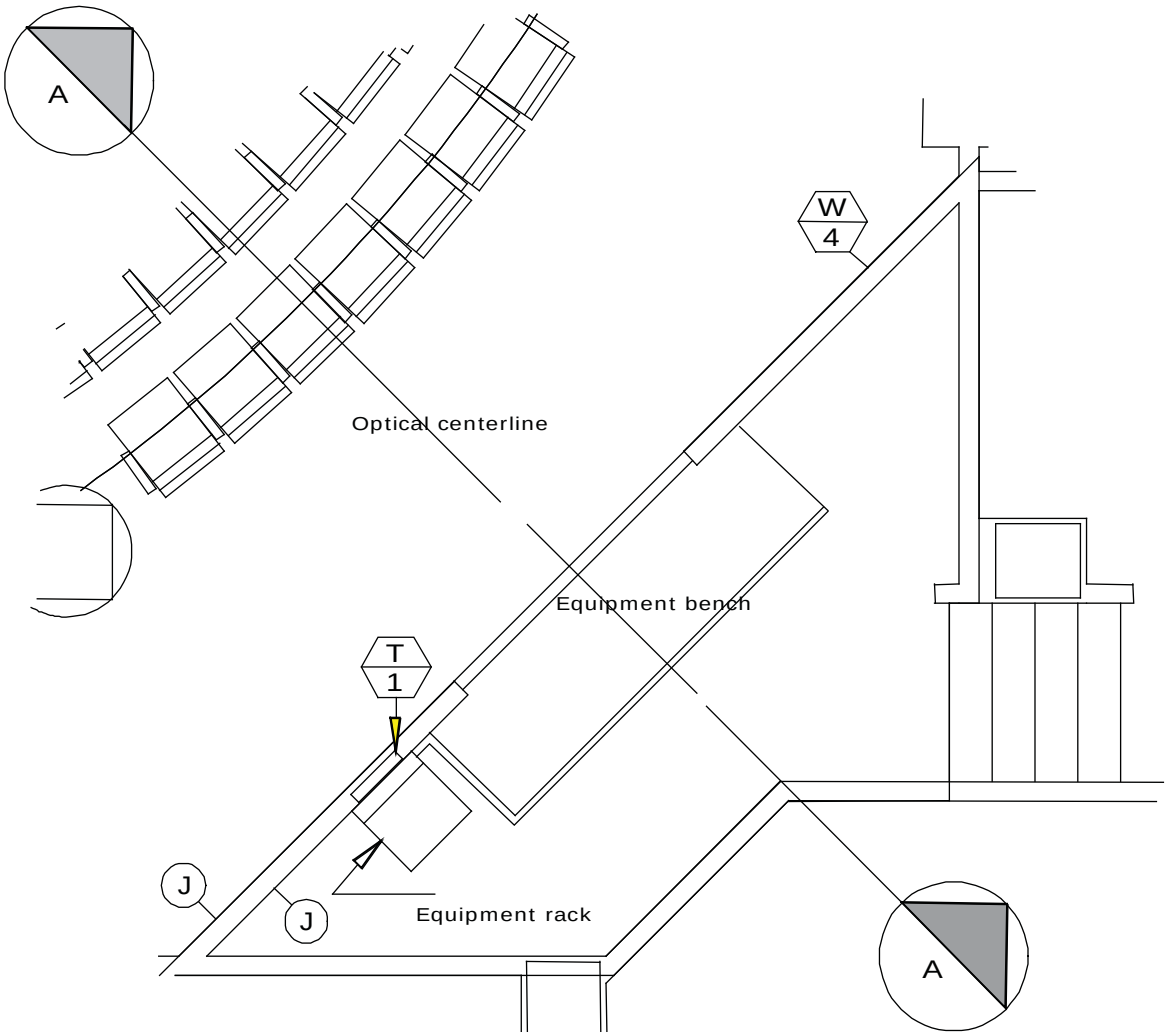
- Number and type of projectors.
- Projector mounts.
- Size for projectors, people, racks, and access.
- Sightlines.
- Use of optically flat glass.
- Glass size, location, and mounting details.
- Heating, ventilating, and air conditioning (HVAC) for equipment heat loads.
- Other building system requirements.

NOTE: Local disability access requirements should be considered when creating room layouts, including issues such as wheelchair access and counter heights.

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Audiovisual (AV) Support Spaces, continued

Figure 13.10
Front projection room layout plan



A = Standard section detail
J = Junction box
T = Terminal cabinet
W = Wall plate

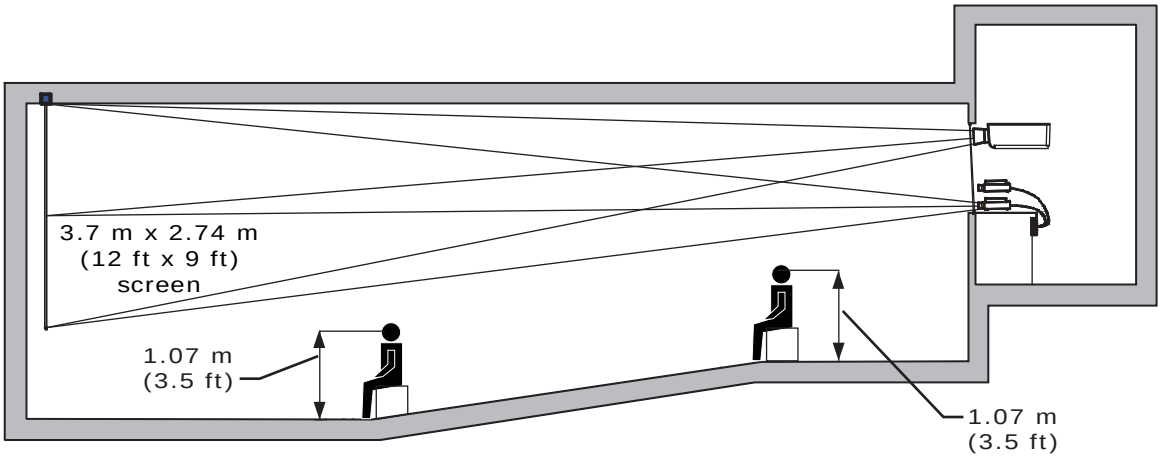
NOTE: This illustration depicts a typical floor plan of a projection booth (or control room) centerline of auditorium stage with lighting/sound desk position, equipment rack, and infrastructure locations shown. A standard section detail (A) would typically be included to provide information regarding acoustic wall construction, window construction, as well as details on projector mounting. Additional details may be required to layout audiovisual equipment located on or below the lighting/sound desk. Detail plans, sections, elevations, and device location drawings provide information for construction as well as information for coordination between all required trades.

Audiovisual (AV) Support Spaces, continued

The front projection design plan also should include a sightline plan (see Figure 13.11) intended to ensure a clear LoS from projectors to the screens.

NOTE: The audience eye height also is addressed within this type of plan.

Figure 13.11
Front projection sightline plan



ft = Foot
m = Meter

The AV systems designer must plan for heat removal within the rack and from the area immediately surrounding the rack. For example, if the rack is installed within a wall space, a path must be provided to exhaust heat from the space. The same issue applied to racks installed within control rooms.

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Audiovisual (AV) Support Spaces, continued

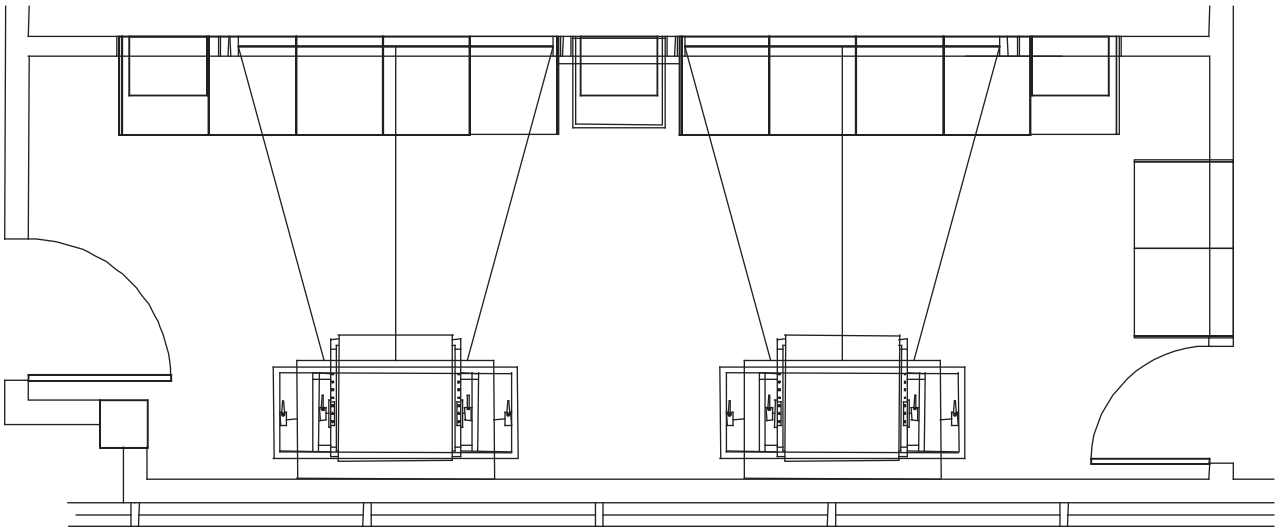
Rear Projection Room

The size of the rear projection room must be sufficient to allow the image to be projected at the required size and viewing angle.

Rear projection rooms present a challenge for AV designers. The design of a rear projection room (see Figure 13.12) should:

- Address whether the projection path is direct or folded.
- Provide sufficient room depth based on projector lens, image size, and image height requirements.
- Provide sufficient details for projection screen mounting to ensure that the architect and carpenter can understand the mounting requirements including which contractor is to provide which components.
- Coordinate layout for door location, projector access, and any racks.
- Provide sufficient room for technicians to operate and access equipment.
- Address equipment heat loads and other building system requirements
- Include black flat finishes to reduce light reflectance

Figure 13.12
Rear projection room design



Audiovisual (AV) Support Spaces, continued

Localized Audiovisual (AV) Equipment

AV equipment can be installed within the room for localized AV systems. In many cases, the components that provide the source for an AV presentation should be installed in a location that is accessible to the presenter (e.g., in front of the room or at the podium).

Typical equipment that may be installed in the presentation room includes:

- Source devices.
- Switchers and routers.
- Control system components.
- Audio mixers and amplifiers.
- Network interface equipment.
- Device interface connector plates.
- Power and data distribution.

Devices may be installed in furniture, walls, and ceilings or can be installed in equipment racks. Equipment racks can be installed in fixed position or designed to slide out of the position to allow access to technicians and maintenance personnel. Fixed-position racks are used in situations where the rack houses a large amount of equipment and is accessible through a rear panel.

When specifying installation requirements for racks, the power, telecommunication ports, closed-circuit television (CCTV), and other services should be located adjacent to the equipment rack.

Wall-mounted equipment racks can be provided. Servicing of this type of rack is simplified by its ability to swing. Structural backing should be provided for the load of the equipment rack, AV components, hardware, and cabling.

Electrical circuits should be provided to junction boxes above rack locations, to junction boxes internal to the equipment rack, or at outlets on an adjacent wall. Proper grounding of all equipment racks, cable trays, conduit, and AV equipment is important for safety and noise reduction.

AV equipment generates heat, so an AV rack requires ventilation. Rooms and enclosures with many pieces of heat-producing equipment require additional cooling. Rack fans are sometimes required; however, convection ventilation may be acceptable for most source racks.

Creating an effective and efficient room design early in the AV system design and installation process is essential to the success of the project. The AV systems designer must address the required technical interconnections between system components, the logistics of cabling and power, and other issues to create the best value for the client.

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Audiovisual (AV) Support Spaces, continued

Disability Access Considerations

Disability access should be considered throughout space planning process according to the AHJ. Considerations may include:

- Wheelchair access to presentation and support spaces, including ramps, slopes, egress, ingress, and seating.
- Assistive listening systems.
- Visual paging and subtitling.
- Horizontal and vertical obstructions.

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Chapter 14
Audio Components

Components or individual pieces of equipment are the foundational building blocks of audiovisual (AV) systems. This chapter explains a variety of audio components that the AV designer may encounter.

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Overview

To both the seasoned veteran and the beginner, professional audio can be a complex subject. The hundreds of varieties in audio equipment can be best understood by grouping the components into the following five main stages of signal flow:

- Sources
- Mixing
- Signal processing
- Amplification
- Destinations

This chapter deals with the individual audio components.

Audio Sources

Microphones

Microphones are transducers that convert acoustic energy into electrical energy. This electrical energy can then be processed and adjusted before being transmitted to an amplifier and sent to loudspeakers or transmitted to remote listeners.

The two common types of microphones are:

- Dynamic microphones.
- Condenser microphones.

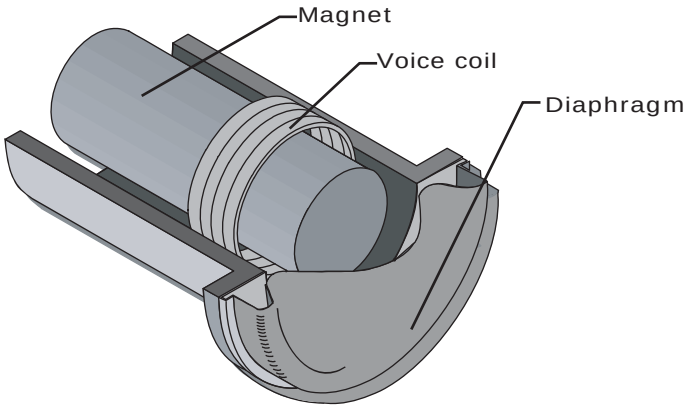
The difference is simply in the process the microphones use to convert the acoustic energy into electrical energy.

Dynamic Microphones

Dynamic or moving-coil microphones have diaphragms that vibrate when struck by sound waves (see Figure 14.1). The diaphragm is attached to a voice coil that moves over a magnet, generating an electrical signal that corresponds to the sound wave. Because the coil is moved in proportion to the sound wave intensity, the electrical current is representative of the wave's amplitude. The sound wave is transduced into an electrical signal.

Dynamic microphones tend to be heavier, larger, and less sensitive than most other types. They are extremely durable and dependable and can withstand high sound pressure levels. Dynamic microphones are versatile because they do not require a power source. Because dynamic microphones tend to be rigid and inexpensive, they are often used for stage vocals and applications which may be subject to greater use.

Figure 14.1
Dynamic microphone



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Microphones, continued

Condenser Microphones

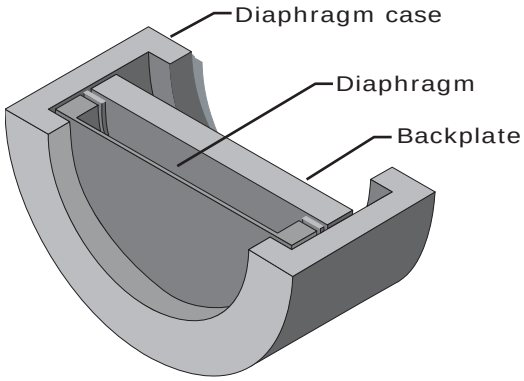
Condenser microphones (see Figure 14.2) convert sound into electricity using a capacitor and electrostatic principles. They have two plate elements: one moveable and one fixed. The moveable plate is given an electrical charge from a power source, creating electrostatic energy between the plates. Sound waves vibrate the movable plate. As the distance between the movable and fixed plates change, the amount of stored electricity changes.

The electrical signal derived from these changes in capacitance is very low and requires amplification prior to being sent across a microphone cable. To accomplish this, condenser microphones incorporate a pre-amplification stage within the microphone. To provide this signal boost, an external direct current (dc) power source cn be used. That source is commonly referred to as phantom power and can range from 9 to 48 volts direct current (Vdc). The phantom power signal is usually supplied by the audio mixer and is sent down the microphone cable as a dc signal with the alternating current (ac) audio signal. In addition to amplifying the signal, the dc voltage also charges the plates of the capacitor.

Electret microphones most often use a battery instead of the phantom power. These microphones use capacitors with permanently charged plates and a battery to power the pre-amplification circuitry in the microphone. This can be useful in applications where phantom power may not be available from the audio mixer.

Condenser microphones are very sensitive and can respond quickly and accurately to sound. They are more sensitive and have a wider frequency response than dynamic microphones. This makes them well suited for demanding applications requiring great detail and clarity but less appropriate for applications that are subject to greater use and require very high sound pressure levels.

Figure 14.2
Condenser microphone



(Requires phantom power)

Microphone Pickup Patterns

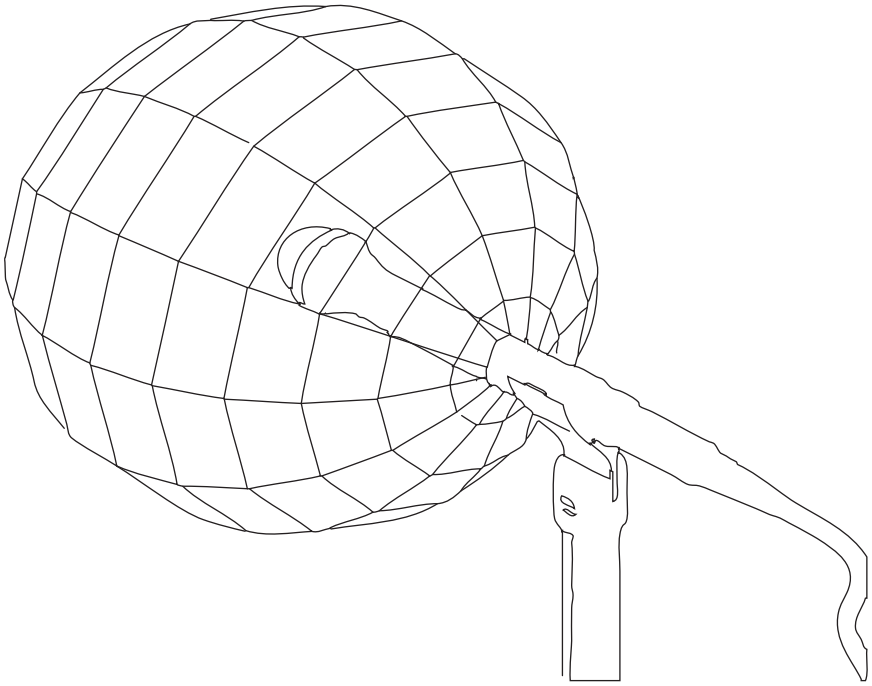
Microphones are commonly characterized by their polar pattern. Polar pattern refers to how the microphone senses sound occurring in the vicinity of the microphone. Microphones can be designed to be sensitive to sounds from given directions while rejecting sounds from others. The directional characteristics, or pickup patterns, are defined by noting the direction from which a microphone is optimally sensitive to sound waves. The most common patterns are:

- Omnidirectional.
- Cardioid.
- Hyper or super cardioid.
- Bidirectional.

Omnidirectional Microphones

Omnidirectional microphones (see Figure 14.3) pick up sound from all directions equally. Omni-directional microphones are equally sensitive to sounds from nearly all directions. Omni-directional microphones are typically used for recording and group pick-up.

Figure 14.3
Omnidirectonal pattern



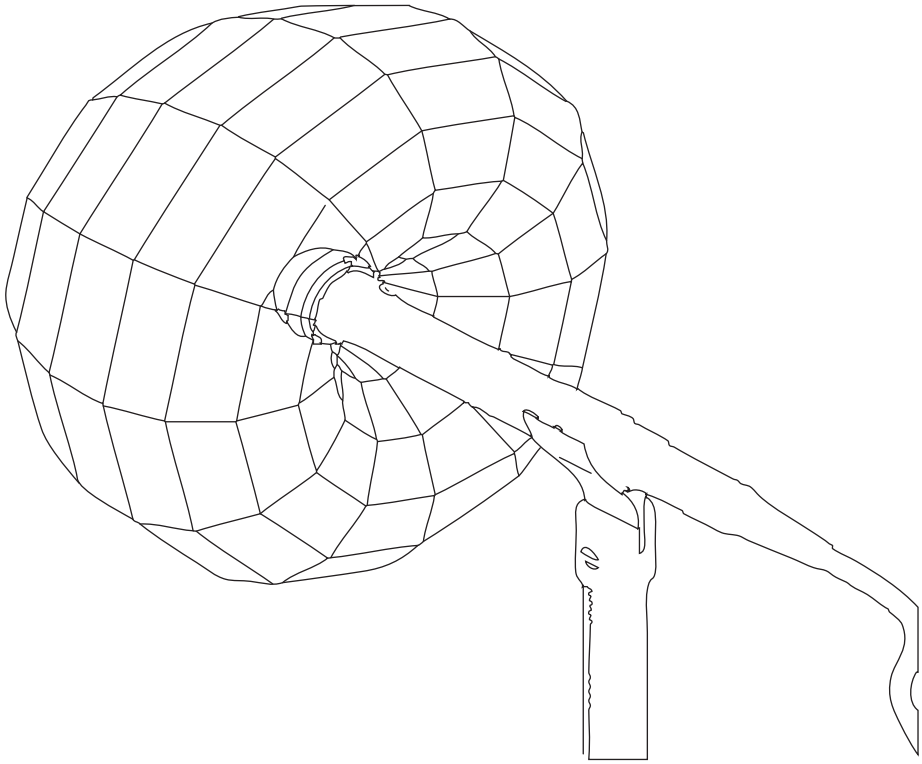
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Microphone Pickup Patterns, continued

Cardioid (Unidirectional) Microphones

Cardioid microphones (see Figure 14.4) have a heart-shaped pickup pattern and are sensitive to sounds predominantly from the front of the microphone diaphragm. They are most sensitive to the sound from the direction in which they are pointed and are less sensitive to the sound coming from the sides. They are practically nonresponsive to the sound coming from the rear of the microphone.

Figure 14.4
Cardioid pattern



Microphone Pickup Patterns, continued

Hyper and Super Cardioid Microphones

Hyper and super cardioid microphones are even more directionally sensitive. They are sensitive to sound coming from one direction and are typically used for sound reinforcement for one or two people. It is important to note that these microphones, while being very directional, also have a very pointed tail that picks up sound at the rear of the microphone.

Bidirectional Microphones

Bidirectional or figure-8 microphones are sensitive to sounds from the sides 180 degrees apart, while they reject the sound from all other directions.

Hemispheric Microphones

Hemispheric pickup patterns for boundary microphones use a large flat surface (e.g., a tabletop or wall) to create a large, smooth, dome-shaped, pickup pattern. They are often used in boardrooms to pick up many people with relatively few microphones.

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Microphone Pickup Patterns, continued

Shotgun Microphones

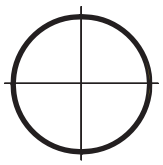
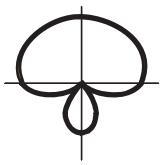
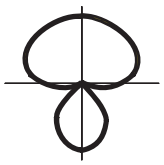
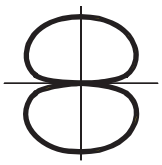
Shotgun microphones must be aimed at the sound source. They have a long, slotted, tube designed to reject unwanted sound and pick up a talker or sound source from many meters or feet away.

These microphones can either be handled by an audio technician, who ensures they are pointed in the right direction, or mounted on a boom pole.

They are used when the microphone cannot be placed close to the talker, as in a press conference.

For characteristics of the common types of microphones, see Table 14.1.

Table 14.1
Characteristics of common types of microphones

Characteristic	Omni-directional	Cardioid	Super-cardioid	Hyper-cardioid	Bi-directional
Polar response pattern					
Coverage angle	360°	131°	115°	105°	90°
Angle of maximum rejection (null angle)	–	180°	126°	110°	90°

Microphone Pickup Patterns, continued

Identifying Microphone Pickup Patterns

A manufacturer often provides the polar pattern of a microphone, which plots the sensitivity of a given microphone based on its sensitivity to specific frequencies coming from all directions.

If the manufacturer's specifications are not available, the potential pickup pattern can be determined in two ways by observing the microphone. If it is sealed so the sound only strikes the front of the diaphragm, the microphone is omnidirectional. If it has slots and is unsealed, the microphone is directional.

Secondly, many microphones have an icon on the side that indicates the type of pickup pattern.

Common Types of Microphones

A microphone also is classified by how it is physically designed and subsequently placed.

Handheld Microphones

The talker can hold a handheld microphone, allowing movement while speaking. This type of microphone can be mounted to a stand near the talker or suspended using a boom pole.

Because microphones can be sensitive to handling noise, many mounting options offer shock and vibration isolation.

Lavalier Microphones

The lavalier microphone also is called a lav, lapel, or a clip-on microphone. This is a small, lightweight, microphone that can be attached to the talker's clothing in a manner that ensures the microphone would not move and produce rustling noises.

Such microphones are very common in television (TV), film, and stage production because they are easy to conceal on a costume or wig.

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Common Types of Microphones, continued

Headworn Microphones

The headworn microphone is a hands-free microphone, typically designed to be worn as a headband or wrapped behind the ear. These microphones provide advantages over lavalier microphones in that they follow head movement, and reduce the level and frequency variations typical in lavalier microphones.

Recent versions of these microphones are now available in a variety of skin colors and have a very small profiles to minimize the visual distractions commonly associated with headworn microphones.

Ceiling / Choir Microphones

Ceiling/choir microphones are small profile microphones suspended from the ceiling. They are used in circumstances where microphones are desired overhead but microphone stands are not an option. Microphone jacks are located in the ceiling and cables suspend microphones at a certain height above or in front of the source.

A rigid wire assembly is often incorporated close to the microphone element to allow the microphone to be angled. These microphones are often available in either white or black to allow them to blend in with the room.

Table (Button) Microphones

Table (button) microphones are small microphones that are flush mounted onto tabletops, typically for conferencing situations. Their installation requires drilling holes into the table for seating the microphone body and cable. Mounted flush with the table, these microphones are not susceptible to phase cancellation caused by reflections off the table.

Some issues to consider with these microphones are their tendency to be affected by rustling papers on the table and the implications of permanent mounting onto, often costly, conference room tables

Common Types of Microphones, continued

Boundary Microphones

Boundary microphones also are called surface mount microphones. The pickup element on this type of microphone is located in a manner that only picks up the sounds reflected off a nearby surface. The low-end frequency response of the microphone is dependent on the size of the reflecting surface on which it is mounted.

These microphones are often used in boardrooms and other environments where a number of talkers must be picked up and where the microphone has to remain unobtrusive.

Gooseneck Microphones

Gooseneck microphones are named after the thin, flexible, suspension arm that supports the microphone element. They are commonly found on lecterns, pulpits, and tables. The flexible arm allows the microphone to be placed in a close proximity to the sound source. The length of the neck can vary from a few centimeters or inches to several meters or feet.

Wireless Microphones

Wireless microphones use the patterns of cable microphones but eliminate the need for a microphone cable by transmitting the signal wirelessly over a radio frequency (RF) signal. This transmission is accomplished using a transmitter (often the actual microphone used) and a receiver (often the rack mounted near the audio mixer).

Transmitters are available in many varieties but most common are either handheld or belt pack with a lavaliere (lapel) microphone. Some versions use detachable transmitter packs to which a standard dynamic microphone can be attached.

Wireless microphones operate on a specific frequency, usually in either the very high frequency (VHF) or ultra-high frequency (UHF) TV spectrum. Some varieties use a fixed frequency, while others, known as agile, allow the user to select the frequency from many available ones. This is particularly beneficial in geographic areas where a great deal of RF activity is present and may cause interference.

Consumer Microphone

The increasing popularity of consumer camcorders and other recording electronics has brought with it the introduction of consumer grade accessories into professional AV applications. An example is the unbalanced, stereo microphone commonly used with consumer video recording equipment. As a general rule, these microphones can be difficult to integrate into a professional AV system successfully, and are not recommended.

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Electronic Instruments

Electronic instruments have become commonplace in both live sound and recording environments. Not unlike microphones, they present their own unique considerations to the AV professional. Examples of electronic instruments include synthesizer keyboards, electric guitars, and electronic drum sets. These instruments typically produce unbalanced, high impedance, line level signal as an output.

Either a mono or stereo signal may be available depending on the instrument. Because stage inputs are typically balanced microphone inputs, a conversion must take place to interface these instruments with the sound system. This is most commonly done using a direct box. These boxes take an unbalanced, high impedance, line level input, provide a loop output to feed a local amplifier or monitor, and convert the signal to a balanced, low impedance, microphone level output. The input is typically 1/4 inch (in) phono connector, and the output is always an X series, latch, rubber (XLR) male connection.

The boxes are available in two main varieties: passive and active. The passive box uses a simple transformer to accomplish the signal conversion. The active box requires either a battery or phantom power. The power source allows both signal processing devices (e.g., equalizers) and more sophisticated electronics to convert the signal.

In some situations, these instruments may be able to plug directly into an audio mixer without plugging into the microphone input on a panel. Most mixers provide line level inputs to accept these connections directly. The mixer then handles all of the necessary signal processing.

NOTE: Incorrect interfacing of electronic instruments is a leading cause of hum and signal level issues in sound systems.

Program Sources

Program audio sources include such devices as compact disc (CD) players, digital versatile disc (DVD) players, cassette decks, hard disk recorders, tuners, computers, and upstream switchers. Like electronic instruments, these sources are often unbalanced, stereo, line level signals, which must be interfaced with great care to avoid problems. Ideally, an active interface should be used to convert an unbalanced signal to a balanced signal or from a balanced signal to an unbalanced signal. The interfaces typically adjust level, impedance, and balancing.

Some program sources may provide a digital output signal. This may be useful in providing a multichannel or higher fidelity signal if the connected device can accept a digital signal.

Audio Mixing, Switching, and Routing

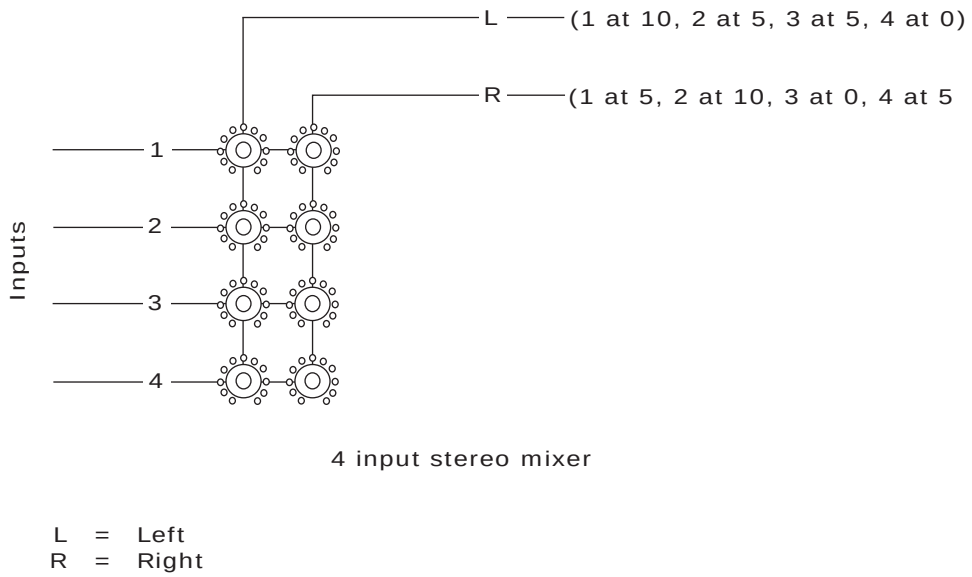
In the most basic configuration, an audio system has a sound source at one end and a destination for that sound on the other. Even so, a situation with only one sound source is not the norm. Audio technicians often deal with dozens of audio signals (e.g., from various instruments in a concert or several panelists at a conference). These various sources must often be combined and routed to various destinations. To accomplish this, the sources are fed into a mixer, switcher, or router.

All mixers, switchers, and routers have a similar purpose—to combine, control, and direct audio signals from a number of inputs to a typically smaller number of outputs.

Mixers

Mixing is a process of combining different audio sources or tracks and their blending for the best sound quality and balance. A mixer's controls often have the ability to balance out volume levels among different audio sources. For example, in a system with two microphones for two presenters, if presenter A is soft spoken, the mixer can adjust A's microphone level to match the level of presenter B. More advanced mixers have more advanced controls. See Figure 14.5 for an example of mixer.

Figure 14.5
Mixer



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Mixers, continued

The audio from the input channels can be blended and output into one channel for monophonic sound, two channels for stereo sound, or multiple channels for surround sound.

Mixers can be identified by how many inputs and outputs they have. For example, a mixer with 8 input channels and 2 output channels would be referred to as an 8-in–2-out or an 8-by-2 mixer.

In other cases, multiple channels can be mixed to multiple channels for professional recording or surround sound mixing. In a recording studio, a mixer might blend 64 separate channels into 24 to make a 24-track recording.

Mixing Consoles

The most common type of audio mixer is the traditional mixing console (also referred to as a desk, board, or mixer). It is typically a large-format mixer with many input and output channels and extensive processing. It is intended to have an operator at all times. These mixers are commonly found in houses of worship and auditoria.

Rackmount Mixers

For smaller scale audio systems, a rackmount style mixer is commonly encountered. These mixers typically have fewer inputs (often 8 or less) and provide very limited signal adjustment. Each channel commonly has a gain knob, a master gain, and some limited equalization. These mixers are often found in systems requiring very few sources with very little fluctuation in the source material. They are typically used in such places as restaurants and gymnasiums.

Automatic (Auto) Mixers

Automatic mixers automatically turn microphones on and off when volume levels are above or below a certain threshold. They are often initially adjusted by a technician and are then intended for use without an operator. They are typically rack mounted and are used in systems requiring a limited number of inputs. One common application of automatic mixers is audio conferencing.

Automated Mixers

Many mixers are automated by a computer and store presets, control settings, and various mixing moves. Automated mixers should not be confused with automatic mixers. They are most commonly encountered as a special form of large mixing consoles and are often used in production and recording environments.

Mixers, continued

Digital Mixers

Many manufacturers are now making digital mixers. These provide much more extensive flexibility than traditional analog mixers. The software on these mixers allows extensive processing to be located on a small mixer without all of the knobs and faders typically required on an analog mixer.

A similar amount of processing on an analog mixer would require a very large and expensive mixer to accommodate the same amount of processing options. While digital mixers provide great flexibility, they also can provide a more complicated environment to mix in, especially for live sound.

Common Mixer Applications

Mixers are used for a wide variety of applications. The application should typically guide the selection of the appropriate mixer. A mixer that is appropriate for one application may be inappropriate for another.

Some of the most common applications for mixers are:

- Front of house (FOH) mixers.
- Monitor mixers.
- Conferencing mixers.
- Recording and post-production mixers.

Front of House (FOH) Mixers

FOH mixers are used for live sound mixing. FOH is a term used to refer to the main sound system in an auditorium, theater, or church. This mixer's main purpose is to mix the sound for the main loudspeakers.

Monitor Mixers

A monitor mixer is used for very large events where extensive stage monitoring is required and cannot be handled by the main FOH mixer. For large events where mixing 10 to 20 monitors by an FOH operator would not be practical, a separate mixer is often located on the side of the stage for a separate operator to mix.

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Common Mixer Applications, continued

Conferencing Mixers

An audioconferencing mixer is often a rack-mountable mixer set up to function automatically. It often serves both as a mixer and as a router for the microphones used in a room. It mixes them for transmission to the far end of the conference. Additionally, these also may incorporate acoustic echo cancellation, audio processing, routing for zoned sound reinforcements, and an audio codec.

A conferencing mixer often combines mixing and routing to allow multiple microphones to project to certain destinations. When meeting participants have to be heard as well as the person making the presentation, microphones must be distributed and mixed very carefully to each group of loudspeakers. This presents several engineering problems for the system to work without becoming unstable, since placing a live microphone in the vicinity of a loudspeaker amplifying its signal could cause acoustic feedback.

The approach is to create a separate sound subsystem for each loudspeaker or group of loudspeakers. The microphones close to a given zone of loudspeakers are not assigned to that zone in the router, since it would render the system unstable (i.e., cause feedback). The material picked up in those microphones would not likely have to be reproduced in the adjacent loudspeakers.

Conferencing mixers are typically found in large boardrooms, meeting rooms, or in learning environments.

Recording and Post-Production Mixers

Recording mixers can be large or small-format mixers similar to the FOH mixers. These mixers additionally often incorporate such things as automation and more extensive metering.

With the growing popularity of hard disk-based recording media, recording mixers are now often outputting multiple channels directly into a computer for mixing at a future time.

Switchers and Routers

A switcher is a device that has the ability to choose between two or more sources and send the information from that source to a particular destination. For example, a tuner, a CD player, and a cassette deck can be connected to a switcher. The switcher output can be connected to a single-input amplifier. Choosing the player is as easy as selecting the corresponding source on the switcher.

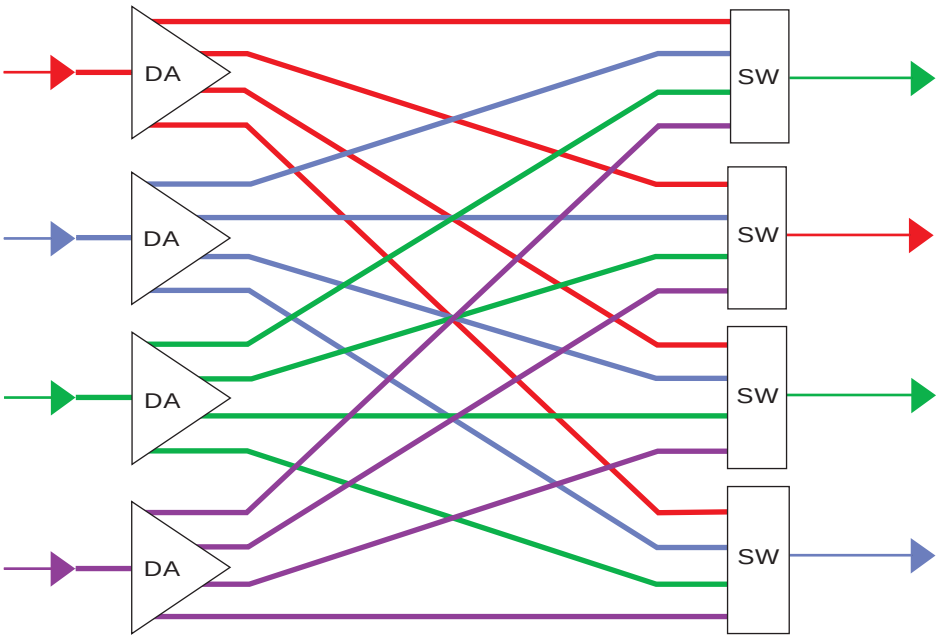
Switchers can be passive and require no power to operate, but many are active and provide some amplification on each input to allow individual level control for each source. The latter allows maintaining a consistent volume as different sources are selected.

Unlike mixers, which can send several sources to a destination simultaneously, switchers send only the one selected source to the destination.

A router or matrix switcher, on the other hand, is a compilation of several switchers, the number of which is the actual number of outputs specified by the size of the matrix. For example, a 4-by-2 matrix switcher contains two switchers.

The matrix is capable of selecting a particular source to one output and simultaneously selecting the same or a different source to be routed to the other output. To avoid loading at the inputs, each input contains a distribution amplifier (DA), which distributes the input source to each input of every switcher contained in the matrix (see Figure 14.6).

Figure 14.6
4-in–4-out router diagram



DA = Distribution amplifier
SW = Switcher

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Audio Signal Processing

Processing audio signals in addition to mixing and routing is often necessary or desirable. This may be done to correct such things as poor signal quality and for personal preferences. Some types of processing may affect the frequency of the signal, while others may affect the dynamic level of the signal.

To refine an audio signal, any number of processors may be used. Which processors are needed is determined by the application and listening environment.

The majority of signal processing equipment used today is accomplished digitally through digital signal processing (DSP). Many DSP devices incorporate various processors in one unit. In many cases, DSP-based devices provide software as the user interface. The user is often able to customize the signal chain within the device by dragging and dropping whatever specific processors are desired and arranging them in the desired order.

Equalizers (EQs)

Equalizers (EQs) are sophisticated frequency controls that allow a range of frequencies of a given signal to be either boosted or reduced. At its simplest, an equalizer divides audio signals into low, mid, and high frequencies. The most common types of equalizers include:

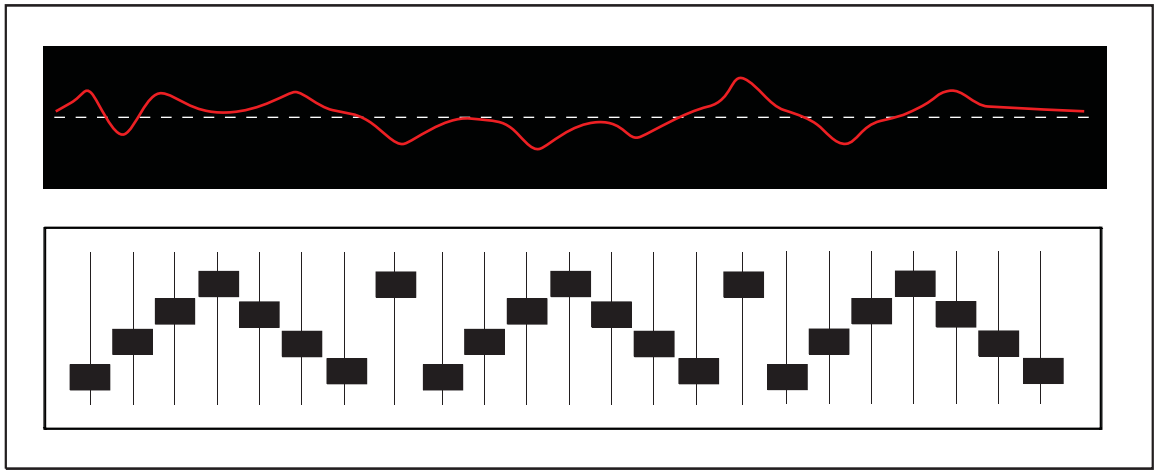
- Graphic EQs.
- Parametric EQs.
- Notch filters.

Equalizers (EQs), continued

Graphic Equalizers (EQs)

A common type of equalizer is the 1/3 octave equalizer, sometimes called a graphic EQ (see Figure 14.7). The graphic EQ has 31 control points over 10 octaves to raise and lower the gain of the center frequency labeled above the control. The resultant signal has a frequency response analogous to the graph or curve created by the controls on the EQ.

Figure 14.7
Graphic equalizer interface



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Equalizers (EQs), continued

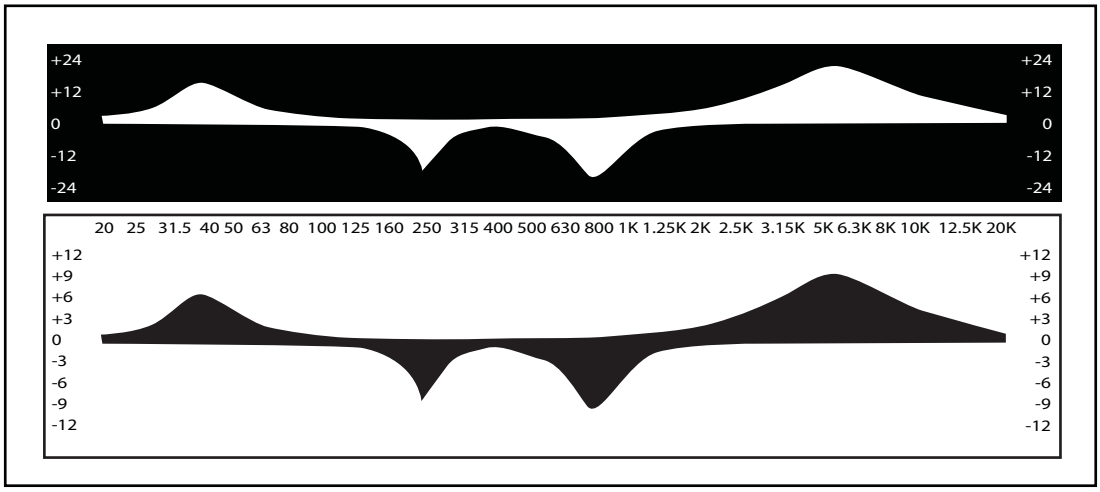
Parametric Equalizers (EQs)

Parametric EQs typically have two or three knobs to allow users the control over various frequency aspects of the signal. One control allows selecting a specific frequency. Another control determines how much boost or reduction is applied to that frequency.

Fully parametric equalizers provide a third control for filter bandwidth, referred to as Q. The Q determines how wide or narrow the frequency band centered on the selected frequency is affected by level adjustment.

Many audio mixers provide several parametric EQs on each individual channel. See Figure 14.8.

Figure 14.8
Parametric equalizer interface



Filters and Feedback Eliminators

Filters allow specific frequencies to be removed from a signal. Notch filters remove extremely narrow frequency bands.

The most common application of notch filters is in feedback eliminators. These devices have become commonplace in live sound environments where feedback may be problematic. These DSP-based devices quickly detect feedback when it occurs and automatically set a notch filter on that frequency to effectively eliminate the feedback.

These devices typically have between 8 and 12 notch filters per channel, allowing multiple frequencies to be removed from the signal. Using very narrow notch filters, the integrity of the original signal is minimally impacted. The filters can usually be assigned as either dynamic or fixed. In the dynamic mode, they are constantly monitoring the signal to react against any feedback that may arise. In the fixed mode, the frequencies are determined prior to an event and do not fluctuate.

Compressors, Limiters, Expanders, and Gates

Compressors, limiters, expanders, and gates are devices that affect the signal's dynamic range. They are some of the most useful and the most misunderstood audio processors.

All four devices have similar controls. The two most important controls to understand are threshold and ratio.

Threshold determines the level above or below which the signal is affected. The ratio then determines the amount of level change that will occur above or below the threshold. These two controls work differently on each of the four devices, but the basic principle remains the same.

Other common controls on these devices are attack time and release time.

The attack time determines how quickly or slowly the device responds to the signal when it exceeds the threshold. The release time determines how quickly or slowly the device stops responding to the signal when it stops exceeding the threshold. These two controls should be set with care, as incorrect settings can result in such events as the pumping, breathing, or clipping of the signal.

Compressors, Limiters, Expanders, and Gates, continued

Compressors

A compressor evens out loud variations in the dynamic range for a more consistent sound. Compressors affect a signal when it rises above the set threshold. The signal is then reduced according to the set ratio.

For instance, a ratio setting of 2:1 and a threshold setting of +10 mean that when the signal exceeds a level of +10, the resulting output is then reduced to half of the input level above that threshold. An input level of +12 would output as +11, and an input of +20 would output as +15.

A ratio of 5:1 at the threshold of +10 would change an input signal of +15 to an output level of +11; an input of +20 would result in an output of +12.

The compressor is a valuable tool for restricting vocals and drum kits, which may have very occasional transients above a desired level. By compressing the signal, these types of sudden fluctuations can be controlled in an unnoticeable manner.

Limiters

Limiters are set to prevent all signals from going above a given threshold. They are triggered by peaks or spikes in the audio signal, and react quickly to cut them off before they exceed a certain point. They prevent the audio signal from being too intense, causing distortion or damage to the audio system.

Limiters are essentially compressors with ratios greater than 10:1. Just like a compressor, the threshold is set at point (e.g., +10 decibels [dB]). Then, any time the input signal exceeds +10 dB, it will be output as +10 dB. For example, an input level of +12 dB will result in an output of +10 dB. An input level of +20 dB will result in an output of +10 dB. As another example, a table microphone may be limited to 90 dB as a precaution. If a heavy book is dropped on the table, the loud noise would not be amplified even louder and startle the audience.

Compressors, Limiters, Expanders, and Gates, continued

Limiters are often placed in the signal chain prior to the power amplifier to protect extreme variations in the signal level from damaging the loudspeakers.

Expanders

Expanders reduce low signal levels and effectively expand the dynamic range of the signal. This is accomplished by decreasing the volume of signals that go below the set threshold according to the set ratio.

For instance, a ratio setting of 2:1 and a threshold setting of –20 dB, mean that when the signal drops below a level of –20 dB, the resulting output is then reduced to a level twice as low as the input level below that threshold. An input level of –22 dB would output as –24 dB, and an input of –30 dB would output as –40 dB.

Expanders are rarely found as standalone devices. They are commonly used in conjunction with compressors (often referred to as companders) to reduce noise level in equipment. The most commonly encountered use of the expander is as a gate.

Gates

Gates set the level a signal must exceed to pass. They function by passing through audio signals that are above a user-determined threshold, and shutting off the signal when the sound falls below the threshold. They are often used to reduce feedback and lower system noise resulting from amplifying open microphones.

Just as limiters are compressors with an infinite ratio, gates are essentially expanders with a ratio greater than 10:1. Just like an expander, the threshold is set at point such as –20 dB. Then, any time the input signal drops below –20 dB, no output is generated. For example, an input level of –22 dB will result in no output. An input level of –30 dB will result in no output.

For example, a whisper is approximately 25 dB. Therefore, when setting up a sound system for a board meeting, eliminating sounds 25 dB and below helps control the intended audio.

When the gate's input signal reaches the threshold level, it allows that signal to pass through to the output. When the input signal does not reach the threshold for a pre-determined amount of time, the gate closes, not allowing the signal to pass through to the output until the signal again reaches the threshold level.

An incorrectly set gate can be more distracting than having no gate at all. For example, the occasional presence of a noticeable noise floor when the gate is open may be more distracting than having the noise floor constantly present.

Gain Control Devices

Automatic Gain Control (AGC)

Automatic gain control (AGC) automatically maintains gain at a specific level or within a specific range. It is typically a DSP-based device that incorporates complex compression and limiting circuitry. It is often used in automatic microphone mixers to maintain a consistent level among multiple microphones and various voices.

Outboard Microphone Pre-Amplifiers

Because the output of microphones is very low, their signal requires amplification, known as a microphone pre-amplifier, before it can be processed. This amplification is typically done internally at the first stage of the audio mixer. Some applications may require amplifying a microphone signal prior to its reaching the audio mixer. This may be done to overcome very long cabling distances or to provide localized phantom power.

Line Drivers

Line drivers are very similar to microphone pre-amplifiers in that they boost an audio signal for transmission over a long distance. All audio cables produce a signal loss that is directly proportional to the cable distance. If the cable distance is so great that the resultant audio signal is reduced into the noise floor, then it must be amplified prior to traveling down the cable. This is done by an audio line driver. They are typically small boxes and should be located as near to the source as possible to maximize the signal-to-noise ratio (SNR).

Gain Control Devices, continued

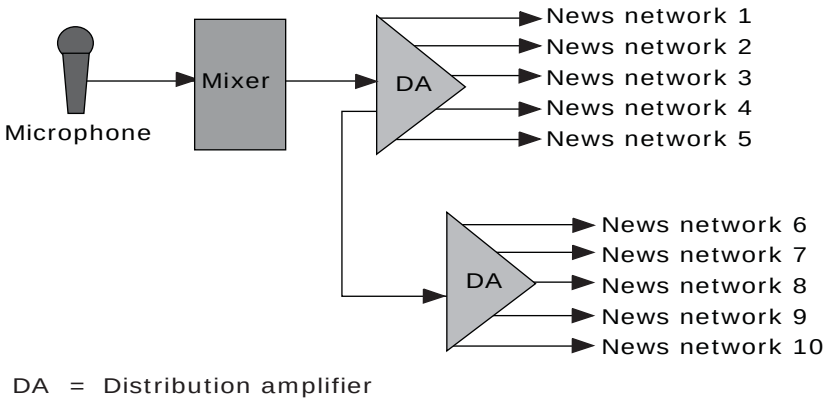
Distribution Amplifiers (DAs)

A DA is an amplifier that accepts a signal at its input and distributes the signal to two or more outputs. Each output is, therefore, isolated from the others.

In audio systems, taking an audio signal and sending it to two or more places often becomes necessary. Simply connecting the devices together may either load the signal down or cause other undesirable anomalies.

As an example, a press box distribution accommodating up to 24 press feeds allows a talker to make a presentation at a podium with one microphone rather than being obscured from the camera by two dozen microphones. The press corps simply connects the tape recorders to a receptacle on an output panel that provides a fixed, isolated, signal from the output of a distribution amplifier. If one member of the press corps has a shorted cable, it affects only that feed rather than shorting the feeds of the others. See Figure 14.9 for an audio system with two DAs.

Figure 14.9
Audio system with two distribution amplifiers



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Echo Cancellation

Echo cancellers are systems designed to electronically eliminate echoes that may be picked up by the microphone. Echo cancellers allow the operator to select the tail length (timing of the echo in milliseconds [ms]) to eliminate the echo. The most common application of echo cancellation is in conferencing systems. There are two types of echo cancellation functions:

- Electronic echo cancellation
- Acoustic echo cancellation

Electronic echo cancellation eliminates reinforcing the locally generated sound. (Speakers' hearing their own voice reinforced as they talk sounds like an echo and can be distracting.)

Acoustic echo cancellation is an electronic circuit that handles an echo in a room caused by a reinforced voice through a loudspeaker interacting with the environment, picked up again by a microphone, and sent back to its originator.

Noise Reduction

Noise reduction is a process of reducing unwanted noise in the audio signal. In the past, when analog storage media were widely used, noise reduction was essential to overcoming the deficiencies of the storage process.

Several competing protocols that used a process known as companion (derived from compression/expansion) were developed. This process used compression at the recording stage of a signal and then reversed the process with expansion circuitry at the output side. Because of the need to alter the signal at two points, this was known as complementary noise reduction.

With the migration toward all-digital storage media, the need for complementary noise reduction has been greatly reduced. Noncomplementary noise reduction or single-ended noise reduction is a different process that only alters the signal at one point. This is typically done using expansion circuitry combined with complex dynamic frequency filters. This process allows only certain frequency bands to be affected by expansion at a given time.

The advent of DSP has provided many new opportunities for noise reduction. Complex algorithms now allow a signal to be digitally sampled to isolate signal components that are either constant or are repeated at consistent intervals. These types of signal anomalies are often indicative of such things as tape noise, clicks, hiss, hum, and background ambient noise. Many of these more sophisticated DSP noise reduction options tend to be costly and are more commonly found in the production industry rather than in the commercial AV industry. Nevertheless, noise reduction can be commonly found in audio codecs and large-scale DSP devices.

Reverb

Reverb is a process that adds artificial reverberation to an input signal. It is often desirable in both live and recorded sound to enhance the natural sound of a performer by adding artificially created reverberation. For example, this can help to provide warmth and richness to vocals. It also may help to overcome some undesirable acoustical qualities of a room.

A wide range of reverb options are typically available, ranging from concert halls and small clubs to various plate reverbs and chorusing effects.

Reverb and other outboard effects are typically set up by the end user rather than by the system installer. However, they are commonplace in churches and performing arts venues, so the AV professional should understand their purpose and know how to properly integrate them.

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Delay

Delay is a process that artificially timeshifts the output signal relative to the input signal. Sound travels at 344.42 meters per second (m/s [1130 feet per second (ft/s)]) in air, whereas the electronic transport of the audio signal to the loudspeaker is almost instantaneous.

Sound reinforcement systems often use delay to prevent the hearing of the natural sound after the reinforced sound. For example, in a live audio environment, listeners seated in the front of the space can hear the reinforced sound from the stage loudspeakers. But, in the rear of the space, listeners may be subject to the sounds of the concert via the rear loudspeakers and then the stage loudspeakers. With delay, the rear loudspeakers will not relay the signal until the sound arrives from the stage loudspeakers. This ensures a more pleasant listening experience.

Surround Processors

Systems designers also may have to incorporate surround sound or cinema processors within a room design. These may range from standard home theater receivers used in a conference room to commercial grade processors used for theaters and large auditoria.

A wide range of surround sound protocols are currently available. The AV professional should understand that these formats are continually evolving and expanding.

Audio Amplification

The amplifier is the last stop before the signal reaches the loudspeakers. Power amplifiers boost or amplify electronic audio signals sufficiently to move the loudspeakers. They do this by increasing the voltage of the signal from line level to loudspeaker level.

Line level is around 1 volt (V). Loudspeaker level depends on the type of system. It can:

- Range from 4 to 20 V or more for small sound systems.
- Be up to 70 V in a distributed sound system.
- Be up to hundreds of volts in large venues.

Amplifiers are found in all audio reinforcement and playback systems.

The two main types of power amplifiers are impedance-based and constant-voltage amplifiers.

Impedance-Based Amplifiers

Impedance-based amplifiers are intended for use with direct coupled (transformerless) loudspeakers of low impedances. These types of loudspeakers typically have impedances in the range of 4 to 16 ohms.

The specifications of an amplifier should be consulted before connecting a load because the expected loads may vary by manufacturer.

Impedance-based amplifiers and transformerless loudspeakers are preferred in the applications demanding high fidelity and few loudspeakers per channel.

Constant-Voltage Amplifiers

Constant-voltage amplifiers are designed to serve applications requiring many loudspeakers on a given channel or applications requiring very long cable runs. They provide a maximum voltage (typically 25, 70, or 100 V) to each channel of the amplifier. The higher voltage is then stepped down with a transformer at each loudspeaker. The operating impedances allow adding multiple loudspeakers to a given circuit with a minimal impact to the existing loudspeakers already on that circuit.

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Amplifier Channels

Another distinguishing property of amplifiers is the number of channels. The most common configuration is a 2-channel amplifier, commonly used for stereo applications. Some amplifiers incorporate as many as eight channels of amplification in one chassis. These can help to reduce required rack space when the amount of available power is not critical.

Multichannel amplifiers are popular for zoning and surround-sound applications.

Mixer-Amplifiers

Some amplifiers are combined with an audio mixer in the same chassis. These are common in small-scale audio systems where budget and space are factors. Some models are modular to allow a wide variety of input options for the mixer.

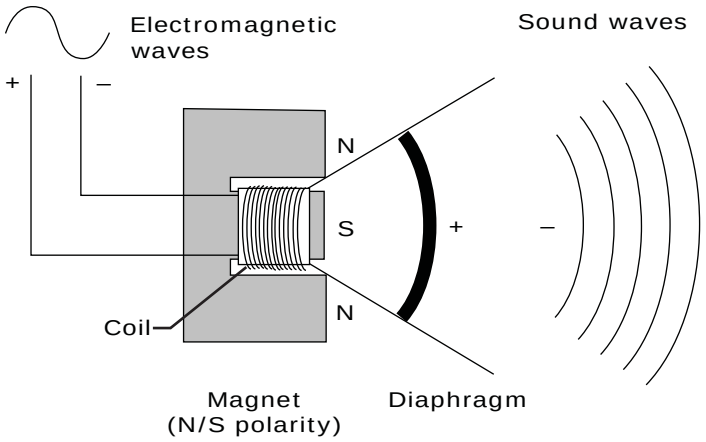
Audio Destinations

Loudspeakers

For the purpose of sound reinforcement, loudspeakers are the end of the audio signal's path. The sound wave transduced into electrical energy in the microphone is transduced back into a sound wave by the loudspeaker (see Figure 14.10).

Many different kinds of loudspeakers are available; each designed to reproduce a specific range of frequencies, have a distinctive dispersion pattern, or fit a specific purpose. The two major categories of loudspeakers are cones and compression drivers.

Figure 14.10
Converting electric waveform to sound pressure



N = North-seeking
S = South-seeking

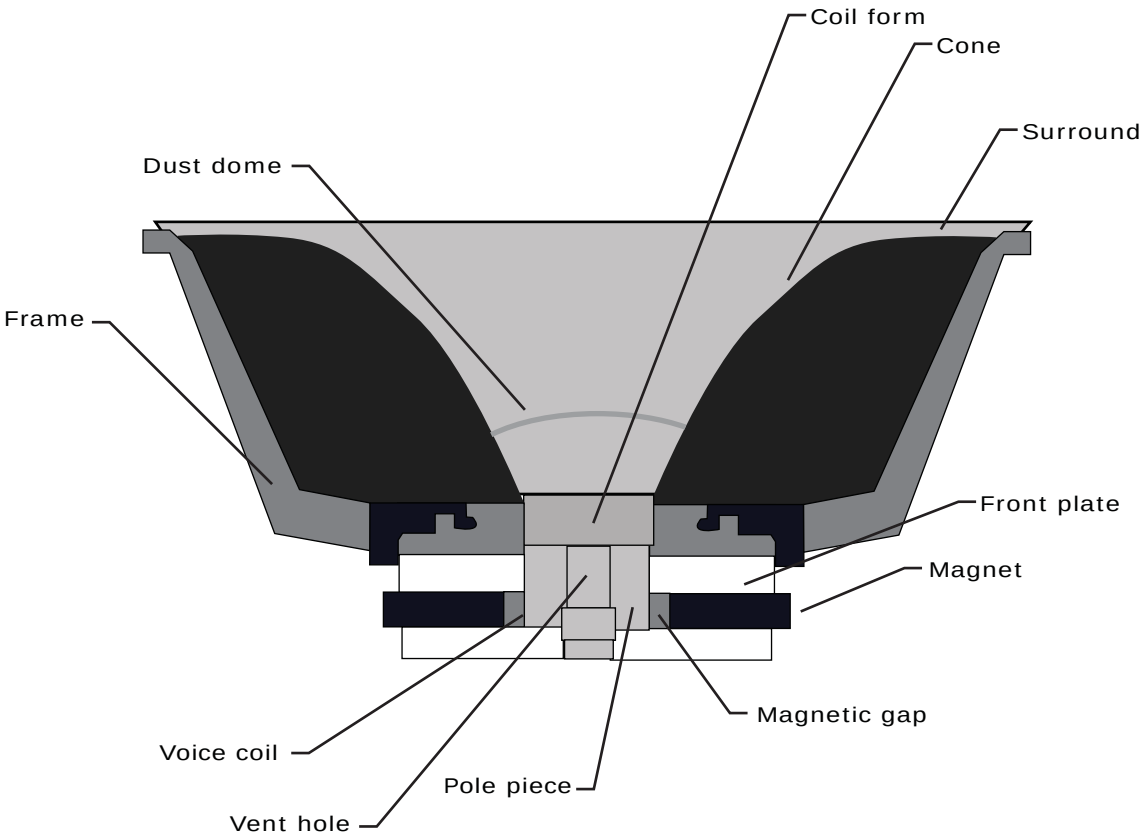
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Types of Loudspeakers

Cones

A typical cone loudspeaker (see Figure 14.11) consists of a magnet, voice coil, spider, dust dome, coil form, surround, and frame.

Figure 14.11
Cone loudspeaker



Types of Loudspeakers, continued

Cones range in size from a few centimeters (cm) or inches to as large as 46 cm (18 in). Normally, the larger the diameter of the cone, the lower the frequency produced by the loudspeaker.

The loudspeaker enclosure also helps determine frequency response and directionality of the acoustic energy. A cone loudspeaker can be used for bass, mid-range, high frequencies and even full reproduction.

Large cones dedicated only to low frequencies are commonly referred to as woofers or subwoofers. Many times, a loudspeaker enclosure which houses subwoofer drivers also is referred to as a subwoofer.

Tweeters are a very specific type of loudspeaker transducer similar to a cone. A tweeter is a small transducer which reproduces very high frequencies (typically between 2 and 20 kilohertz [kHz]). Unlike cones, tweeters are usually made from a very thin metallic dome. Tweeters are more common in smaller scale loudspeakers not requiring extremely high output levels.

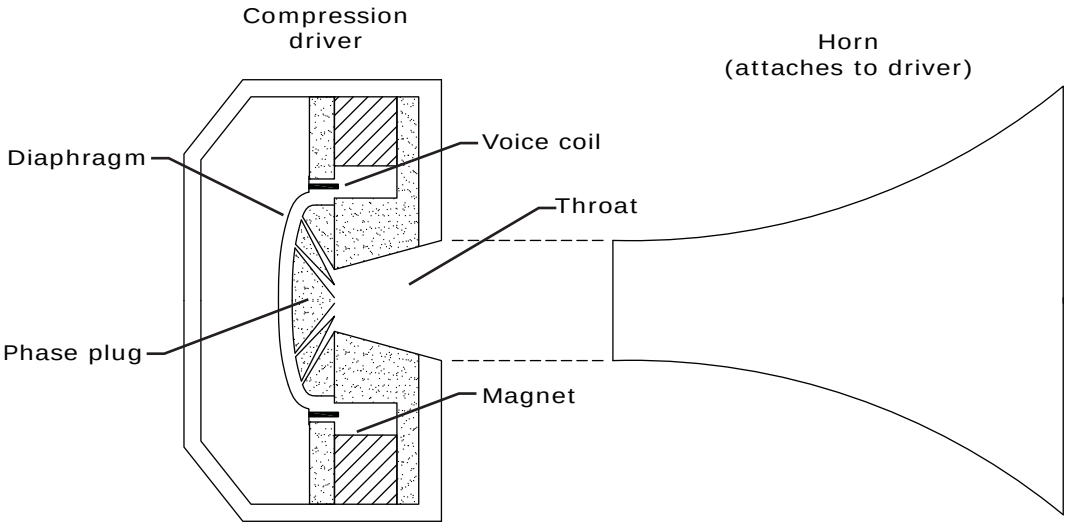
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Types of Loudspeakers, continued

Compression Drivers and Horns

A compression driver (see Figure 4.12) consists of a voice coil diaphragm and is most frequently used for mid to high frequencies, but it may occasionally be used for low frequencies.

Figure 14.12
Compression driver



Compression drivers are coupled to another element called a horn. The horn couples the motion of the diaphragm to the air, producing a high-efficiency loudspeaker. Compression drivers combined with horns are used to produce a more focused, longer, throw. They are common in applications requiring high output levels in a very tight pattern.

Types of Loudspeakers, continued

Crossovers

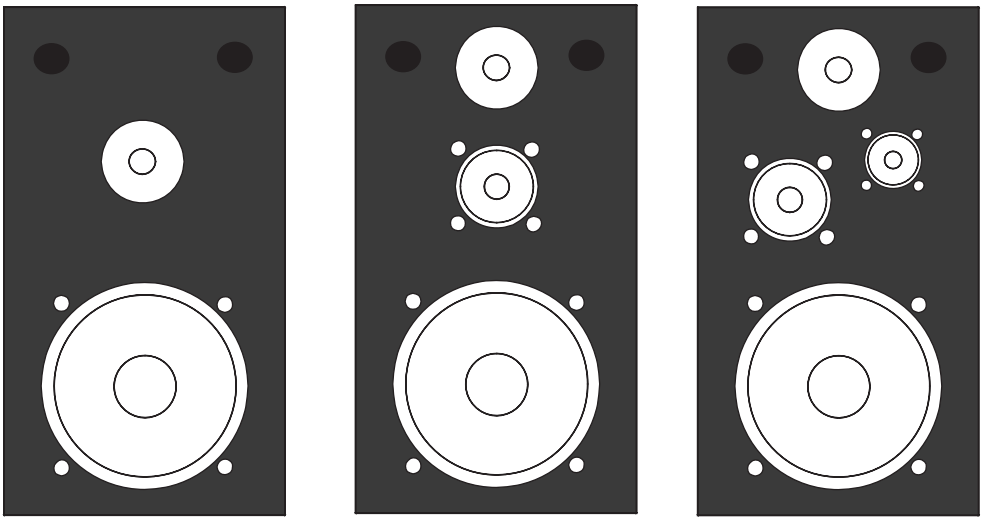
Loudspeakers with more than one driver have a circuit called a crossover. When loudspeakers reproduce sound, specific drivers are dedicated to reproducing sound within a certain range of frequencies. Crossovers determine which frequencies are sent to which drivers.

The audio spectrum has wavelengths and frequencies that vary dramatically. No single loudspeaker driver can reproduce the entire range accurately. This is why several drivers are usually located in one enclosure.

To have more than one driver in a loudspeaker cabinet, a crossover is used. The crossover is an electronic circuit which steers a certain frequency band to one driver, while steering a different band to a different driver. This is done using high-pass and low-pass filters in the crossover.

Crossovers ensure that each driver is reproducing the band of frequencies it is most suited to handle. A loudspeaker enclosure containing more than one driver is referred to by the number of drivers it contains (see Figure 4.13).

Figure 14.13
Loudspeaker enclosures with multiple drivers



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Types of Loudspeakers, continued

Most crossovers are located within the loudspeaker enclosure and are passive in nature. One drawback of a passive crossover is that it must filter the signal at a high level, generally requiring the use of sizable inductors. Large inductors can induce undesirable anomalies into the signal chain.

Another drawback of passive crossovers is that amplifier power is seldom used efficiently. Small high frequency drivers require significantly less power than large woofer drivers. With passive crossover networks, however, separating the amplifier power supplied to the loudspeaker is impossible.

Active crossovers, on the other hand, actually process and filter the signal at the line level stage, usually directly in front of the amplifier stage. The circuitry required to process the signal at this stage tends to perform significantly cleaner than that required to filter it inside the loudspeaker.

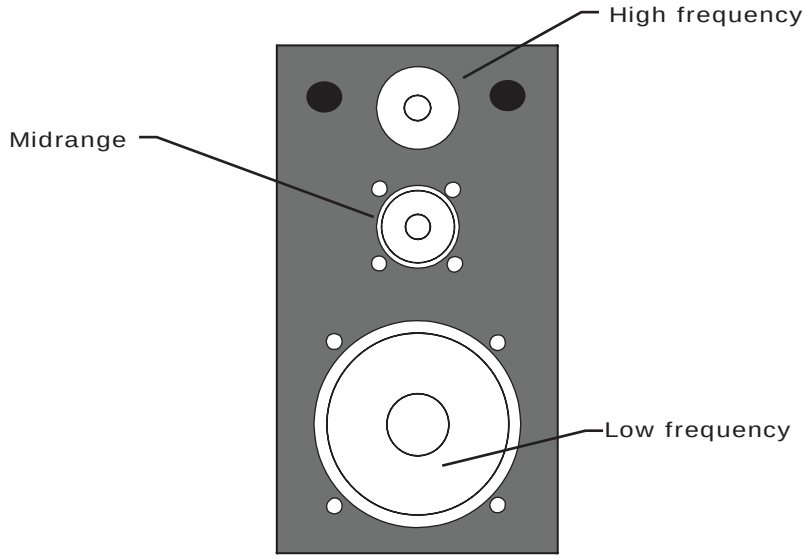
Another factor of active crossovers is that they provide users the ability to alter the crossover filtering to their choosing. The outputs of the active crossover are then routed directly into power amplifiers to drive the respective loudspeaker drivers. Powering loudspeakers in this manner is often referred to as bi-amplified (separately powering two drivers) or tri-amplified (separately powering three drivers).

Types of Loudspeakers, continued

Loudspeakers may have the following frequency ranges (see Figure 14.14):

- Tweeters—High frequencies (typically 2,000 to 20 000 hertz [Hz])
- Horns—Mid to high frequencies (typically 300 to 8,000 Hz)
- Midrange cones—Midrange frequencies (typically 200 to 8,000 Hz)
- Woofers—Low frequencies (typically 40 to 600 Hz)
- Subwoofers—Lower frequencies (typically 20 to 200 Hz)

Figure 14.14
Loudspeakers by frequency range



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Loudspeaker Characteristics

Loudspeaker performance is typically stated by manufacturers through several key specifications. These are very beneficial to a designer in selecting the most appropriate loudspeaker for a given application. Some of the more commonly encountered characteristics are power handling, sensitivity, and directivity.

Power Handling

Power handling is a loudspeaker specification that states how much amplifier power the loudspeaker can handle before it is damaged. It is often stated in a variety of ways. The most common methods are:

- Continuous power—A rating based on a continuous sine wave fed into the loudspeaker, resulting in the worst-case heating of the voice coil.
- Program—A rating based on a complex signal which closely resembles typical program material. This rating can vary from one manufacturer to another so caution should be used in comparing manufacturer specifications.
- Peak power—A rating that refers to the maximum amount of instantaneous power that the loudspeaker can handle with sustaining damage.

Sensitivity

The sensitivity of a loudspeaker is a specification that helps the designer know what output level will result from a loudspeaker given a specific input level. This is important because each loudspeaker model may reproduce a different output level based on the same input level because of the inherent properties of the loudspeaker enclosure.

The rating is typically stated as an output level in decibels sound pressure level (dB SPL) taken at 1 meter (m) in front of the loudspeaker given a 1 watt (W) input signal. This is the most standard method but occasionally the derivation of this specification varies, so the designer should pay close attention to the specification parameters.

Loudspeaker Characteristics, continued

Directivity

Each loudspeaker has a specific directivity or coverage pattern. This pattern is often stated by the manufacturer both in the horizontal and vertical planes. As with microphones, the polar pattern of loudspeakers varies with frequency. High frequencies tend to be much more directional than low frequencies. The stated coverage pattern typically shows the point at which the signal level drops 6 dB below the on-axis level at any point over the usable frequency range.

Loudspeaker directivity is of paramount importance to a designer. If directivity is not carefully considered, the resultant loudspeaker system could steer sound to places where it is unneeded, like side walls, on stage, or to the ceiling. If there is too much overlap of coverage patterns between adjacent loudspeakers, severe phase cancellation can occur and detrimentally impact the perceived sound.

Active versus Passive Loudspeakers

Most loudspeakers used in the commercial AV field are passive loudspeakers. Passive means that the loudspeaker has no active electronics and that does not require electrical power.

Sometimes, however, loudspeakers with built-in amplifiers are needed. This allows feeding line level signals directly into the loudspeaker. This may be beneficial for small-scale stage monitoring or for monitors located near an audio console.

Subwoofers also are commonly active, particularly those in small surround-sound systems. This allows the subwoofer to be adequately powered without the need to locate the amplifier power within an audio receiver. It also allows controls like crossover and volume to be located within the subwoofer.

Active loudspeakers are also commonly found in complex, large-scale, sound systems. Several protocols are currently used to accomplish this, including the delivery of digital audio over unshielded twisted-pair (UTP) cable directly to the loudspeaker. Many of the protocols and methods vary between manufacturers, so the designer should exercise careful research when attempting to deploy one of these systems.

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Types of Assistive Listening Devices

Hearing assistance devices are required in most circumstances by the local disability access requirements. The three most common types of hearing assistance systems are:

- Infrared (IR)
- Radio frequency (RF)
- Inductive loop

Infrared (IR)

IR hearing assistance devices use portable and lightweight receivers to pick up audio signals that are broadcast via invisible light waves within a specific room. These systems allow a person to go between rooms using the same receiver. IR systems work only when the receiver is within the sight line of the transmitter and has a multichannel capability.

Some drawbacks of an IR system are that the transmitters must therefore be positioned in a visible location. The transmitter also requires ac power, and the signal can be affected by some types of light interference. These systems work best in light colored rooms.

Of the three types of systems, IR is the only type that provides security and privacy by eliminating any bleed through of the signal to adjacent spaces.

Radio Frequency (RF)

RF hearing assistance systems use radio waves to transmit the audio program. These types of systems can broadcast a signal 30.5 m (100 ft) to 152 m (500 ft) from the transmitter antenna and use receivers that are portable and lightweight. They may be multichannel capable. Since the transmitter is radio based, it does not need to be visible within the room.

The disadvantage of RF systems is primarily security, since the signal is transmitted up to 152 m (500 ft) and can be picked up by anyone with a suitable receiver. Care also must be taken when selecting the broadcast channel so that it will not be subject to interference from other radio sources. Special power is not required and an RF system setup is relatively simple. The antenna placement must be adjusted to ensure good signal reception.

Inductive Loop

Inductive loop systems utilize a transmission system that produces a signal that can be received by persons with compatible hearing aids (T-coil). These systems work by surrounding the coverage area with a loop cable and creating an electromagnetic field. The signal is then picked up by individuals using their own hearing aids.

This technology is the least secure, and achieving consistent coverage may be cumbersome. The main benefit of inductive loop is that users need no additional equipment apart from the hearing aid.

Audio Storage Devices

In addition to being sent to various playback devices, audio can be stored or recorded on various forms of media.

Audiotape

Audiotape is a medium that uses recording heads to print signals on a magnetic tape. The recording process is easily erased and the tape can be reused. Editing is accomplished by the physical cutting and splicing of the tape. The quality of the recording depends on the speed of the tape, as well as mechanical variations in the transport mechanism.

With the advent of digital storage media and hard-disk–based formats, magnetic tape has fallen out of popularity within the AV industry.

Audio Compact Disc (CD) and Digital Versatile Disc (DVD)

Digital audio is stored optically by changing the 1s and 0s to long strings of pits written helically on a polycarbonate disk. The edges of the pits correspond to 1s and are detected by a laser.

Hard Disk

Hard disk recording systems can be classified as modular hard-disk recorders or digital audio workstations. They can be thought of as a dedicated computer designed to perform one function—record digital audio.

They often include a built-in large capacity mixer and hard disk. They typically require an outboard computer and software. Digital signal processing software is easily applied, so effects, noise reduction, reverb, and equalization are included. A nonlinear editing approach is also built into the software, removing the need for the mechanical cut and splice methods required in analog recording.

Various protocols exist for storing the audio to disk. Some of the protocols use lossless compression, while others use lossy compression. One of the most popular lossy schemes, especially among consumers, is the Moving Picture Experts Group (MPEG) 1 Layer 3 (MP3) format. MP3 has become a popular way for compressing digital audio into less space.

MP3 can achieve up to a 12:1 compression ratio. In other words, digital audio files can be reduced in size by a factor of 12, thereby reducing storage space. Its unique popularity came about because it is an open standard and the specifications are available for anyone interested in implementing the standard.

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———. 2003. *Essentials of the AV Industry Online*. Online course.



Chapter 15
Video Components

Similar to the previous chapter, this chapter addresses the most common video components, or pieces of equipment, that the audiovisual (AV) designer may encounter. These components represent the foundation of larger video systems.

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Overview

Like audio, video can often be more easily understood by grouping components into the main segments of the signal chain. The first stage in that chain is sources of video. This can include such devices as cameras, computers, videotape, digital versatile disc (DVD), and electronic white boards. It is not uncommon to encounter a variety of these sources in each video system.

Sources of Video

Videotape Recorder (VTR) and Videocassette Recorder (VCR)

The videocassette recorder (VCR) provides the following three functions. It:

- Utilizes videotape, which is an extremely thin, somewhat delicate and is a long piece of plastic.
- Records a signal on the videotape in the record mode.
- Reads the signals off the tape and converts them to signals that a television (TV) can understand in the playback mode.

Since video signals contain 500 times more information than audio signals, the same recording and playback process cannot be used. To solve this problem, two recording heads are mounted on a rotating drum tilted with respect to the tape.

In addition to video information, a videotape recorder (VTR) device also records three additional types of information or tracks:

- Audio
- Time code
- Control track

Several separate audio tracks may be available depending on the type of VTR/VCR and the number of audio channels to be recorded and played back.

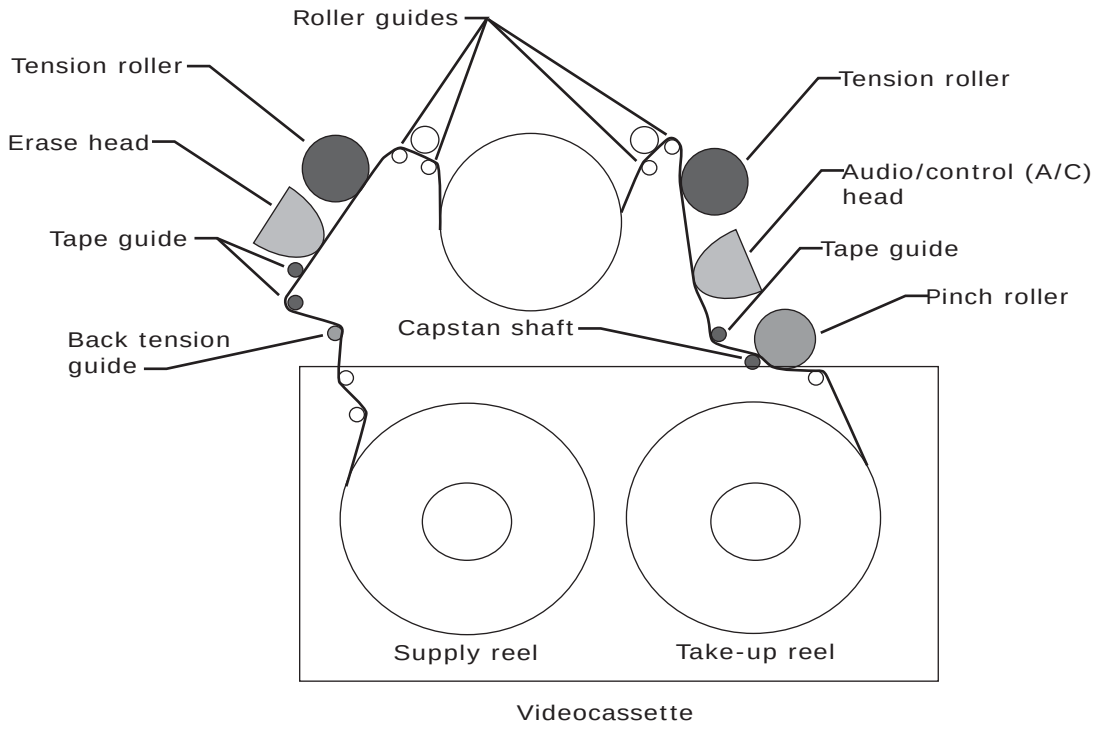
Time code is an electronic digital signal recorded onto videotape. The time code information is electronically synchronized to the beginning of each video frame, providing an exact number reference in hours/minutes/seconds/frames for each frame of recorded video.

Control track is a series of electronic pulses which are recorded onto the tape to ensure the field and frames are recorded and played back exactly as they arrived from the camera. A control track is only necessary for videotape and not for DVD or hard drive.

Videotape Recorder (VTR) and Videocassette Recorder (VCR), continued

The only challenge a VCR design poses is making the videotape wrap around the rotating head to record or play back the tape. In addition, the device has to read the audio and control tracks from the tape, keep the tape moving at exactly the right speed, and detect the end of the tape. To accomplish this, the tape has to follow a tortuous path, as shown in Figure 15.1.

Figure 15.1
Videocassette recorder tape path

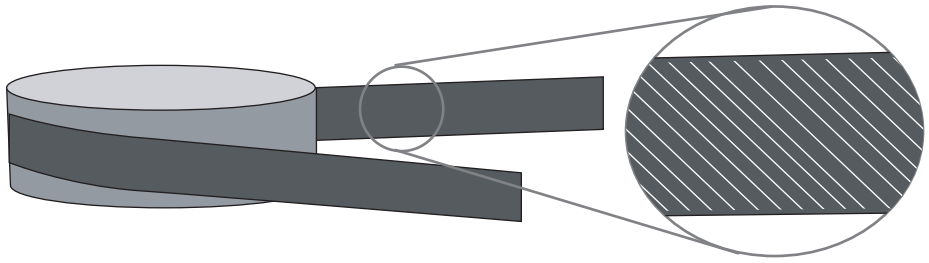


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Videotape Recorder (VTR) and Videocassette Recorder (VCR), continued

Looking at real helical-scan videotape (Figure 15.2), the recorded information tracks cannot be seen.

Figure 15.2
Helical-scan videotape



Digital Versatile Disc (DVD) Player

A DVD player is similar to a compact disc (CD) player but differs in construction and storage capacity. The player incorporates a laser beam mechanism that focuses the beam onto the disc surface to read the pattern of the DVD surface.

DVD players provide many benefits over videotape. They allow users to instantaneously jump to any place on the disc without the need to rewind and fast forward through the material. They also support discreet multichannel audio playback for surround sound purposes. The DVD standard for video encoding is Moving Picture Experts Group (MPEG) 2 and Dolby Digital for audio.

DVD players are typically equipped with a composite S-video and component video output. In addition to the standard analog stereo audio output, a digital multichannel audio output is always provided for connection to a receiver or other surround-sound supporting device.

Digital Video Recorder (DVR)

A digital video recorder (DVR) is a hard drive inside a type of a small form factor (SFF) personal computer (PC). The hard drive is connected through jacks on the back of the box similar to those on a VCR. The DVR is controlled by a customized operating system residing on the hard disk.

In analog signal processing, the TV signal comes into the DVR's built-in tuner through antenna, cable, or satellite. If the signal comes from antenna or cable, it goes into an MPEG-2 encoder, which converts the analog data to digital. From the encoder, the signal is sent to two different places:

- First, to the hard drive for storage.
- Second, to an MPEG-2 decoder, which converts the signal back to analog and sends it to the display for viewing.

Today's devices have developed complementary abilities, such as recording onto DVDs, pausing live TV, instant replays, skipping commercials, and sharing recordings over the Internet. The time shifting features are now much more convenient.

Many satellite and cable companies are incorporating DVR functions into their set-top boxes. In these cases, no encoding is necessary in the DVR as the satellite signal is already a digitally encoded MPEG stream. The DVR simply stores the digital stream directly onto the disk.

Computer Interfaces

Computer video interfaces are devices that enable the client to connect a PC display output to the video system. Computers are becoming a main source component for audiovisual (AV) presentations, due to the popularity of computer presentation software.

The primary functions of a computer interface are to:

- Isolate and buffer (or convert) the computer's output signal to the appropriate level and format of the local monitor.
- Prevent loading (double termination) and impedance mismatch from the display.
- Maintain the video resolution and frequency of the original source.
- Provide sharpness (peaking) and gain to compensate for cable loss.
- Act as a sync processor.
- Convert unbalanced audio to balanced audio (active PC audio interfacing).
- To provide the user some controls over the displayed image, such as shift (image moving off center).

Cameras

Video Camera

Video cameras are commonly used to capture real-time motion video. The output of a video camera may be recorded or sent to a video display. In the simplest form, the camera comprises a camera head, a lens, and a viewfinder.

A wide variety of camera types and accessories are used in the AV industry. They can range in size from small fixed cameras on a wall mount to fully equipped broadcast cameras.

Cameras may output a variety of signal types, including composite, S-video, component video, and serial digital interface (SDI). When dealing with broadcast-heavy designs, the designer should consult more exhaustive texts addressing broadcast standards and methods for a more in-depth discussion of broadcast camera configurations.

Document Camera

Document cameras, also called video overheads, consist of a video camera and at least two lamps focused above a display surface. They look similar to overhead projectors, but a video camera is located where the lens would be. The document camera is then connected to a display device to display the signal.

Document cameras can be used to display printed documents, drawings, photos, books and solid three-dimensional objects. Some allow displaying transparencies, x-rays, and slides. In a presentation, they allow small objects and images to be viewed in close-up detail on a display.

Document cameras also output most of the standard video formats like any other video camera. However, many document cameras also output high resolution five-wire video (e.g., red, green, blue [RGB]-horizontal sync, and vertical sync [RGBHV]) similar to a computer monitor output. This high-resolution output is often used for medical imaging and in other venues where the image quality is critical.

Video Compression / Decompression Devices (Codecs)

Codecs are the focal point of a videoconferencing system. Codecs serve a similar function in videoconferencing as modems do in computer communication.

A codec compresses its audio and video input using mathematical algorithms like H.320 and H.323. The compressed signal is made suitable for transmission over Internet protocol (IP) or integrated services digital network (ISDN).

The codecs at each site interact to establish a videoconference. Each codec then simultaneously transmits local information and receives remote data. The data from the remote site is converted back to audio and video data through the inverse sequence of the algorithm it underwent in the remote codec.

Traditional videoconferencing allows three or more sites to connect at once through the use of a video bridge called a multipoint control unit (MCU). Although this type of hardware can be expensive, certain applications (e.g., distance-learning to multiple classrooms) can be more effective in multipoint configurations.

Video Compression / Decompression Devices (Codecs), continued

Finally, the latest VTC systems on the market use an IP-based software approach and a virtual private routed network (VPRN) that communicates inside the network cloud and does not require the MCU. This advancement reduces equipment cost and complexity and is currently considered the future of videoconferencing.

The videoconferencing systems allow holding a point-to-point (PTP [one-on-one]) videoconference with any other H.323 videoconferencing user. To hold a multipoint videoconference over the network with three or more sites, an H.323 MCU videoconference server and an H.323 gatekeeper are needed.

Portable Media Devices

The use of portable media devices has been growing steadily. From compact discs to flash recorders to MP3 players, these devices are finding there way into corporate AV rooms and classrooms and their use is expected to increase with the need for portable content sharing.

Most of these devices provide a MPEG-2 to MPEG-4 standard of multimedia delivery. However, their connectivity may not be what the designer is accustomed to providing for. Many of these devices have custom output and input cables or docking station for the connection of audio and video. The designer should make provisions for the interfacing of these devices as a standard or at least understand the connectivity required for future integration.

Annotation Devices and Electronic White Boards

An annotation device is a surface that can capture writing electronically through an internal or external computer. Some annotation devices also allow interaction with a projected computer image. The most common form of annotation device is an electronic whiteboard, most commonly used in classrooms, conference rooms, or training facilities.

Electronic whiteboards are used in one of two ways:

- To capture notes written on the whiteboard surface using dry-erase ink.
- To control or mark up a computer-generated image projected on the whiteboard surface from a video projector.

Interactive whiteboards use the following technologies:

- Touch-sensitive—This technology has a soft writing surface and allows using a hand, a dry-erase marker, or a stylus on the whiteboard.
- Electromagnetic—This technology typically has a hard writing surface but requires a special stylus or dry-erase marker holder.
- Laser—This technology has a hard (e.g., ceramic on steel) surface, which has the longest life and erases most cleanly.
- Ultrasonic and infrared—This technology allows whiteboards to be made of any material but requires an active dry-erase marker or stylus.

Types and Uses of Switchers and Routers

Video Production Switcher (Vision Mixer)

A video production switcher routes video signals by switching between them. In a studio or live event, shots from multiple video cameras can be transitioned smoothly. In a video editing room, signals from different sources (e.g., a live shot to prerecorded video) can be easily transitioned.

The main purpose of a video production switcher is to create a master output for a real-time video recording or broadcast. Production switchers are typically used for live events or any event where multiple sources need to be mixed in real-time as opposed to post-production editing. Production switchers also can be used to create various visual effects, from simple mixes and wipes between sources to advanced composite effects.

Production switchers are conceptually similar to audio mixers. They take multiple input sources, apply any desired effects or processing, and provide one or more outputs. Most are based around the preview bus and the program bus, each having its own monitor.

The program bus is the main output feed (i.e., the shot which is being recorded or broadcast). Whichever source is on the program bus is said to be online.

The preview bus is used to select and preview the source, which is about to be put online.

NOTE: The preview bus does not have to be used; if desired, sources can be cut online without previewing. However, the preview is normally necessary for any visual effects such as transitions, as the effect is constructed from the preview and program sources.

Production Switcher Functions

Production switchers may perform any of the following functions:

- Cut—An instant transition from one image to another
- Dissolve—A simultaneous fading down of one image and fading up of another
- Superimposition—A dissolve held at its midpoint so that each image appears together for a moment
- Fade—A dissolve between one video image and black
- Wipe—Usually a left-to-right or top-to-bottom transition from one image source to another with no brightness level change from one to the other
- Color/background generator—Electronic generation of a field of color
- Border/pattern edge—The video equivalent of putting a frame around a picture
- Pattern key—Two different images simultaneously appearing on the screen, separated into screen areas by a particular pattern; it is often called split screen and a pattern key is programmed in terms of the percentage of the screen area each image will occupy
- Luminance and chroma—Manipulation of the brightness and hue of the video

Video Production Switcher (Vision Mixer), continued

- Keying—A key signal has two components, a source and a fill. The key source signal cuts a hole in the background video and the fill signal fills in that hole. Here are three keying functions:
  - Luminance key—The source cuts a hole at a given luminance level.
  - Chroma key—All of one color is removed from the source image and is replaced with the fill image. This is how most TV news programs show the weather person in front of a map.
  - Downstream key—A key used for applying titles and logos or displaying over-the-shoulder still images.

Switchers, like most equipment, are manufactured at many levels of sophistication.

Video Switching and Routing

Video switchers and routers move signals around much like audio switchers. Simple switchers can select one signal from multiple sources and send it to a specific destination. More sophisticated routers can send several signals to several different places. They can even separate audio signals from video signals to process them separately.

Switchers

Switchers route signals by the simple press of a button, automatically or by remote control.

Many video displays provide built-in switchers. However, since these are usually very limited (e.g., allowing switching between two or three inputs), any system over a very small size usually requires a separate switcher.

Switchers are designed to operate in different ways. Some use a mechanical switch to move between video sources, while more sophisticated switchers create seamless transitions from one source to the next.

Standard switcher mechanism types include:

- Crash switchers.
- Vertical interval switchers.

Crash Switchers

A crash switcher is a mechanical connection of the cables or circuit. It functions like a wall switch, meaning there is a mechanical connection or disconnection between two conductors.

Crash switchers do not take a signal's phase (i.e., the signal's location of at a specific time) into account. For example, if a VCR and a video camera are connected to a crash switcher's inputs and the user changes the switcher's output signal to a monitor, the picture may jump, roll, or break up before it stabilizes. This occurs because the signal information for the scan line was not in the starting position for the new source's image.

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Video Switching and Routing, continued

Vertical Interval Switchers

Vertical interval switchers are used instead of crash switchers in presentation systems when visual quality should not be compromised.

Vertical interval switchers monitor the sync information for the second signal, synchronizing the transition when it is in vertical retrace. This feature means that transitions from source to source are clean and transparent, so this switching is called seamless. Seamless switching may not be required when only one source (e.g., computer) is to used for the vast majority of presentations.

Router or Matrix Switcher

Matrix routing switchers are used to route many video sources to many destinations. Matrix switchers are required when different video sources must be displayed on different video displays or in different zones.

Common characteristics of matrix routing switchers include:

- Multiple inputs routed to multiple outputs.
- Several routing configurations running simultaneously.
- Configurations called macros or salvos.
- Audio that follows the video or breaks away.
- Other types of signals (e.g. RS-422) on separate channels.
- Channels that are modular or fixed.

Facilities such as video headends use matrix switchers extensively because of the capability of routing the sources to different rooms within a facility.

Signal Processing

Introduction

Often, substantial signal processing is needed before playback. Signal processing is performed to ensure:

- The technical integrity of the signal (e.g., adjusting the time or amplifying the signal for long cable runs).
- Continuous transitions (e.g., avoiding jumps and shifts between signal sources).
- Deficiencies in the original are corrected.
- The picture's color, brightness, and contrast are adjusted.

Picture quality goes well beyond what is seen on TV. Monitoring equipment is used to see picture impairments that are much more subtle and to look at the signal's technical quality through a visual representation of its waveform. Monitoring also is used to ensure that processing adjustments are made properly. All of the creative input must be balanced by high technical quality to output the best picture.

Video signal processing is a critical aspect of a video system. A video engineer or video editor typically makes controls and adjustments.

Time-Base Correctors (TBCs)

A time-base corrector (TBC) corrects inconsistencies of an analog playback VCR. It accomplishes this by sampling one video scan line at a time (not an entire frame), corrects any instability by stripping the scan line of its old sync signal and replacing it with a new sync signal created by the TBC's own built-in precise timing clock.

Now with vast digital memory, modern day TBCs can correct up to an entire field (262.5 scan lines) of incoming video. These are known as infinite window TBCs.

Frame Synchronizers

A frame synchronizer literally takes a digital snapshot of each incoming frame of video and releases it immediately as the next frame comes in. Once converted to digital, the video frame can be blended with any other digitized video frame through transitional effects.

Like the TBC, frame synchronizers work on the principle of converting the incoming video from analog to digital. Also, they both stabilize the video picture so that their respective outputs can feed other equipment requiring digitally stable signals.

The frame synchronizer, on the other hand, digitally synchronizes two separate video sources without necessarily correcting them.

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Processing Amplifiers

Processing amplifiers allow adjustments for the luminance, chroma, and hue components of the video picture. A processing amplifier prompts raising or lowering video signal levels, black level, and color saturation or correcting color balance problems. It works like a color or contrast control on a TV monitor, but in this case it is adjusting the signal itself, not just the display.

Most processing amplifiers are combined with TBCs, so there is a single unit which adjusts all aspects of the video signal. They also should be used in conjunction with the proper signal monitoring equipment.

Scalers

Modern displays are not able to display all current and older video standards without some form of processing being involved. Most video systems have a large and disparate range of sources with varying output resolutions and refresh rates. None of these sources are likely to actually output a resolution or refresh rate that is optimum for the display. Scalers are able to configure and optimize the capture and processing of all these signals and then output them at the most appropriate resolution and refresh rate for the source material and the display.

Scalers typically accept a wide range of input signal formats, ranging from composite, S-video, component, high definition multimedia interface (HDMI), digital video interface (DVI), RGBHV, or high-definition (HD) component.

Scan Converters

Computer and TV monitors differ technically in several fundamental ways.

The rate at which an image is painted onto a computer monitor can be more than twice as fast as the rate at which it is painted onto a TV monitor. This is called the scan rate.

A computer paints an image onto a computer monitor going from left to right at a horizontal scan rate of 24 to 65 kilohertz (kHz), and from top to bottom at a vertical scan rate or refresh rate of up to 75 hertz (Hz).

The role of a scan converter is to convert the faster scan rate of the computer image to the slower scan rate compatible with TV technology.

This basic process is called scan rate conversion and bridges the gap between high resolution computer video signals and regular video equipment. Scan converters accept a high-resolution computer video signal and output a composite video or S-video signal, which can be displayed on a conventional video display, recorded to videotape, or connected to a video teleconferencing codec. Advanced scan converters also include a component video output, RS-232 control capability, and generator locking (genlock [a system which allows the synchronization of two or more video sources]).

Standards Conversion

Various video standards are used around the world.

NOTE: See Chapter 3: Signals, for more information.

To watch a National Television System Committee (NTSC) tape on a phase alternating line (PAL) TV, the signal has to be converted. The process of standards conversion includes:

- Color decoding or separating the video into its components, usually in a digital form.
- Frame buffering for the timing difference.
- Receiving component video and converting the components through a digital encoder to composite video or luminance/chrominance (Y/C) in the required standard.

Converting one TV standard to another may be difficult and costly. Converting an NTSC to a PAL signal involves changing the color coding, field rate, and resolution. The PAL-NTSC and NTSC-PAL converter boxes generally work by inputting a composite video signal and outputting the converted composite video signal.

Multi-Image Processors

The picture-in-picture (PIP) devices, called multi-image processors, enhance and expand the capabilities of a presentation system. They are available in a variety of types and levels of sophistication, but most typically perform the following tasks:

- Create a variety of effects, including side-by-side and PIP
- Position various images across multiple displays
- Move images around on a display
- Change image sizes on the fly
- Combine images from almost any source (e.g., PCs, cameras, DVDs, videoconferences)

Key applications may include:

- Command and control rooms.
- Network operations centers (NOCs).
- Air traffic control centers.
- Security/surveillance.
- Entertainment venues.
- Digital signage.

Multi-Image Processors, continued

A new generation of windowing systems with many advanced features is available. The best of them offer an outstanding image quality and new features (e.g., Web-based control, dynamic window sizing, borders and titling, and smooth zoom/pan) that make them ideal for any application requiring multi-display.

They accept high resolution RGB, high definition television (HDTV), S-video, component, and NTSC/PAL composite video and optional DVI and high definition serial digital interface (HD-SDI) inputs.

Each input can be sized and positioned anywhere on displays as on a computer desktop and panned and zoomed to emphasize the areas of particular interest. Display alternatives include quad split, side-by-side, PIP, and overlapping windows. They support real-time, dynamic, movement and resizing of windows.

Character Generators

Character generators differ significantly in their versatility and ease of use but generally have the same components, a console with a typewriter-style keyboard and a dedicated video monitor.

A number of dedicated keys on the keyboard control specific functions of the character generator, such as page advance, character size and type style, automatic centering, and other options.

A set of keys position a cursor up, down, left, and right that appears on the character generator's own monitor but not in the signal sent to the switcher and indicates exactly where on the screen the next letter will appear. The output of a character generator is usually inserted over other video by a key or matte.

Most units can store more than one page of graphics and allow recalling them in an order or randomly by pressing keys. The ability to roll (vertically) or crawl (horizontally) the lettering across the screen is useful. Rolling credits are common at the end of programs and crawls are often used to make announcements during a program at the bottom of the screen.

Some machines offer a disk or tape cassette storage system that allows pages of characters to be stored for recall at any time, extending the character generator's page-storage capability.

Finally, more sophisticated character generators offer a wide variety of sizes and styles (and sometimes colors) of characters, variable italicization, outlines, shadows, and even the ability to create custom characters or logos for later regeneration. The most advanced character generators even permit the creation of three-dimensional images and manipulation on screen.

Video Distribution

A video system of any size and complexity has many cables carrying signals to and from different locations and connecting and interconnecting diverse pieces of equipment.

Video distribution design objectives typically include:

- Efficiently directing the signal to the appropriate display devices.
- Monitoring signal strength and how strength diminishes with distance.
- Re-amplifying the signal to prevent signal loss due to cable attenuation.
- Compensating for variations of signal strength at different frequencies resulting from cable attenuation.

The purpose of the distribution system is not only to "steer" the signals to the right destination, but also to care for the signals as they are passed from one component to the next. The designer must consider the video feeds, cabling and intermediate components, and how these elements will change or degrade the video signal.

Distribution Amplifiers (DAs)

Many setups call for the distribution of a video signal to multiple locations and over long distances. This is where the use of a distribution amplifier (DA) comes into play. A DA sends a single video signal to multiple locations while maintaining signal quality and integrity.

Video DAs are available for all types of video sources. They also are available in a variety of sizes with as few as two or more than a dozen outputs.

DAs:

- Can have audio distribution channels to accommodate simultaneous audio and video distribution. This prevents overloading system circuits.
- Are used to send the same video signal to multiple destinations.
- Send one input to multiple outputs.
- Can have audio distribution channels to accommodate simultaneous audio and video distribution.
- May provide unity gain to the signal, while others can provide different output levels to compensate for cable-induced signal attenuation.

DAs or line drivers are used to boost video signals when long cable runs are required. Distribution amplifiers typically provide unity gain at the outputs. Line drivers allow for gain and peaking adjustments to compensate for losses in devices and cabling. Some devices provide buffered outputs, some looping outputs, and some a mixture of both.

Display Technologies

The chief objectives of display devices are to facilitate communication and learning. The options for monitors, projectors, and other types of display devices have been increasing with the advent of new technologies, aimed at decreasing the size of components and abridging the gap between the electronic image display and the human image perception.

This section explains the following old and new display technologies:

- Film
- Cathode ray tube (CRT)
- Liquid crystal display (LCD)
- Digital light processing (DLP®)
- Plasma
- Light-emitting diode (LED)
- Organic light-emitting display (OLED)
- Liquid crystal on silicon (LCoS)
- Digital direct drive image light amplification (D-ILA®)
- Slide and overhead projectors

Photographic Film

As light falls on photographic film, it causes a chemical change. Some of the layers coated on the transparent film filter light or control the chemical reactions in the processing steps.

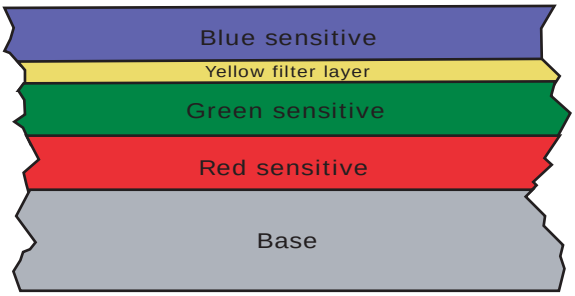
The imaging layers contain sub-micron sized grains of silver-halide crystals that act as the photon detectors. These crystals are the heart of photographic film. They undergo a photochemical reaction when they are exposed to the light.

An image that is focused on the film surface, with the exposure set through a combination of film speed, aperture settings, and exposure time, goes through a process known as photochemistry.

Photographic Film, continued

In color photographic film, this process happens separately for exposure to the RGB portions of the reflected light. The film has separate layers for RGB (see Figure 15.3). Each color light forms a latent image in the respective color-sensitive layer of the film. The image is called latent because its presence cannot be detected until the film is processed, after which, a finished negative or print is produced.

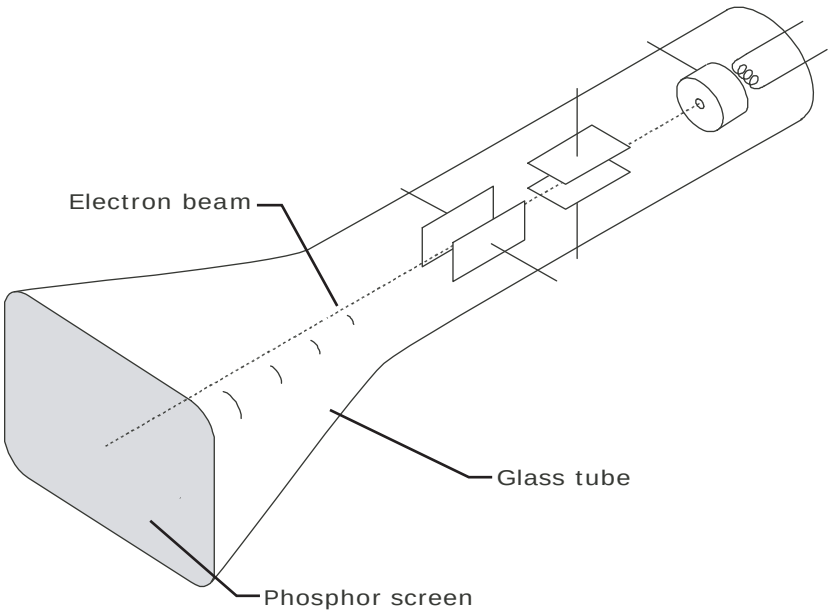
Figure 15.3
Color film



Cathode-Ray Tube (CRT) Technology

At the rear of the CRT, an electron beam is aimed at a phosphor-coated screen. When the electrons hit the phosphors, they glow and produce images (see Figure 15.4). When the CRT is plugged into a display device with a video card, it obtains a scan frequency or a signal that conveys the precise instructions to the electron gun to excite pixels at particular times, thereby forming a complete picture.

Figure 15.4
Cathode ray tube



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Cathode-Ray Tube (CRT) Technology, continued

The beam starts crossing the screen at the top from left to right and exciting the phosphor dots along the way. As it reaches the right side of the screen, it returns to the left side to refresh the line of dots underneath the first one. It continues this process down the screen, returning to the top to repeat the process when it has finished the entire screen.

Each time the gun moves from left to right, repeating down the entire screen, the image is refreshed. Measured in Hz, a refresh rate of 60 Hz means that the refresh cycle is repeated 60 times per second. Refresh rates that are too low could cause a flicker that is noticeable to the human eye. Higher resolutions normally demand lower refresh rates because a larger number of pixels take longer to refresh.

Liquid Crystal Display (LCD) Technology

LCDs work differently than the CRT. In an LCD, each pixel consists of a column of liquid crystal molecules suspended between two transparent electrodes and two polarizing filters, the axes of polarity of which are perpendicular to each other.

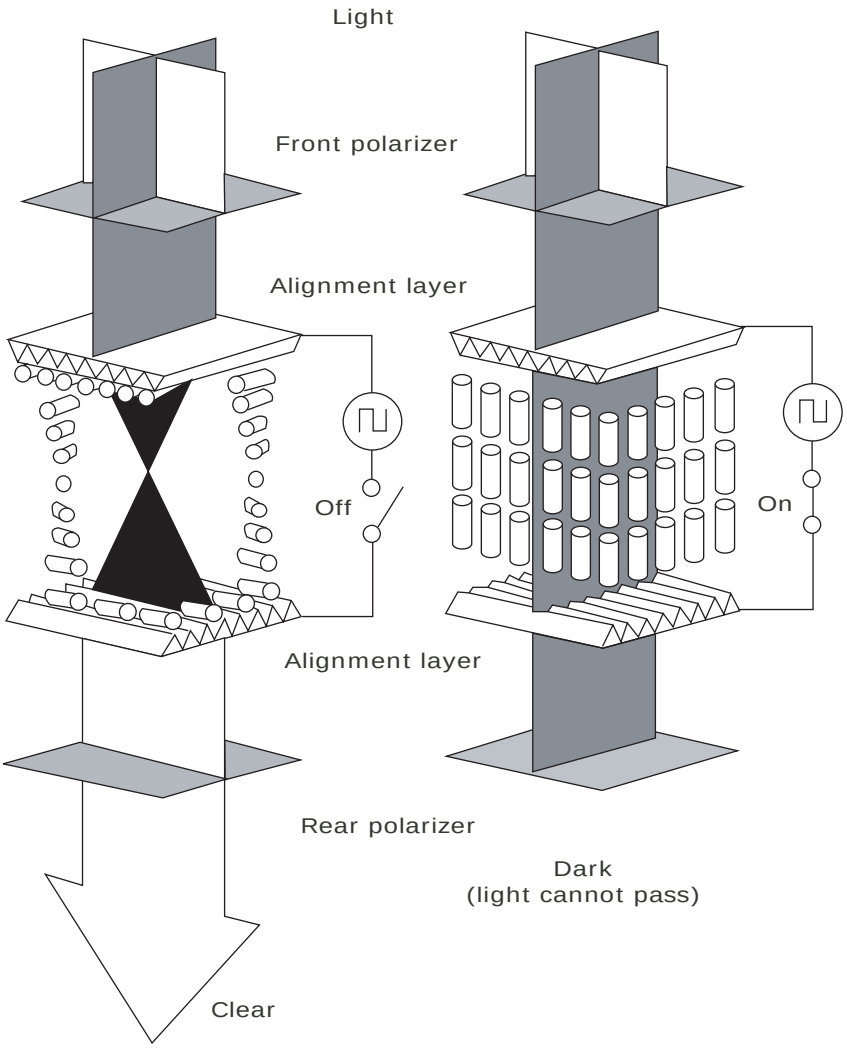
The molecules of liquid crystal are aligned in the same direction as in a solid state matter, but are free to move around slightly in relation to one another as in a liquid state matter. Liquid crystal is closer to a liquid state than a solid state, which is why it is sensitive to temperature.

Depending on the temperature and some specific properties of liquid crystal, it can exist in any number of phases or states. LCDs use the type of liquid crystal that exists in a nematic phase, in which the molecules are oriented in loose parallel lines. The type of nematic liquid crystal used is more specifically called twisted nematic (TN). TN has a natural twist at the molecular level and the degree of twist is highly controllable by applying the electric current to the liquid crystal.

Liquid Crystal Display (LCD) Technology, continued

Undergoing the electric current in varying degrees, the liquid crystal allows or disallows the passage of light, as shown in Figure 15.5.

Figure 15.5
Liquid crystal orientation change with electronic charge



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Digital Light Processing (DLP®) Technology

DLP® is based on an optical semiconductor called a digital micromirror device (DMD) and was invented in 1991 by Texas Instruments.

The DMD is an extremely precise light switch that enables light to be modulated digitally via millions of microscopic mirrors arranged in a rectangular array and reflected onto the screen. Each mirror is spaced less than 1 micrometer (μm) apart.

The mirrors are capable of switching on and off thousands of times per second and are used to direct light towards, and away from, a dedicated pixel space.

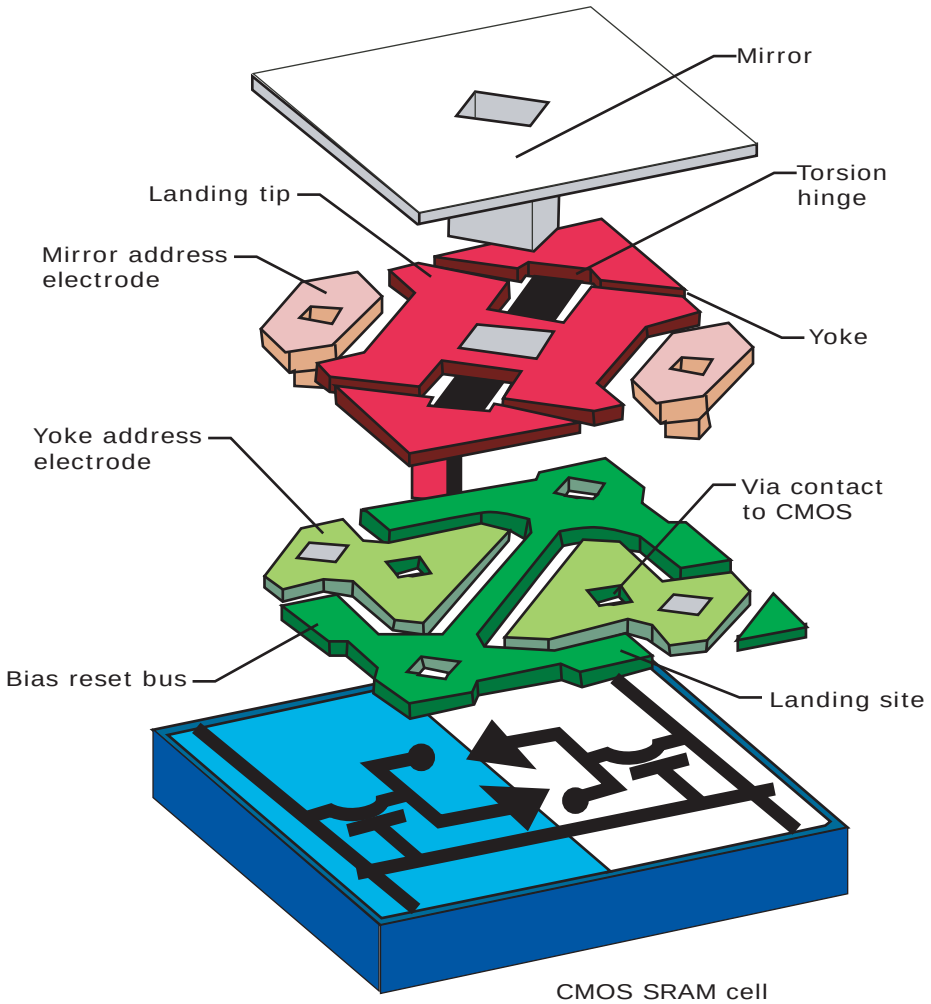
When the display is off, all of the mirrors are flat. When the display is turned on and the chip begins transmitting the signal, the mirrors flip back and forth thousands of times per second. Mirrors in the on position reflect the light through a projection lens and onto the screen. The longer a mirror is in the on position, the lighter the pixel it creates. Mirrors that are off for longer periods create darker pixels, and mirrors that are always off create black pixels. By varying the length of time that the mirrors point toward the projection lens, the DMD creates up to 1024 shades of gray. The grey pixels combine on the screen to create a progressive, fully digital monochrome image.

Digital Light Processing (DLP®) Technology, continued

To add color to the picture, the single chip DLP® system uses a color wheel. The color wheel is a transparent, spinning wheel with RGB segments (see Figure 15.6). The light passing through each section turns red, green or blue. The system‘s processor synchronizes the spinning of the wheel with the action of the mirrors. Together, the DMD and the RGB color wheel can create 256 shades of each primary color. Each pixel of light on the screen is red, green or blue at any given moment. The DLP® technology relies on the viewer‘s eyes to blend the pixels into the desired colors of the image.

The three chip DLP® technology assigns an individual chip to each color channel (red, green, and blue). Using color filters and steering mirrors, they create the color image on the screen.

Figure 15.6
Detail of one pixel on a digital micromirror device chip



CMOS = Complementary metal-oxide semiconductor
SRAM = Static random access memory

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Plasma Technology

Plasma display panels (PDPs) are similar to CRTs. They are emissive and use rare earth phosphors for color, but also are similar to fixed-matrix displays such as LCDs in that they use an x-and-y grid of electrodes separated by a dielectric layer.

In the case of plasma, each cell is surrounded by a mixture of inert gases (e.g., argon, neon, or xenon) addressing individual pixels and excited by passing high voltage through the gas cell to generate both color and light.

Within each cell, three sub cells have one red, one green, and one blue phosphor. To generate the color spectrum, the perceived intensity of each RGB color must be controlled independently. Each sub pixel is divided into 256 different intensities giving a total color combination of $256^3 = 16\ 777\ 216$.

The following are the steps for image creation in plasma cells.

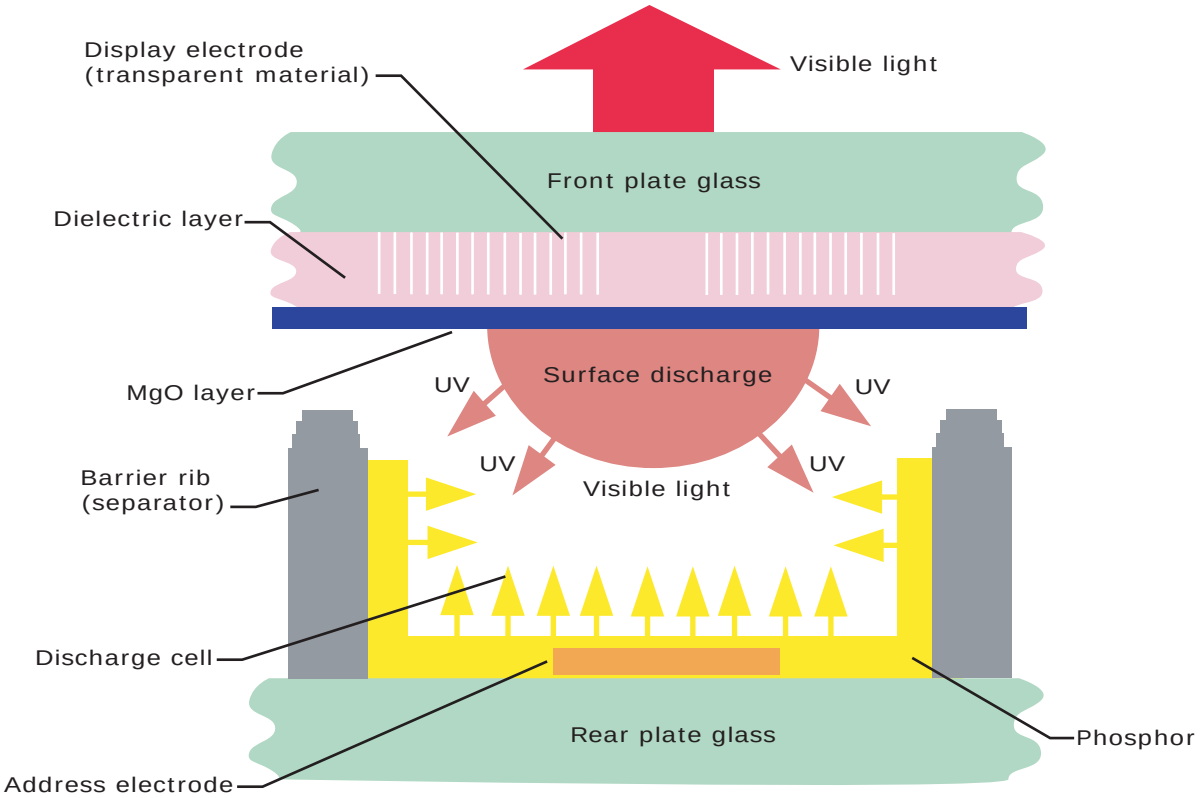
STEP	TASK
1	The cells are filled with xenon and some neon gas mixture.
2	A controlled current is passed through the gas.
3	Ultraviolet rays are produced.
4	Ultraviolet rays hit the red, green, and blue phosphors.
5	Visible light is produced.

Brightness variation is achieved by controlling the number of pulses of light which human eyes integrate to produce impression of dim or bright areas.

Plasma Technology, continued

See Figure 15.7 for image creation in plasma cells.

Figure 15.7
Plasma display operation



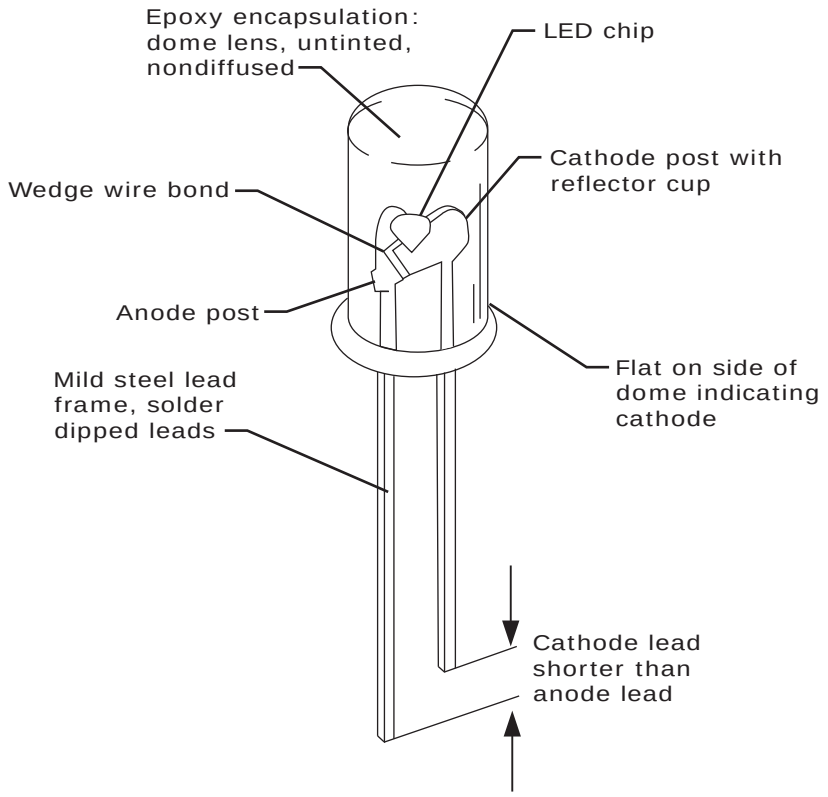
MgO = Magnesium oxide
UV = Ultraviolet

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Light-Emitting Diode (LED) Technology

LEDs are tiny light bulbs in an electrical circuit (see Figure 15.8). One advantage over ordinary incandescent bulbs is that they do not have a filament that will burn out or become very hot. They are illuminated solely by the movement of electrons in a semiconductor material, and they are as long lasting as a standard transistor.

Figure 15.8
Light-emitting diode



LED = Light-emitting diode

Light-Emitting Diode (LED) Technology, continued

Light is produced in the form of energy that can be released by an atom. It is made up of many small particle-like packets that have energy and momentum but no mass. These particles, called photons, are the basic units of light.

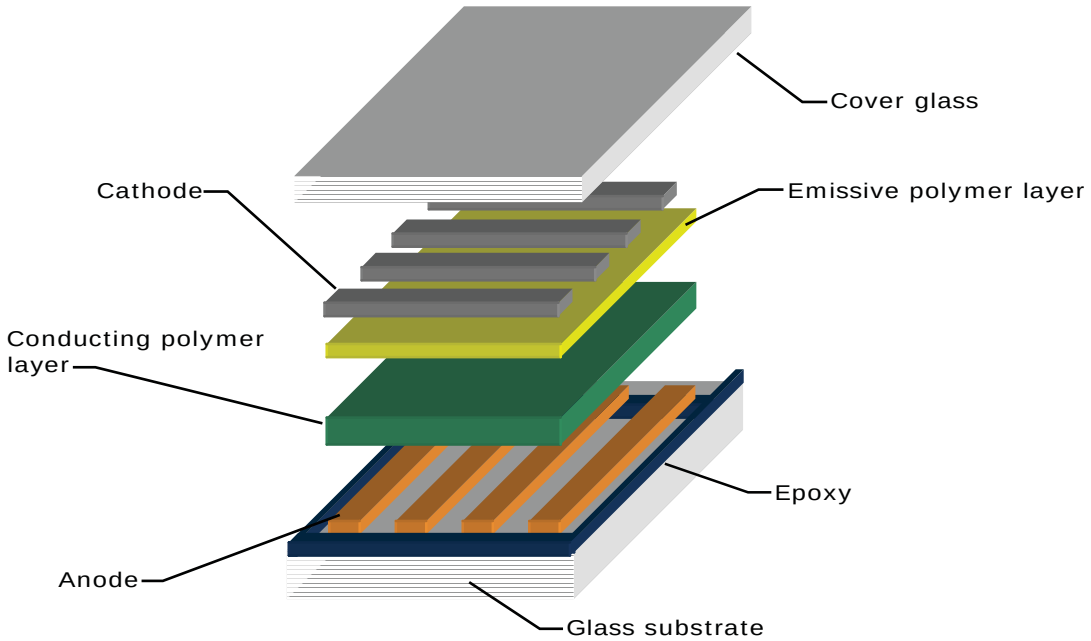
Photons are released as a result of moving electrons. In an atom, electrons move in orbits around the nucleus. Electrons in different orbital paths have different amounts of energy. Generally speaking, electrons with greater energy move in orbits farther away from the nucleus.

For an electron to jump from a lower orbital to a higher orbital, something has to boost its energy level. Conversely, an electron releases energy when it drops from a higher orbital to a lower orbital. This energy is released in the form of a photon or, in the case of LEDs, light.

Organic Light-Emitting Display (OLED) Technology

OLED technology is based on layers of organic (carbon-based) chemical compounds that emit light when an electric current flows through the device (see Figure 15.9). It has separate organic layers for red, green, and blue.

Figure 15.9
Organic light-emitting display structure



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Organic Light-Emitting Display (OLED) Technology, continued

OLEDs are emissive devices, meaning they create their own light, as opposed to LCDs, which require a separate light source (backlight). As a result, OLED devices use less power and can be capable of higher brightness and fuller color than liquid crystal microdisplays.

OLEDs are imprinted on a very thin silicon substrate. The active matrix silicon-integrated circuits are imprinted directly under the display controlling the power to each organic point of light diode (pixel), performing certain image control functions at a very high speed.

OLEDs' capability to refresh in microseconds rather than milliseconds, as LCD displays do, contribute to a virtually flicker-free display in near-eye applications, even with highly dynamic motion video.

A current is applied across an anode (A) and the cathode (B), causing negative charges to move from the cathode and positive charges to move from the anode (C). The negative and positive charges combine in the emissive layer, where they create light. The chemical composition of the emissive materials determines the color of the emitted light.

The major problem hindering all OLED displays is the life of the device. The brightness of the organic material decreases with the length of the on time. The red and green materials last at least 20 000 hours, with the blue layer lasting a shorter time.

Liquid Crystal on Silicon (LCoS) Technology

The liquid crystal on silicon (LCoS) technology is a reflective liquid crystal modulator where electronic signals are directly addressed to the device.

The LCoS device has an x-y matrix of pixels configured on a complementary metal-oxide semiconductor (CMOS) single crystal silicon substrate mounted behind the liquid crystal layer using a planar process that is standard in integrated circuit (IC) technology.

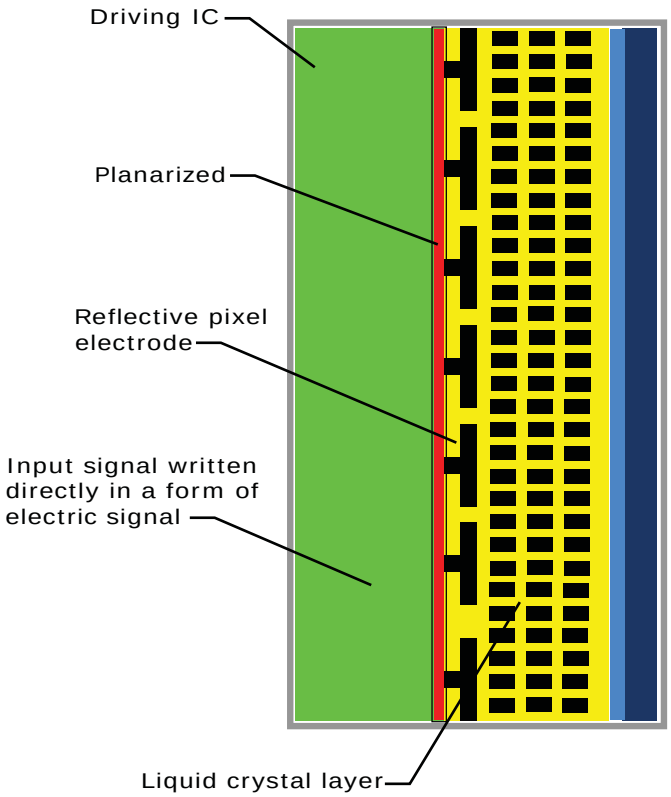
The liquid crystal is placed on top of the CMOS substrate on an array of aluminum mirrors that define each pixel. Unlike DLP® technology, the mirrors do not need to move. A glass counter electrode covers the liquid crystal to complete the structure.

Liquid Crystal on Silicon (LCoS) Technology, continued

A voltage is applied to a selected pixel of the matrix in accordance with the input signal, making the liquid crystal change double reflection or birefringence, thus changing the polarization direction of the incident projection light (see Figure 15.10).

The nonactive area between the pixel mirrors is minimal, only serving to separate each pixel; the rest of the electrode is active as a reflective surface, thereby providing a high aperture ratio or fill factor of 93 percent.

Figure 15.10
Liquid crystal on silicon



IC = Integrated circuit

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Digital Direct Drive Image Light Amplification (D-ILA®) Technology

D-ILA technology works similarly to LCoS. The D-ILA technology stores 2048 • 1536 pixels on a single 33 mm (1.3 in) chip. This enables displaying HD images at the full specification resolution of 1920 • 1080 pixels.

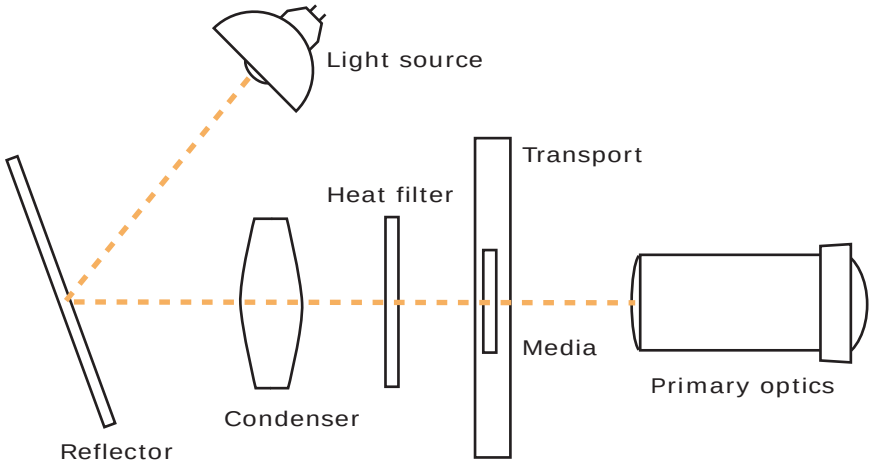
With the matrix addressing switches and electronics behind instead of between the light-modulating liquid crystal layer, a D-ILA chip has a three-dimensional layout. The result is a 93 percent fill factor and virtual elimination of the grid or screen-door effect found in other fixed-matrix display technologies.

Slide and Overhead Projectors

The slide projector (see Figure 15.11) used to be one of the most popular and versatile tools in the history of the AV industry.

A slide projector contains a light source and a lens system that focuses and projects a mounted image or a slide. The slides are simply transparent photographs, mounted in 51 mm (2 in) by 51 mm (2 in) mattes. Depending on the structure of the projector, slides are organized in carousel trays or cartridges. Light from the projector lamp passes through the image, is focused by the primary optics, and illuminates the screen. This is a transmissive process.

Figure 15.11
Slide projector



Slide and Overhead Projectors, continued

The slide projector attained its wide-spread use because it is:

- Small, easy to transport.
- Reliable.
- Capable of producing large image sizes.
- Yields high image quality with good brightness and contrast.
- Used for 35 mm images.
- Controllable remotely.
- Available with wide variety of lenses.

For many years, the best way to magnify and present information over the heads of the audience was to write on a transparent film and display it with the use of an overhead projector. An overhead projector uses a lamp to create light, and then lenses and mirrors redirect and focus the light. A projected image results from light passing through the transparency film, traveling through the optics, and transmitting the image onto a screen. Therefore, this is a transmissive process.

Overhead projectors are capable of emitting bright images. Because of this, they can tolerate high levels of ambient light. This is particularly useful in a classroom, where lights may be on for note taking. Because of these advantages, overhead projectors are still used in some applications and educational institutions as cost-effective solutions for visual display.

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Monitor and Projector Summary

Table 15.1 summarizes display technologies by their characteristics.

Table 15.1
Monitor and projector summary

Type	Raster or Pixel	Digital or Analog Display	Technology
Monitors			
CRT	Raster	Analog	Emissive
Plasma	Pixel	Digital	Emissive
LCD	Pixel	Digital	Transmissive
LED	Pixel	Digital	Emissive
OLED	Pixel	Digital	Emissive
Projectors			
Slide	Light	Analog	Transmissive
Film	Light	Analog	Transmissive
Overhead	Light	Analog	Transmissive
Document Camera	Depends on signal output to another display device	Digital	Depends on signal output to another display device
CRT	Raster	Analog	Emissive
LCD	Pixel	Digital	Transmissive
D-ILA	Pixel	Digital	Reflective
LCoS	Pixel	Digital	Reflective
DLP®	Pixel	Digital	Reflective

CRT = Cathode ray tube
D-ILA = Digital direct drive image light amplification
DLP® = Digital light processing
LCD = Liquid crystal display
LCoS = Liquid crystal on silicon
LED = Light-emitting diode
OLED = Organic light-emitting display

Projection Screens/Surfaces

Introduction

The projection screen is critical to ensuring the quality of the projected image. The purpose of the screen is to:

- Focus and resolve the projected image to ensure a quality image.
- Direct the light from the image back to the viewer in the most efficient manner possible.
- Provide limits on the image (a border) to visually separate the image from the wall.
- Provide a focal point within the room for the audience.

The two main types of screens are:

- Reflective screens—Front projection screens in which light is bounced off of the screen and returned to the viewer.
- Transmissive screens—Rear projection screens in which light projected from behind the screen passes through the screen to a viewer in front of the screen.

The commercial AV industry uses many types of screens, each suited to a particular purpose. There are two major categories of screens:

- Front projection
- Rear projection

An AV designer should understand screen gain and screen hot spotting as they refer to projections screens.

Screen Gain

A screen is a passive device and does not have the capacity to amplify or create brightness. But the surface of a screen can increase reflected light to multiply projector brightness. Screen gain is the ability of a screen to redirect projected light to make the image appear brighter within the viewer axis.

The higher the gain number of a screen, the brighter the picture viewed on the axis.

A screen should provide uniform brightness over the entire image area, with no dim areas or hot spots. This is referred to as a unity gain screen, meaning it disperses reflected light evenly and equally in a spherical pattern of 180 degrees with the same brightness.

Ambient light rejection generally increases as the gain of the screen increases. This is because the light becomes more directional as the screen gain increases. Reflected ambient light then appears outside the viewing cone. Ambient light will have its own viewing cone, which should be outside the projected image's viewing cone. If this is not the case, the lights need to be adjusted.

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Introduction, continued

Screen Hot-Spotting

As gain increases, so does hot spotting. Hot spotting is caused by the properties of the screen surface. It manifests itself as a brighter area on the screen. For example, when shining a flashlight on a wall, the reflected spot is not of uniform brightness. The brightest area in that spot is the hot spot.

Screen manufacturers develop surfaces to yield high gain with minimal hot spotting. Hot spotting is one of the tradeoffs for screen gain in front projection and some rear projection screens and is most noticeable when viewing the projected image off-axis.

Projection System Brightness

The brighter a projection system, the more it can stand up to ambient light. Today, with the benefit of technical advancements, more projection displays distribute a fairly even brightness over the screen's surface. However, not long ago, projection systems created images that were less uniform, with dark spots in some areas of the screen. Manufacturers use brightness ratings to compare and contrast their products.

Display brightness specifications for projection systems are often stated in lumens. A lumen is an average brightness rating. This rating does not take into account the screen type or the type of image to be projected (e.g., full-color photo or spreadsheet).

Peak brightness is a measurement of the maximum light output of the display without regard to contrast ratio (i.e., the difference between the darkest and lightest areas) or resolution (i.e., the image detail). The measurement is taken from a small, illuminated, portion of a screen. A white window is projected onto 10 to 20 percent of the screen. The light level is read in footcandles (or lux) at the screen's surface.

The following formula is applied to determine peak brightness:

$$L = SH \cdot SW \cdot AF$$

Where:

L = Lumens

SH = Screen height in feet (ft)

SW = Screen width in feet (ft)

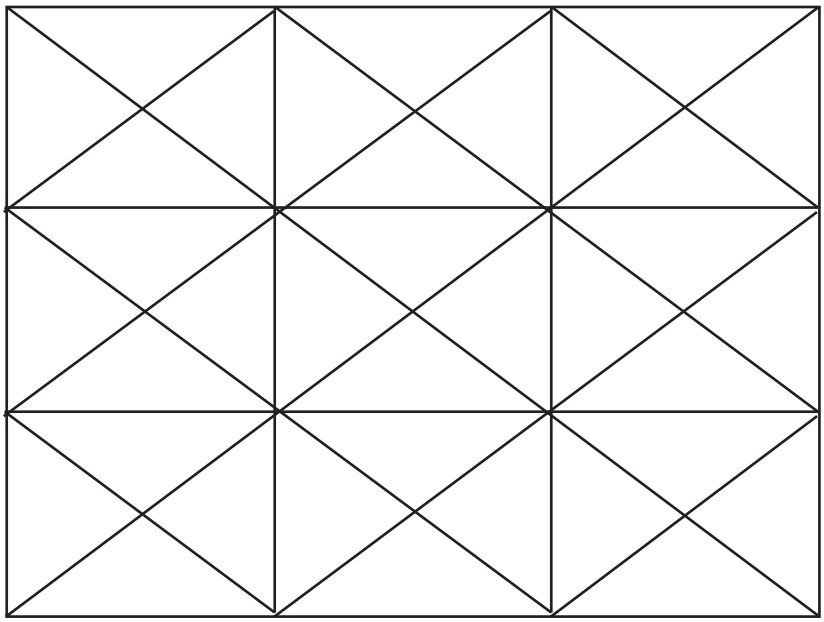
AF = Average footcandles (fc)

The average of full field brightness is another way to state a display's brightness. This number gives a more realistic idea of the amount of light actually produced by the display, yet it is still not the most accurate. To determine full-white field brightness, a full-white field is projected and the lumens are measured at the brightest spot.

Introduction, continued

The American National Standards Institute (ANSI) nine-zone method (see Figure 15.12) is perhaps the most accurate way to measure display brightness because it averages in even the darkest spots of the screen.

Figure 15.12
Nine-zone method



For this measurement, the following steps are taken.

STEP	TASK
1	Project light onto a screen and focus it at maximum aperture.
2	Divide the screen into nine equal squares.
3	Take an incidental light meter reading in the center of each area.
4	Add the readings.
5	Divide the total by nine to get the average footcandle reading.
6	Use the peak brightness formula (above) to obtain the ANSI lumen rating.

ANSI publishes a set of specification and measurement standards, including setup parameters and scan rates for performing these measurements.

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Front Projection Surfaces

With front projection, the image is viewed from the same side of the screen as the projector's location. A front screen is simply a reflecting device. It reflects both wanted (projected) and unwanted (ambient) light back into the viewing cone, so front screen contrast is dependent on the control of ambient light.

This type of projection generally requires less space than rear projection. It offers simplified equipment placement. However, having the projector in the same space as the viewer poses noise problems because most projectors have cooling fans. Another downside is that people, especially the presenter or instructor, can interfere with the image by walking in front of the projected light. Front projection may be used because of its lower cost or due to limited space behind the screen.

A front projection screen is a passive reflector of light. Its light reflection can be manipulated to improve brightness by changing the screen's surface, position, or contour.

Front projection screens can be made of a variety of surfaces and are usually chosen based on application. They can be:

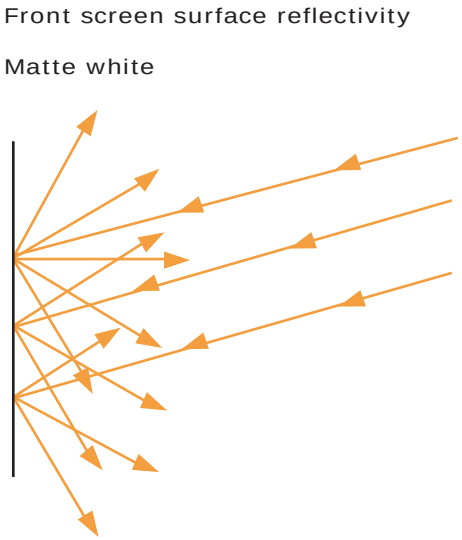
- Matte white.
- Glass beaded.
- Lenticular.
- Angularly reflective.

Matte white (see Figure 15.13) is the most common type of front projection screen. These are usually composed of magnesium carbonate.

A matte white screen evenly disperses light 180 degrees both horizontally and vertically, creating a wide viewing cone and wide viewing angle. A matte screen has a smooth nongloss surface similar to a white sheet. It provides a good color rendition and is considered the best for data and graphic applications.

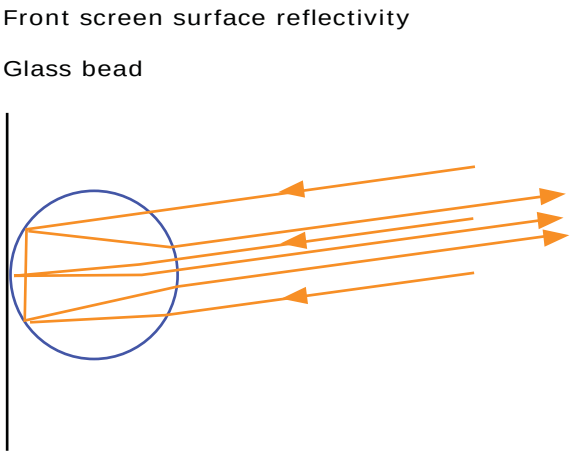
Front Projection Surfaces, continued

Figure 15.13
Matte white projection



Glass bead screens (see Figure 15.14) are covered with tiny glass beads, each of which provide a spherically reflective surface. They reflect light back at the source, and are best used if the viewer's eyes are near the same general level as the projector, such as when the projector is positioned at desktop level and the viewing audience is seated. This screen type is recommended for video and larger-font computer data only.

Figure 15.14
Glass bead projection



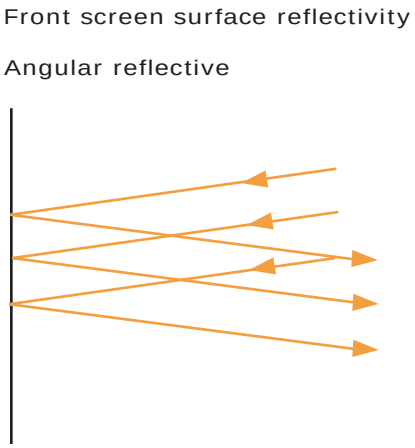
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Front Projection Surfaces, continued

Lenticular screens use a series of ridges arranged in a geometric pattern that act as a Fresnel lens, condensing the light, and transmitting the light to the viewer with a high level of efficiency, resulting in high levels of brightness and contrast.

Angularly reflective screen (see Figure 15.15) surfaces provide performance similar to that of a mirror. The light is reflected back at the same angle that it strikes the screen but on the other side of the screen's axis. If a projector is mounted at a height equal to the top center of the screen, the viewing cone's axis would be directed back at the audience in a downward direction. Most high gain screens (with a gain greater than 5) are of this type. This screen type works well for video.

Figure 15.15
Angular reflective projection



A screen gain of 1.0 identifies a reference screen surface that does not absorb or channel light. This reference is based on matte white surface created using a coating of magnesium carbonate, and produces a uniform reflection.

A screen with higher gain returns a more focused reflection of the projected light, creating a brighter image. Due to this focused reflection, higher gain screens have a reduced viewing angle, requiring the audience to be positioned on axis to view the highest quality image.

Front Projection Surfaces, continued

Criteria for specifying the characteristics of a front projection screen for installation within a room can include a range of factors:

- Product type—Screens are available in a range of variations, such as fabric or solid, wall or ceiling mounted, foldable, rolled up (retractable), manual retraction or electric retraction.
- Extra drop—Adding extra length to the screen is specified for some screens installations to compensate for a higher ceiling or a need for a lower projection height.
- Reverse wrap—Specifying a screen retraction system that winds in a non-standard manner may be appropriate for installations where the mechanism cannot be installed in the typical manner.
- Screen size can affect a number of characteristics, such as the location of the retraction motor.
- Masking systems are used to create a border to separate the image from the background. The border masking can be designed and incorporated on the edges of the screen surface itself.

To achieve optimum performance from any projection system, the same attention must be paid to the screen as to the projector. The quality and brightness of a video projector's image can be greatly influenced by the projection screen.

A well-designed projection system incorporates a screen type that reflects projected light towards the audience and is installed so that it does not reflect stray light. Stray light reflected back into the viewing area will cause a loss of contrast and detail, especially in the dark areas of the image.

Rolled and Folded Screens

Display screens have two parts:

- Frame that holds the screen
- Surface used to display the image

In the commercial AV industry, two primary types of frames can hold front screen surfaces:

- Rolled (roller) screens
- Folding screens

Rolled screens are typically contained in a metal or wooden tube in which they are rolled on spring-loaded or motorized rollers. Almost all rolled screens are opaque, front projection screens, although special purpose rear projection rolled screens are sometimes manufactured for ceiling-mounted applications in the middle of a room.

Wall- or ceiling-mounted rolled screens are very common in classroom or meeting room settings. These can be manually operated screens in which the screen surface is withdrawn from the tube with a pull-on ring. They also can be motorized and controlled by a switch.

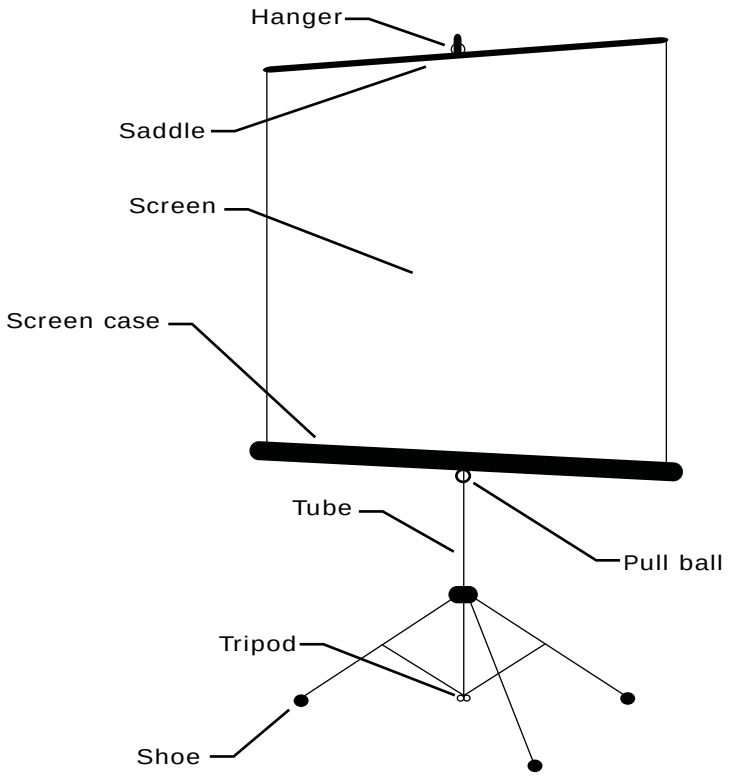
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Front Projection Surfaces, continued

Matte black borders on the edges of a screen frame the image while increasing the perceived brightness and masking the alignment errors.

The most common screen used in small presentation situations is the tripod screen (see Figure 15.16). This type of screen is essentially a roller screen on a collapsible stand. The screen is drawn up from the roller tube and attached to a hook at the top. While rolled screens are convenient, they are not stretched tightly to all corners. Thus, they are not truly flat when in use. This makes the tripod screen less than desirable for some types of projection.

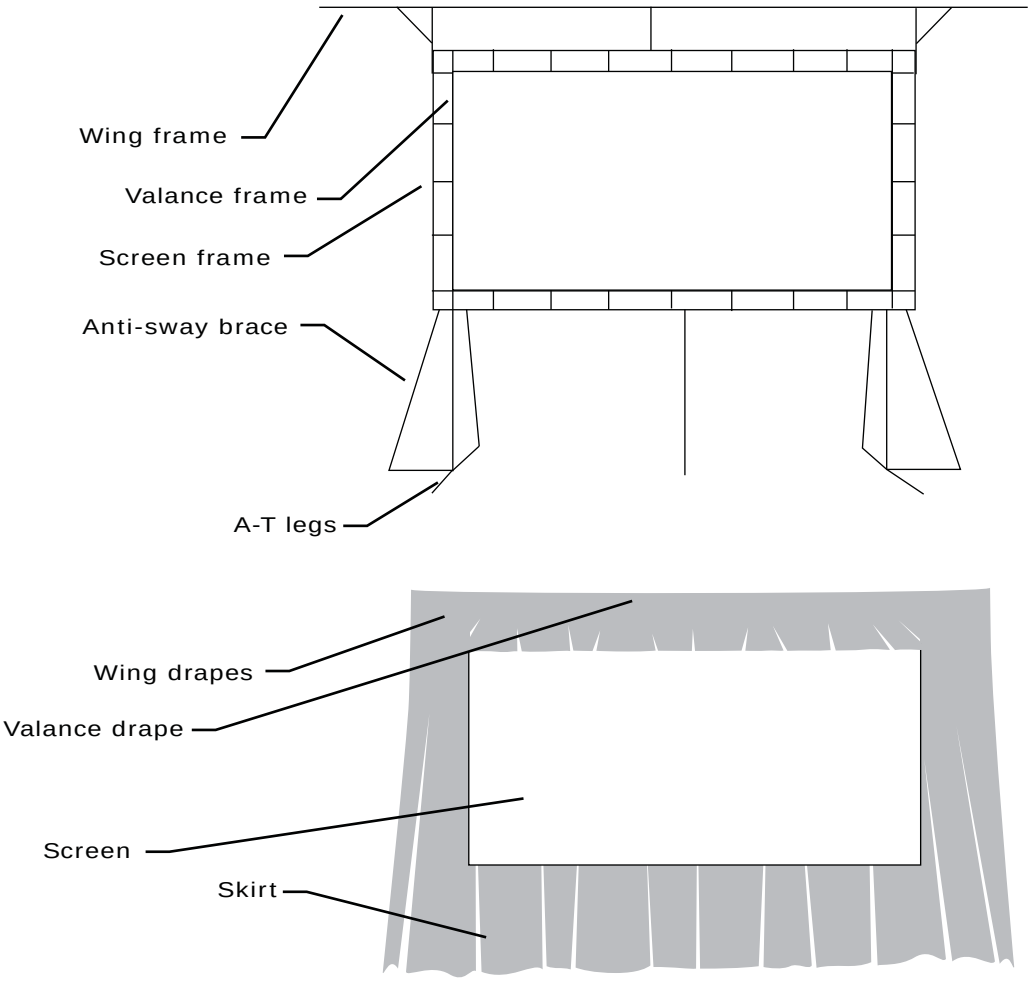
Figure 15.16
Parts of a tripod projection screen



Front Projection Surfaces, continued

Folding screens have a flexible fabric surface that is snapped or laced to a rigid, four-sided frame. The outer frame of the screen is a single, jointed piece made of lightweight metal that unfolds to form a rectangle of a fixed size. A flexible fabric sheet is then snapped to the frame, and the frame is mounted on collapsible folding legs. Because the surface is a stretched fabric, Fast-Fold® (see Figure 15.17) are extremely flat, allowing precision focus of the projected image. These screens are commonly used with a black skirt-and-side curtain, which makes them look like a portable theater environment. These foldable setups are capable of much larger image sizes than tripods.

Figure 15.17
Parts of a Fast-Fold® projection screen



NOTE: Fast-Fold® is a registered trademark of Da-Lite.

Rear Projection Surfaces

Generally, better contrast and color saturation are possible in environments of high ambient light when a rear projection is used. Rear screen projection is more dependent on screen materials and installation design than front screen projection. For rear screen configurations, there are a range of screen materials available, each with different gain and directional properties. In general, rear screens have a narrow cone of viewing. These cones can be either very bright or are wide viewing cones with a less bright image.

Diffusion screen material is used in some rear projection screen applications. The screen substructure may be:

- Rigid acrylic.
- Glass.
- Vinyl fabric for portable applications.

These materials provide diffused, coated or frosted surfaces on which the image is focused. They provide a wide viewing angle both horizontally and vertically but with little or no gain. There may be some hot spotting due to the transparency of the screen fabric, depending on the vertical placement of the projector with relationship to the audience.

The light from the projector is transmitted through the screen with relatively little bending. The ambient light rejection of these materials is moderate and is based on the viewer-side material's reflectivity or sheen.

Optical screen material is used in most permanent rear screen applications. This screen system is made up of a series of lenses formed into the screen material. Most common is the two-lens system, in which:

- The lens that faces the projector is a Fresnel lens. It is a flat glass or acrylic lens in which the curvature of a normal lens surface has been collapsed in such a way that concentric circles are impressed on the lens surface. This lens gathers the light from the projector.
- The second lens, molded to the other side of the piece of acetate or to another sheet, is a vertical lenticular lens (it must be held very flat to avoid hot spots). It is a screen surface characterized by silvered or aluminized embossing, designed to reflect maximum light over wide horizontal and narrow vertical angles. This lenticular lens faces the viewing audience and spreads the light horizontally, providing a relatively large horizontal viewing angle.

Rear Projection Surfaces, continued

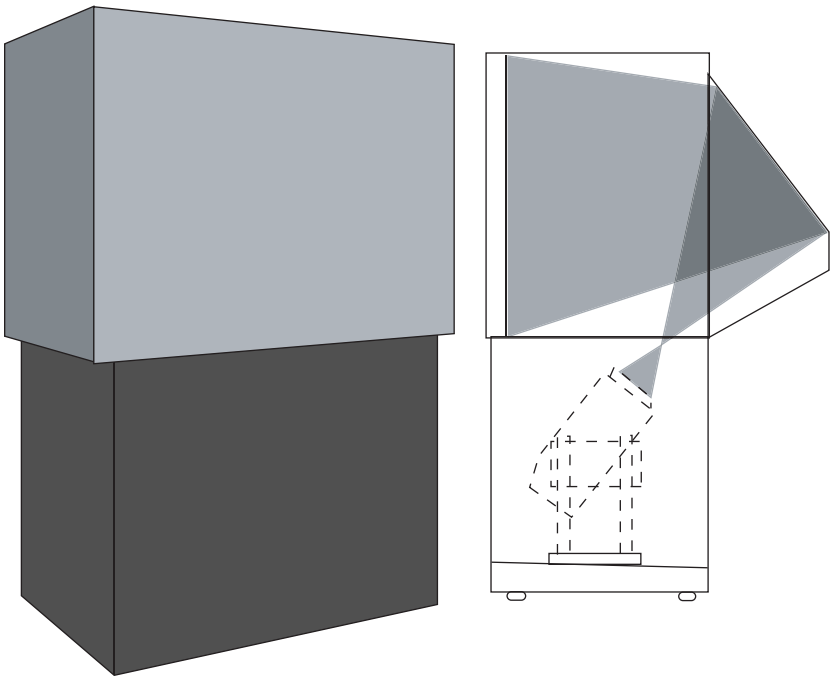
Retro Units

Another common configuration for a rear screen projection system is the retro or big screen video rear projection cabinet (see Figure 15.18).

With a retro, a projector is mounted in a rear projection enclosure. One or more first-surface mirrors are used to fold the projection path, directing the light onto a rear screen. The mirror or mirrors reflect the light while retaining its frequency and intensity, and reduce the depth of the rear projection space. (This method also is used in small rear projection rooms). Mirrors produce picture sizes from 0.91 m (3 ft) to 1.83 m (6 ft).

Most retro-type units come from the manufacturer in retro configuration, but they also make empty retro-style enclosures into which a stand-alone projector can be mounted.

Figure 15.18
Retro unit



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Rear Projection Surfaces, continued

A first surface mirror has no protective layer over its reflective surface. Most household mirrors are second surface mirrors. A protective glass coating is on top of the delicate reflective coating.

Rear projection screens have a number of characteristics that make them especially suited to meet specific AV installation requirements, including:

- High tolerance to ambient light—The images on rear projection screens can be clearly viewed without requiring the rooms to be as dark as with front projection screens.
- Unobtrusive equipment placement—Since the projector is placed out of sight in the rear projection room, it will not interfere with the layout within the room, and will not interfere with sightlines.
- System black level—Rear projection screens rely on the black level of the projector and the design of the rear projection room to create a system black level that is superior to front projection screens. This can produce brighter images and greater contrast.
- Brightness—The images produced by rear projection systems are typically brighter than front projection systems, due to the ability of these systems to focus projected light at the viewer, and the reduced effect of ambient light.
- Low noise level—Since the projector and associated equipment are located in the rear projection room, the noise produced by this type of system is isolated.
- Mobility—Presenters can walk in front of the screen without disturbing the projected image, making rear projection screens more appropriate for some types of rooms.
- Image reversal—Images are reversed on a rear projection screen, requiring a projector that can electronically reverse the image or a mirror-based reversal system.

Rear projection screens present a number of AV design challenges, including:

- Increased floor space requirements compared to a front projection system. Since a separate rear projection room is required, designers must determine if the advantages are worth the amount of floor space used by this type of system.
- The need to reduce sources of reflections within the room. Shiny objects can reflect back onto the screen and reduce viewability.
- Short focal length lenses that are required to minimize the size of the rear projection room. However, these types of lenses can create distortion. Short focal length lenses also can reduce screen brightness compared with longer focal length lenses that create a straighter light throw that is more closely aligned with the viewers.
- Difficult implementation of mirror systems. Mirror systems should only use first surface mirrors.
- Diffusion rear projection screens with the required density, tinting, and protective coatings.
- Optical rear projection screens with the required focal length.
- Frames of the appropriate type and finish to create borders around the rear projection screen.

Rear Projection Surfaces, continued

Specifying Rear Projection Screens

When creating specifications for a rear projection screen, AV designers should consider:

- The required size of the screen—The raw screen should be of sufficient size to include room for mounting and framing. This means that the screen will be larger than the desired viewing area. Other size issues to consider include what framing to specify and whether the screen will fit through the doors of the building (since a rigid screen cannot be folded or broken down into separate pieces).
- The size of the wall opening for the installation.
- Timing of delivery—Rear projection screens are delicate and must be protected if stored on site while the space if being completed. If the screen is installed early in the construction process, it must be protected from accidental damage by the other trades working at the site.
- Which side of the screen should face the audience—The emulsion side is designed to face the audience. However, some designers specify putting the coated side away from the viewers since it can be easily damaged.

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Chapter 16
Control Components

Control systems are frequently used to pull together the remainder of an audiovisual (AV) system. This chapter explains the most common components or pieces of equipment that typically make up a control system.

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Overview

Purpose of Control System

A control system consists of a central processing unit (CPU), control modules, interconnect cables, and user interfaces. The hardware components of a system rely on software. When required, programmers work with a system designer's plans to write the necessary code for the desired results and load this software into the CPU.

A control system essentially works as a supervisor and a translator. It integrates various manufacturers' equipment and systems (e.g., lighting; sound; video; security; and heating, ventilating, and air conditioning [HVAC]). It has the ability to monitor all functions in a system. A control system can communicate with multiple pieces of equipment simultaneously, operating this equipment with the assistance of a CPU. A control system will communicate with nearly any electronic device currently available.

When numerous pieces of audiovisual (AV) equipment come together to form a system, the operation of the system can become quite complex (e.g., a remote control for the video cassette recorder [VCR], another remote for the digital versatile disc [DVD] player, another for the projector). A control system integrates all of these controls into one user interface that is easy to use—multiple functions can be programmed into a single button.

Controllable Elements

Examples of controllable elements within AV components include:

- Switches/relays—simple current-limited devices that control components such as screens or slide projectors.
- Infrared (IR) controllable devices such as DVD, television (TV), or projectors.
- Voltage—Usually a signal from 0 to 10 volts direct current (Vdc) that can be used to control elements such as volume control, HVAC, lighting, or fluid levels.
- Contactors—Used to control system power for items such as screens, drapes or blinds, and lighting.
- Dual tone multi-frequency (DTMF)—Used with items such as dialers, access control, and home automation systems.
- Proprietary manufacturer bus—Dedicated control systems available from various manufacturers.
- Serial and Internet protocol (IP) controlled devices using a range of standard connection protocols.

Control System Interfaces

The goal of a control system is to allow easy operation of every function. This is done through wiring, programming, and the interface. The interface design goal is to provide the user access to the subsystems in an easy-to-understand, intuitive, method.

One-button actions that trigger a sequence of events are a commonly used interface method. This is physically achieved through either mechanical push button panels or a more sophisticated color liquid crystal display (LCD) touch screen that communicates with the CPU.

While a single master touch panel may be the heart of the system, often other panels are incorporated. For example, touch sensitive panels or keypads are mounted near the entrance to a room. They may control tasks such as regulating electronic systems, including lights, HVAC, security, and AV equipment, through the touch of a graphic icon.

The most advanced AV installations allow for very sophisticated operation. For example, with a single button, a projector can descend from the ceiling on a lift, a screen can lower from the wall, the lights can dim, the drapes close, the DVD player start, and the audio convert to surround-sound.

Each piece of hardware in the system is given a name, an electronic tag that allows the software to identify it.

Software Programs

The control system's manufacturer usually provides authoring programs. Individual devices may require different software. For instance, creating a touch panel layout and functionality requires corresponding software. Writing the program for a main processor unit requires a separate program.

Programmers develop the pages for touch panels and the logic to operate the equipment. They must use detailed systems drawings to know which device is connected to which port on a switcher, which audio channel is routed to which amplifier, and so on. They must obtain exact model numbers of the equipment to use the correct control protocol for each device.

Software programming for control systems can be proprietary and nonproprietary, although the industry is moving further towards open-architecture systems. Software components of control systems are:

- Firmware
  - Platform specific or non-platform specific software
- Applications
  - Proprietary or nonproprietary software
  - Platform-specific or nonplatform-specific software
- Programming languages
  - Proprietary
  - Nonproprietary (hypertext markup language [HTML], extensible markup language [XML], Java, and Active X)

Control Processors for Audiovisual (AV) Equipment

Proprietary Central Processor

Control systems revolve around a central processing device, which serves as a hub for the user inputs and the controlled devices. Control systems incorporate microprocessors custom configured for each installation.

The first part of the system consists of the devices that are controlled. All of them must allow remote control through a specific control format.

Connections may be made either by hard wire or by multiplexing. Multiplexing is a method of transmission where more than one channel of information or signals is transmitted over a single signal path. With multiplexing several different signals (i.e., video, audio, and data) can be combined into a single communication channel for transmission.

The master processor communicates to the different types of control connections for each device (e.g., RS-232, IR, relay, contact closures, transmission control protocol (TCP)/IP, and others).

Personal Computer (PC)

Personal computers (PCs) can be used in two different ways. A PC can be:

- A user interface (e.g., web page control).
- The master processor of a control system.

Today's PCs are designed to perform many different tasks. One of those tasks is to act as a user interface to a control system. However, using a PC as a master processor is more complex.

The master processor needs very detailed timing and cycling to handle simultaneous inputs from many different user interfaces, touch panels, sensors, Ethernet commands, and RS-232 connections. This type of timing and structure is not built into the standard operating systems available in current PCs.

Once a PC contains a custom operating system, it can no longer support the basic features of a PC, like off-the-shelf software packages. On the other hand, if a custom operating system is created, it could be authored for one of many custom microprocessors that are significantly less expensive then a PC processor. Ultimately, however, using a PC as a master processor presents many serious design drawbacks.

Show Control Devices

Using a custom control system with a master processor as a show control device is a sensible solution. In fact, show control has some unique requirements that create differences in the market. Show control systems need the ability to communicate to theatrical lighting systems.

Most theatrical lighting systems use a communications protocol called digital multiplex (DMX) 512. This unique protocol is not a common control method for AV devices.

The second and more complex protocol in show control is the musical instrument digital interface (MIDI). This communications protocol allows electronic musical instruments (e.g., digital keyboards) to communicate with one another.

MIDI protocol contains two formats:

- Time based
- Beat based

The time based format places all commands on a clock and starts everything based on a start timing cue. When using MIDI time code (MTC), every cue is based on a time event.

Typical professional AV control systems are not easily synched to external timed events. Therefore, traditional show control systems should be used.

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User Interface Control Devices for Audiovisual (AV) Equipment

Control systems are mostly hidden, with the exception of the user interface. Many different methods allow the user to interact with the AV system. The design may include a simple wall control with one button or, perhaps, a wireless transmitter that fits in a pocket. For more control flexibility, a large, full color, touch panel is provided. It may be wireless, mounted in the wall, or sitting on a boardroom table.

The human interface is the most critical element of the control system. But, there is much more that goes on behind that point of control.

Typical user interfaces include:

- Touch panels.
- Web pages.
- Push buttons.
- Multi-button keypads.
- Voice-activation.
- Sensors.
- Handheld remotes.

Touch Panels

Touch panels are a form of graphical user interface (GUI). Touch panels are available in many different screen sizes, wall mounted or tabletop versions, full color to grayscale, and wired or wireless.

The touch panel provides flexibility and customization for any application.

The layout and design, from the color scheme to the functionality, is completely customizable through programming. Other touch panel features may include the capability to display video and red, green, and blue (RGB) sources, audio for conferencing or intercom, built in video annotation and embedded PC applications for streaming media, internet surfing, desktop videoconferencing, and built-in viewers for Microsoft® and Adobe® applications.

Web Pages

Using Web pages in the context of control implies that a standard Web browser can be used to control an AV system, including the auxiliary equipment.

A standard Web browser is a computer program that can request and receive information via hypertext transfer protocol (HTTP). The transferred information is originally authored in HTML.

Web Pages, continued

HTML has no provision for changing the information or data by any other device or sending instructions back to a device once the file is transferred. This code typically resides on a web server.

To accomplish control from a Web page, other languages and applications are included with the HTTP file transfer. The most commonly used tools are called Java applets or Active X applets. These pieces contain the control commands for the device. Although these commands are all customized for each device, more than one can be included in a transfer. Routers and firewalls require custom configuration to be aware of these customized applets before control of a device can occur outside of the local computer sub-network.

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Chapter 17
Systems

The components explained in the previous chapters represent the basic building blocks of audiovisual (AV) systems. An assemblage of those components represents a system. Systems can range from very small to very large and may contain many subsystems. This chapter addresses the most common systems the AV designer may be required to design.

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Overview

The previous chapters addressed the wide range of considerations concerning audiovisual (AV) technologies, the aspects of the physical environment effecting AV systems, and an outline of equipment components and their functions.

This chapter outlines the design considerations at the larger system level and presents discussions of the different system elements. This chapter also shows how the system elements apply and interconnect to form functioning entities capable of manipulating audio and video signals for the purposes of imaging viewing, audio listening, recording, electronic conferencing, and other purposes.

An assembly of AV devices does not create an AV system. The system is the interconnection of component elements in a meaningful configuration that accomplishes specified functions or provides required capabilities. Moreover, while the interconnections of components may have typical configurations, there is no proscribed approach to achieve a particular solution.

The designer has access to a wide range of products that support different design solutions. Oftentimes, multiple solutions fulfill the requirement and can offer additional features. The particular approach taken by the designer reflects the unique approach and application of technology for the situation.

A significant element of system design is the understanding of the customers and their expectations for the performance and functioning of the system. In the process of formulating a design solution, the designer encounters multiple options, some of which enhance one capability over another, while others preclude some additional capability or feature. Thus, the best design solution for a system is one that fulfills the functional requirements and provides other features as well, including cost savings.

The challenge and uniqueness of AV design is that:

- No one solution is better than another.
- Different solutions offer a variety of correct solutions.
- Alternate design solutions are and should be encouraged.
- Changes in technology provide new and interesting design solutions.

The sections of this chapter are divided into the discrete elements of an entire system and offer different considerations for each element. This chapter does not portend to describe how to design for a particular solution, rather it provides a series of considerations for each element of the system and how these interrelate.

Visual Display Systems

The visual displays are a significant element of any AV system. In most systems, the display is the focus of the system, at least for its non-audio elements. The display function of the AV systems also ranges from simple single image systems to complex multi-image systems.

The range of displays include a number of different image formation technologies, some occurring in a variety of different products.

The technology of visual displays has undergone significant change within the last five years. This rapid change will likely continue. As new image formation technologies and delivery systems are developed, the AV designer will face a complex set of selection criteria for these devices. Further fueling the change in display technologies is the constant trend of increasing the resolution of displays in the pursuit of lifelike images from any display technology. The rate of change in display technology and diversity of solutions continues to increase.

Finally, the number of display technology manufacturers has increased markedly. A significant number of companies well known in other fields, notably computer and printer technology, are now participating in the display arena. The AV designer should proceed with some caution when selecting products. Not all manufacturers truly fabricate the products they represent but rebrand products developed and fabricated by others. At stake is the level of support for the offered products.

Previous chapters discuss the physics of display and human vision as well as the various current technology display system solutions. The following are the questions that arise during the display solution design:

- Which display solution is appropriate for the design requirements of a particular project?
- What are the elements of architecture, requirements for viewing of display, and the overall purpose for the display?

Design considerations for direct view displays and projected images differ. The following discussion outlines the considerations for each.

The human factors discussed in Chapter 2: Foundations, apply to both direct-view and projected forms of displays. In all cases, the factors of character height versus viewing distance need to be examined to ensure character readability. Other factors that need to be considered with display selection are:

- Contrast ratio.
- Display resolution.
- Viewable pixels.

Contrast ratio is a ratio between the projected image and the ambient light condition at the image location. Selection of the display type reflects a comparison of architectural conditions in which the displays will need to operate.

Display resolution of the display device, measured as horizontal and vertical pixel counts, determines the pixel density of the display. The resolution of the display device is very significant in that the device should match or at least approach the resolution of the source image. For example, an incorrect match of a lower resolution display as compared to the source signal can result in unacceptable image where significant image pixels cannot be generated by the display.

Direct-View Displays

Direct-view displays include:

- Cathode ray tube (CRT) monitors and televisions (TVs).
- Liquid crystal displays (LCD) and gas plasma flat panel displays.
- Light-emitting diode (LED) and organic light emitting displays (OLED).

Direct-view displays are integrated devices with the image formation technology and the viewing surface integral to one another. With the exception of LED and OLED devices, display types are relatively smaller in size than projected images and typically intended for small group or individual viewing.

Cathode Ray Tube (CRT) Displays

CRT displays have been the mainstay display technology and the basis for video signal format since their introduction in the 1940s. CRT displays ranging in sizes from 229 millimeters (mm [19 inches (in)]) to 1016 mm (40 in) diagonal and larger, are ubiquitous in homes and desktops. While many consider the direct-view CRT displays to be on their way out of residential and corporate meeting facility uses, the CRT display remains the quality check display for broadcast applications.

CRT displays have the advantage of a wide range of adjustment for convergence, the alignment of red, green, and blue (RGB) electron beams, black level, and coloration. The wide range of adjustment makes CRT display useful as quality control monitors for broadcast applications, but also in critical viewing applications.

Flat Panel Displays

The most common flat panel displays are LCD and plasma display product (PDP) types. The flat panel displays offer great improvement in light output and contrast ratio, consuming far less electricity at the same time, than CRT displays.

An important consideration for flat panel displays is off-axis viewing. Flat panels typically exhibit color shift and loss of brightness when viewed off-axis. This is a consequence of the image formation method. Flat panel displays need to be viewed on both the horizontal and the vertical axis. These displays usually employ tilt-adjustable mounts to correct the vertical off-axis viewing. Also, these displays need to be located at normal viewing heights.

Liquid Crystal Displays (LCD)

LCD devices are generally considered more robust in terms of long-term performance and, in particular, resistant to image burn-in. Another advantage is the ability to relamp the LCD display for greater product longevity. The most common disadvantage has been the lack of a true black level and, therefore, the color rendition is adversely affected.

Direct-View Displays, continued

LCD displays are available in a very wide range of sizes, from 38 mm (1.5 in) to 1143 mm (45 in) diagonal and used for:

- Video camera monitors.
- Program and preview monitors.
- Digital signage and wayfinding.
- Conference room displays.
- Video displays in nonstop applications.
- Small-format confidence monitors.
- Touch screen control panels.
- Computer displays.

Gas Plasma Displays

Gas plasma displays are capable of creating a more correct black level and the color rendition is considered superior compared to those of LCD displays. While image quality is superior, PDPs tend to lose overall image quality and tend to suffer from image burn-in if a static image is left on the screen for an extended period of time. Also, PDPs are not recommended for most nonstop operations.

PDPs are available only in larger formats and, therefore, applications are more limited.

PDP devices are most commonly used in:

- Conference and meeting rooms.
- Videoconference systems.
- Digital signage and wayfinding.
- Applications requiring true color rendition.
- Applications not requiring nonstop operation.

The pixel count of a display reveals the application intended by the manufacturer. Displays intended for video or general purpose signage applications are generally lower in resolution than displays intended for conference or meeting room application. The latter application usually includes direct view of computer images for meetings, often including fairly dense text or subtle imagery. Such applications need the highest resolution in the product size appropriate for the audience.

NOTE: With respect to lectern or small-format confidence monitors, the smaller-format LCD displays, generally less than 483 mm (19 in) diagonal, are not available at the highest resolutions often found in projection display or larger flat panel displays. The image on the confidence monitor is not a true replication of the primary display and, therefore, its image will be smaller and perhaps unreadable given the signal content.

Direct-View Displays, continued

Light-Emitting Diode (LED) Displays

LED displays may be the fastest developing technology in the display industry. LEDs are very bright discrete lights sources available in monochrome through four-color displays.

For some years, LEDs were used in text-only displays for short-viewing distances, but more notably in very large displays in stadiums or other large venues. The great increase of pixel density of LED displays has opened up new applications, such a motion video.

The extreme brightness of LEDs now support outdoor applications even under daylight conditions. They are commonly used for vote tally boards or information displays in transportation systems. LEDs are less suitable for short viewing distance applications, especially for computer graphic or imagery applications.

LED displays are built in small modules, ranging from 101 mm (4 in) by 101 mm (4 in) to 254 mm (10 in) by 254 mm (10 in) and combine in various configurations to create image surfaces of exceptionally large size, even curvilinear displays. With the wide range of applications and increased resolution, the applications for LED displays are expected to increase.

Typical LED display systems include:

- Monochrome displays.
  - Time clocks.
  - Public information displays (PIDs).
  - Wayfinding.
- Multi-color displays.
  - Vote tally displays.
  - Billboard and advertising.
  - Outdoor bulletin boards.
  - Very large format video displays.

Projection Displays

Projection display solutions are defined as image display systems with a discrete projection device and an image (screen) surface. Projection display solutions fall into two general categories:

- Front projection
- Rear projection

While the same projection devices can be used for either design scenario, some projectors lend themselves to one solution. The discussion that follows addresses displays in terms of projection solution and design considerations for each.

Projection Displays, continued

Front Projection

Front projection systems are the most common design solution found today. They combine an efficient use of space and a relatively unobtrusive presence of the table-top or ceiling-mounted projection device.

Front projection solutions are common for medium-size conference rooms, classrooms, and meetings spaces, typically housing 20 to 30 persons and having standard office environment ceiling heights of 2.4 meters (m [8 feet (ft)]) to 2.74 m (9 ft). Designs in such spaces vary only by screen location.

In larger spaces, the following factors are considered in front projection design:

- Projector location—In larger venues, larger screen sizes are required due to viewing distances. Larger screen areas require brighter video projectors and the location of the projector can be of concern. If the vertical angle of projection to the screen is less than 30 degrees, the projector's bright light source will impact the talker's ability to see their audience.
- Presenter's location—The presenter's or the lectern's location should not block any portion of the optical path to the screen.
- Screen height—In very large venues, maintaining a minimum image bottom at 1.83 m (6 ft) allows the presenter a path in front of the screen that does not block the projected image.
- Aesthetics—Concern for aesthetics enters into the coordination of architecture and equipment placement. Motorized lifts are typically used to conceal projectors above the finished ceiling when not is use; however, if the operating position for this project is within a bulkhead and has a clear optical path to the screen, a lift mechanism allows for projector service access.
- Acoustics—Larger projectors generate greater operation noise and placement concerns must address the projector's acoustic isolation from the audience. In larger venues, this usually involves a projection booth design, a projector concealed in a bulkhead or, in some examples, a complete projector acoustic enclosure.
- Lenses—For most projectors designed for larger venues, a selection of different lenses for different throw distance applications is available.

Of important concern for front projection screens are the screen materials. Chapter 15: Video Components, outlines matte white, glass beaded, and other screen elements.

With the advent of solid-state projectors and limited ability to generate correct black levels, a variety of neutral gray or black-stripped front projection surfaces have been developed. While such screens improve contrast and black level quality with projected video images, the white background of data images appear grayed or muted.

Screen flatness is of great importance, particularly for maintaining image flatness from edge to edge. To this end, fixed tensioned screens serve very well but are not always practical. Tab tensioned screens are common, but newly emerging screen fabrics include internal tension elements.

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Projection Displays, continued

Rear Projection

Rear projection and front projection systems differ in several elements aside from screen type and projector location.

Rear projection solutions offer a different character to the space and afford greater latitude in architectural features. For all spaces, with the exception of very large stadium or auditorium venues, rear projection is always an option that should deserve some consideration. Some considerations for selecting rear versus front projection are shown in Table 17.1

Table 17.1
Front and rear projection pros and cons

Rear Projection	Front Projection
Pros	**Cons**
Projector is located out of the audience space—acoustic isolation	Projector is located in the audience space—not acoustically isolated and may require acoustic isolation
Projector is located out of the audience space—aesthetics isolation	Projector is located in the audience space and is a negative architectural element
Talker standing in front of the image does not cast a shadow on the image	Talker standing in front of the displayed image casts a shadow
Allows for a higher ambient light level in the audience space as the rear screen does not reflect ambient light	Screen reflects ambient light equally with direct light and image appears washed out in higher ambient light conditions
Cons	**Pros**
Occupies valuable floor space in the building	Front projection efficiently uses the room space
Image size is limited by available rear projection screen materials sizes	Front projection screens can be made to nearly any size (with seams)
Limited application for laser pointers or interactive screen elements	Fully functional with laser pointers and interactive software/writing board solutions

Projection Displays, continued

Once a decision has been made for a rear projection solution, other design factors come into play with the system. Typically, the rear projection space becomes an equipment room (ER) with space allocated for supporting equipment racks, installed video cameras, infrared (IR) emitters, wireless microphone antennae, or audio loudspeakers.

The choice for rear projection further burdens the designer with the choice of screen material and various lens options available. Screen materials are often glass or acrylic with a variety of thickness ranging from 6.3 mm (0.25 in) to 12.7 mm (0.5 in). Glass screen substrates are much more rigid than the acrylic and are generally used for larger sizes because the more rigid material is less likely to bow due to weight.

In smaller screen sizes, various rear screen types are available depending on the audience's viewing angle to the display. Screen options for smaller screen sizes include:

- Fresnel lenses for even screen illumination.
- Lenticular slits that serve to focus more light to the audience area.
- Black stripping and masking to improve overall black levels and provide for greater contrast.

The important element is the application of the correct screen material for the viewing distance and sightline angle to the display and to match the screen material performance with the selected display device.

Projector Selection

Projector and screen material selection must be made in tandem. Outside the diffusion rear projection screen surfaces and the matte projection screen surfaces, any screen that reflects or redirects light is affected by how the light is directed to the screen. For example, a number of the LCD projectors use polarized light as the means to achieve brightness whereas a lenticular-screen surface attempts to redirect polarized light in orthogonal direction with poor image result.

Similar mismatches in the dot pitch of the screen and the pixel resolution of the projector can result in imprecise alignment of projected pixel and the screen surface black backing or stripping, with some light lost to the black and undesirable coloration occurring on the display image.

Rear Projection Mirror Assemblies

Rear projection mirror assemblies are very common in rear projection installations. The significant benefit is the reduced floor space required for a rear screen display system.

When using large-size rear projection, mirror quality should be closely considered because any striations on the mirror surface are reflected onto the projected image.

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Projection Displays, continued

Distributed and Multiple Display Solutions

Many AV systems require the use of multiple displays or at least a variety of displays that perform specific functions for the system as a whole. Clearly, the primary display is the one watched by the audience. However under certain requirements, additional displays may be required for audience viewing or in particular function locations as part of the system.

Distributed Displays

Additional displays are often required for a variety of operational and performance requirements. Distributed displays are often and typically found in control rooms, waiting (green) rooms, or simultaneous interpretation rooms. These secondary displays satisfy the operational requirement for event monitoring at a required location.

Distributed or supplemental displays are often included in the primary audience area to improve overall image viewing in certain seating configurations. Additional displays can be in the form of added projection devices, self contained rear projection displays (e.g. projection cubes), or flat panel displays. Such displays are used for two primary reasons:

- The seating configuration prevents sufficient proximity to the primary display for image clarity and readability. In these examples, the goal is to locate displays of appropriate size at locations that meet the image clarity criterion. The subtle problem here is to locate such displays at sufficient size without detracting from the audience sightline to the primary display.
- The purpose of the displays is for effect, typically used in image magnification during live events. Image magnification is the practice of displaying live video from the stage events onto large screens. The general intent is to make the person on camera look larger and the issues of image readability are subsumed under the goal of image impact.

Projection Displays, continued

Single versus Multiple Displays

The vast majority of display systems are single image displays:

- Systems using image processors with multiple image videos
- Picture-in-picture (PIP) processors

Multiple image surfaces are required when the customer has the need to display multiple images simultaneously. Usually the requirement involves comparison of two or more images, data, or processes.

Typically, two screen surfaces of equal size with independent image source and projection devices are provided. Common design solutions are dual side-by-side image displays or dual side-by-side image displays with a third, center image capability.

A more recent variation originated from university education designs with the integration of remote participants into the classroom instruction. A person at a remote site may make a presentation or participate in a classroom instruction through a videoconference or other transmission system, their images occupying one display. A second display is required to show the content under discussion. In some professional schools, a third screen surface is added for a second remote participant. The content screen is made larger than the remote participant screens.

Room Focus

One disadvantage of multiple-screen layouts is that multiple-image surfaces detract from a room's single point of focus. When the audience or meeting participants look at several screen surfaces for a visual display, their attention is not necessarily directed toward the talker, which diminishes the talker's goal of holding the audience's attention.

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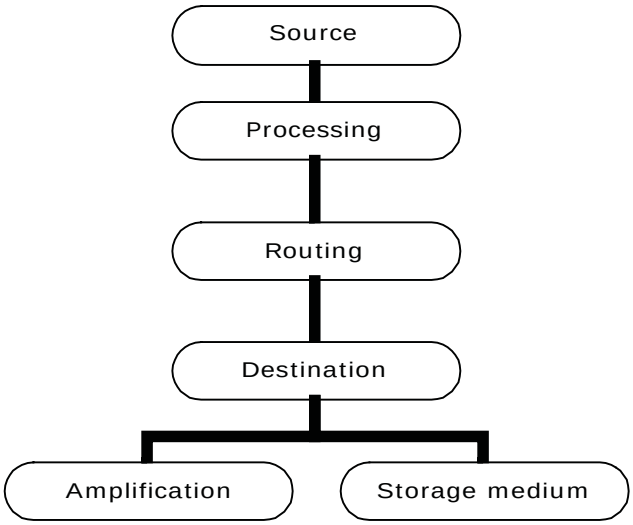
Program Audio and Speech Reinforcement Systems

Introduction

In the realm of audio systems design, innumerable applications and, subsequently, variations of included components are used. Covering the breadth of all audio systems is an impossible task; however, significant unifying factors that can apply to the majority of these systems can be identified in a typical system component chain.

Regardless of the application for a particular audio system, the component chain shown in Figure 17.1 is almost always followed in some form.

Figure 17.1
Chain of typical audio components



Each section of this chain has been covered in detail in the previous chapters of this manual (specifically Chapter 14: Audio Components) and some of the various applications can be found further in this chapter as well as in Chapter 18: Venues.

In this example of the audio chain, the amplification stage encompasses the sound reproduction process from line level signals to audible sound waves. This can include simple headphones for a single listener, a hearing assistance system, or a complete loudspeaker system.

Loudspeaker System Types

Just as the system chain is a unifying factor between various types of audio systems, so are the loudspeaker systems within them. Notwithstanding the numerous variations, loudspeaker systems can essentially be classified into two types:

- Program systems
- Reinforcement systems

Program systems contain no microphones and are used strictly for the reproduction of recorded or transmitted audio. Microphones are used for recording or live sound reinforcement. However, at the location of the sound reproduction, a program system has no open microphones. Program audio can be purely an audio event or, more typically, it is associated with some sort of presentation (video or live).

Reinforcement systems are, as the name suggests, reinforcing an acoustic event within the same space. These can be music reinforcement systems (e.g. live concert) or speech reinforcement systems, and sometimes both.

For the purpose of this section, the focus of the reinforcement design considerations will be on speech reinforcement, though the same principles apply to both. Music reinforcement typically involves many more open microphones, wider sound stage, and, more importantly, an extended system frequency response.

In many real world scenarios, a single loudspeaker system is required to perform both tasks of program and reinforcement. Additionally, many types of loudspeakers and many more methods of placing them in a venue are available. Therefore, the designer should have a thorough understanding of the basic design considerations for each system before attempting a full system specification.

Additionally, the type of audio material determines the bandwidth of the system and the type of loudspeakers. The three main categories of audio material are:

- Vocal range—Use limited bandwidth loudspeakers primarily for speech—90 Hz–16 kHz.
- Full range—Use loudspeakers that cover most of the frequency range required by both music and speech—70 Hz–16 kHz.
- Extended range—Use full range as well as separate bass loudspeakers for an extended bandwidth—40 Hz–16 kHz.

The advent of acoustic and loudspeaker modeling software has given easy access to what had been extremely complex and arduous system design calculations. Even so, without a solid base of the following design considerations, these software applications could not be helpful.

Understanding the application of any system before attempting the design is critical. For example, attempting speech reinforcement through a system designed for program audio can be disastrous.

The following sections address some of the main considerations in program and speech reinforcement systems. Some principles apply to both.

Program Audio Design Considerations

The main requirements for a program audio system are that it is:

- Loud enough.
- Intelligible.

Factors that contribute to whether the system is loud enough are:

- Achieving the target sound pressure level (SPL) of ±3 decibels (dB) throughout the listening area.
- Meeting the required frequency response.
- Adequate electrical signal-to-noise ratio (SNR) (greater than 60 dB).

Factors that contribute to intelligibility are:

- Achieving at least 25 dB SNR (room noise).
- Meeting the required frequency response.
- No perceived distortion (less than 1 percent total harmonic distortion [THD]).
- Good direct-to-reverberant sound ratios.

Loudspeaker Input Power

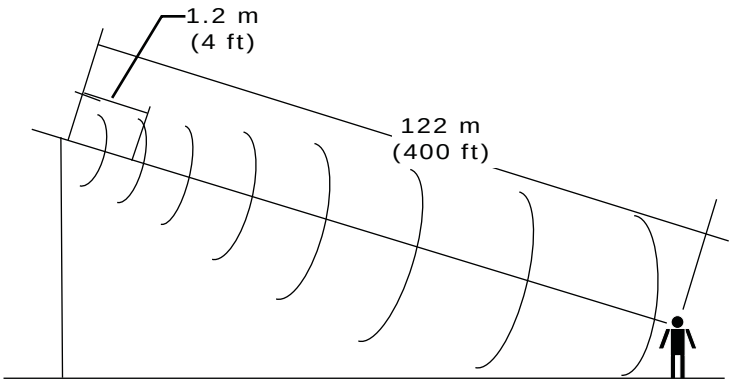
Loudspeakers are rated by the manufacturer to provide the designer with a performance criterion known as sensitivity. It is expressed as SPL measured on axis at a specified distance from the loudspeaker and with a given power input of pink noise band-limited for the system under test. If the loudspeaker is a sub woofer, it is tested only on the very low frequencies. However, if the loudspeaker is a full-range system, it is tested over a much wider frequency range. The standard distance usually is 1 m (3.3 ft) and the power input usually is 1 watt (W).

With the manufacturer's sensitivity rating for a given loudspeaker measured at 1 m (3.3 ft) with a 1 W input, a comparison can be made with the SPL required at that point to produce the required SPL at the furthest listener location. Then the power value above the 1 W level required to produce the required SPL can be calculated.

Program Audio Design Considerations, continued

Figure 17.2 depicts the outdoor installation of a typical pole-mounted horn aimed to cover listeners up to 122 m (400 ft) away.

Figure 17.2
Example of horn installation



ft = Foot
m = Meter

The goal of the example installation is to reach the fathest listener with an SPL of 83 dB. The available horn can produce 114 dB SPL at 1.2 m (4 ft) and 1 W input. Its driver is rated to handle 100 W of audio power.

To calculate the attenuation between points A and B:

Attenuation = 20 log (400/4)

= 20 log (100)

= 20 (2)

= 40 dB

If SPL at listener's location is 83 dB, then SPL required at point A will be 123 dB.

NOTE: It is customary to add 10 dB to account for the additional power delivered at the peaks of the sinusoidal audio sound waves, inasmuch as the sound pressures involved in audio measurements are root mean square (rms) values and not peak sine-wave values. This additional power is sometimes referred to as headroom.

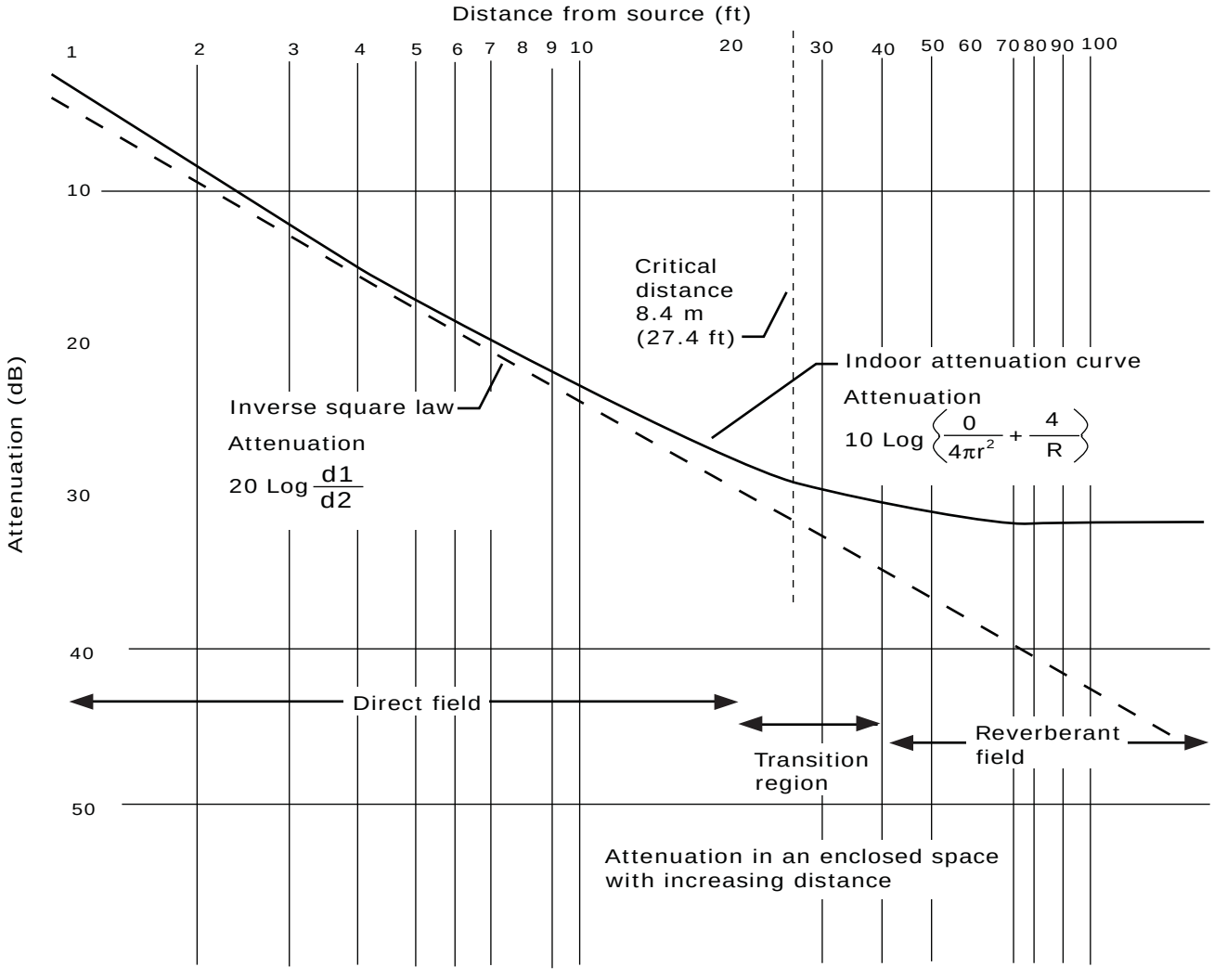
Program Audio Design Considerations, continued

Critical Distance (D_c)

Critical distance (D_c) is defined as a distance from the sound source at which the direct and reverberant fields have the same attenuation or, simply put, the point where the direct and reverberant sound have the same SPL.

The room space between the source and the critical distance is known as the free, or direct field, and that which lies beyond is called the reverberant field. There is not a sharp line of demarcation between the two fields, and there is an area of transition lying between them. These fields are approximated in the Figure 17.3.

Figure 17.3
Critical distance calculations



dB = Decibel
ft = Foot
log = Logarithm
m = Meter

Program Audio Design Considerations, continued

In spaces utilizing program audio systems, the sound from a program loudspeaker can cause no feedback, but attenuation beyond the critical distance continues in accordance with the inverse square law (double distance equaling –6 dB), while the reverberant SPL remains constant or virtually so.

At twice D_C, a 6 dB drop from the indoor attenuation curve to the inverse square law attenuation line is registered. With critical distance doubled again ($4D_C$), articulation suffers and hearing becomes difficult due to the registered 12 dB drop. In other words, the direct sound level drops 12 dB below the reverberant SPL. Four times the critical distance is the maximum distance at which any listener can be expected to hear with good intelligibility.

Speech Reinforcement Design Considerations

The main requirements for a speech reinforcement system are very similar to those for program audio, with one addition. A speech reinforcement system must be:

- Loud enough.
- Intelligible.
- Stable.

A stable system is paramount and the design parameters for stability will affect loudness and intelligibility.

A speech reinforcement system must be designed to ensure that audience members in the least favored listening positions (i.e., the farthest from the talker) receive the same listening experience as the audience members closer to the talker. Through the use of potential acoustic gain (PAG) and needed acoustic gain (NAG) equations, system parameters can be determined and possibly adjusted to ensure overall system effectiveness.

Needed Acoustic Gain (NAG)

NAG specifies how much to electronically increase the amplitude of an original acoustic wave that strikes a microphone for it to be equivalent to some closer location where no amplification would be required for adequate hearing.

NAG is only relevant for systems incorporating microphones; it has no relation to the program material, which can be as loud as the system can make it without concern for feedback.

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Program Audio Design Considerations, continued

The most basic NAG formula, which does not compensate for acoustic information and is intended for outdoor scenarios, is as follows:

$$NAG = 20 \log D_0 - 20 \log EAD$$

or

$$NAG = 20 \log (D_0/EAD)$$

Where EAD is the equivalent acoustic distance measured from the talker at which the farthest listener's ears perceive the talker is located when the sound system is in use.

The following is an example of NAG calculation (see Figure 17.4).

Determine the NAG required to make SPL for a listener 50 m (164 ft) away the same as for a listener at the EAD of 3 m (10 ft).

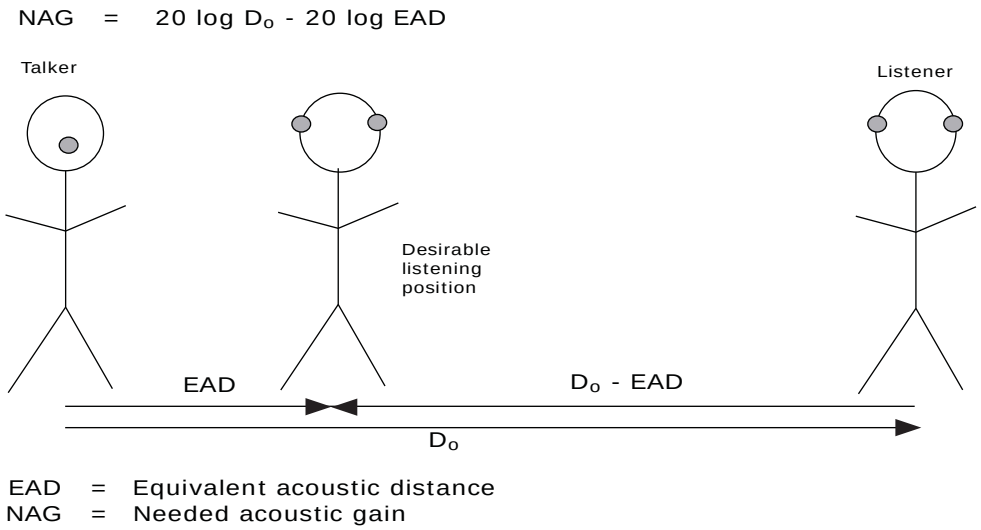
$$NAG = 20 \log D_0 - 20 \log EAD$$

$$NAG = 20 \log 50 \text{ m} - 20 \log 3 \text{ m}$$

$$NAG = 34.3 - 9.5$$

$$NAG = 24.8 \text{ dB}$$

Figure 17.4
Needed acoustic gain measurements



Program Audio Design Considerations, continued

Other factors can be involved in obtaining a true NAG. These include room size, acoustics, and the number of open microphones (NOM) used.

If the quantity of microphones is increased, the possibility of creating feedback increases since there is much greater opportunity for the acoustic energy to become recycled. This necessitates turning down the system volume.

Each time the NOM (set to the same level) is doubled, 3 dB in possible gain is lost. So, the NOM at any one time will be included in the NAG formula. The formula becomes:

$$NAG = 20 \log D_0 - 20 \log EAD + 10 \log NOM$$

Some audio mixing components self monitor the number of open microphones and adjust their output accordingly. In this case, the output of that component would be equivalent to a NOM of 1.

Including some headroom in the system design is common. This would be extra gain that may be required only momentarily, or not at all. This can be included in the equation as well and is called the feedback stability margin (FSM). A FSM of 6 dB is common. The formula then becomes:

$$NAG = 20 \log D_0 - 20 \log EAD + 10 \log NOM + FSM$$

$$NAG = 20 \log D_0 - 20 \log EAD + 10 \log NOM + 6 \text{ dB}$$

Reconsidering the previous example of a D_0 of 50 m (164 ft) and an EAD of 3 m (10 ft) with the NOM and FSM, the results would be as follows:

$$NAG = 20 \log D_0 - 20 \log EAD + 10 \log NOM + FSM$$

$$NAG = 20 \log 50 \text{ m} - 20 \log 3 \text{ m} + 10 \log 1 + 6 \text{ dB}$$

$$NAG = 24.8 + 0 + 6$$

$$NAG = 30.8$$

Potential Acoustic Gain (PAG)

Potential acoustic gain (PAG) is the formula that determines what the audio system will be able to produce in SPL before the room begins to feedback. In other words, PAG is how much gain can be expected from the system by the location of the devices within the space.

If the design allows for enough gain, that is, it meets the requirements of the customer by equaling or exceeding NAG, the audio system can be built. If the theoretical model does not work (i.e., PAG calculation cannot meet the NAG requirements), the designer can expect some difficulties.

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Program Audio Design Considerations, continued

The PAG formula assumes that loudspeakers and microphones are omnidirectional devices. This means that PAG can be improved upon by selecting directional components in a design.

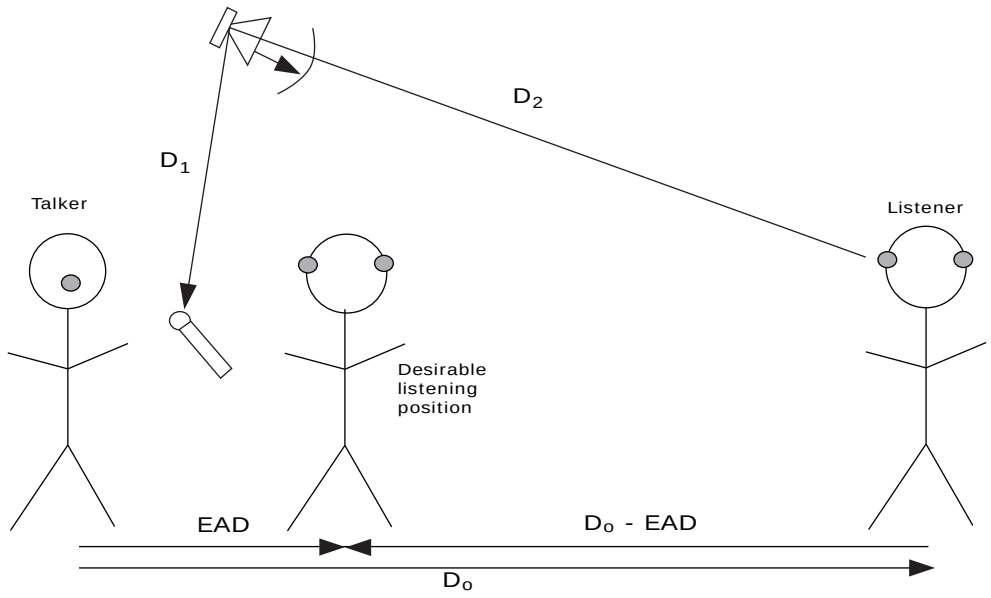
PAG is meaningless without NAG. PAG is compared to NAG and needs to equal to, or be greater than, NAG for the system to work properly. The basic formula for PAG (see Figure 17.5) is as follows:

$$PAG = 20 \log D_0 + 20 \log D_1 - 20 \log D_S - 20 \log D_2$$

or

$$PAG = 20 \log (D_1 D_0 / D_2 D_S)$$

Figure 17.5
Potential acoustic gain measurements



EAD = Equivalent acoustic distance

Program Audio Design Considerations, continued

The following is an example of PAG calculation.

$$PAG = 20 \log D_0 + 20 \log D_1 – 20 \log D_S – 20 \log D_2$$

$$PAG = 20 \log 50 \text{ m} + 20 \log 17 \text{ m} – 20 \log 0.5 \text{ m} – 20 \log 45 \text{ m}$$

$$PAG = 20 \log 50 + 20 \log 17 – 20 \log 0.5 – 20 \log 45$$

$$PAG = 34.3 + 24.6 – (– 6) – 33$$

$$PAG = 31.9$$

Comparing this to the previously calculated NAG of 30.8:

$$31.9 \text{ (PAG)} – 30.8 \text{ (NAG)} = 1.1$$

The PAG exceeds the NAG; therefore, this system has enough gain to meet the required SPL at the furthest calculated listening location.

The placement of the loudspeaker is extremely important, because its SPL, attenuated off-axis over distance D_1 in Figure 17.5 may exceed the SPL of the talker's voice at the microphone. When these two SPLs are equal, the condition is called unity gain. Beyond unity gain the system is vulnerable to feedback and howl at certain frequencies.

Speech Reinforcement Critical Distance (D_c)

The significance of the critical distance is that it represents an SPL within 3 dB of the maximum acoustic separation between a microphone and a loudspeaker that can ever be obtained in a given reverberant room. Once beyond the critical distance, a roving microphone would not be vulnerable to feedback. Hence the critical distance has a distinct importance where microphone and loudspeaker systems are being designed.

A workable relationship in reverberant rooms with voice amplification is that the distance from the loudspeaker to the microphone should equal or exceed the critical distance.

In more reverberant spaces, with reverberation times exceeding 1.6 seconds, the distance from the loudspeaker to the farthest listener should not exceed 3 D_C. When it does, articulation loss increases.

Program Audio Design Considerations, continued

Loudspeaker Deployment Options

Loudspeakers can be placed in several different configurations. The chosen scheme largely depends on the architectural features of the facility.

The two main variations for speech reinforcement systems are:

- Point source (or central cluster) speech reinforcement systems
- Distributed speech reinforcement systems

Each has some variations on the basic idea.

The point source is a group of loudspeaker components gathered together and aimed at the audience. This can be one or more prepackaged cabinets or it can be several discrete components strategically selected for their frequency response and coverage patterns. Point source is sometimes referred to as a high-pressure system because of the higher SPL emitted by these components.

The distributed system uses the opposite approach. Instead of having a high level of energy emanating from a signal location, the loudspeaker components are brought closer to the listeners. The effect is to have the loudspeakers distributed throughout the listening area (usually ceiling-mounted) each with a much lower SPL output than a point source system would have to cover the same area.

Point Source Loudspeaker Placement

A point source is the more preferred method of covering a large area because it locates the source of the sound with the talker. However, adequate ceiling height is necessary to employ it. The cluster is generally placed above the front of a stage or performing area. Elevating the loudspeaker group reduces the difference in D_2 distances for the nearest and farthest listeners.

The listeners' ears cannot easily discriminate between sounds coming from different elevations. So, to the audience, the sound will appear to be coming from the talker on the stage.

Loudspeaker elements are carefully selected during the design process for their coverage pattern and frequency response. They are then carefully aimed during installation to ensure proper coverage.

Some consideration should be given for how high the cluster can be mounted without adversely affecting those seated close to the talker. Generally, if the loudspeakers are higher than 13.7 m (45 ft) above the talker, the listeners who can hear direct sound from the talker as well as the reinforcement will hear an echo or some distortion.

Program Audio Design Considerations, continued

When considering a central cluster system for an environment, a general rule is that D_2 should not exceed four times D_1. However, complex formulae are available to help determine the probable effectiveness of a central cluster system. That level of complexity is beyond the scope of this chapter, but a simple example of a formula that can be used to find the maximum D_2 for a single loudspeaker in a space with a reverberation time (RT60) of less than 2 seconds (s) is:

$$d = 0.1 \times [(Q \times V)/T] \times 0.5$$

Where,

d = Maximum D_2 (ft)

Q = Loudspeaker directivity (0 unit)

V = Room volume (ft^3)

T = Reverberation time (s)

Determining Loudspeaker Coverage for Distributed System Layouts

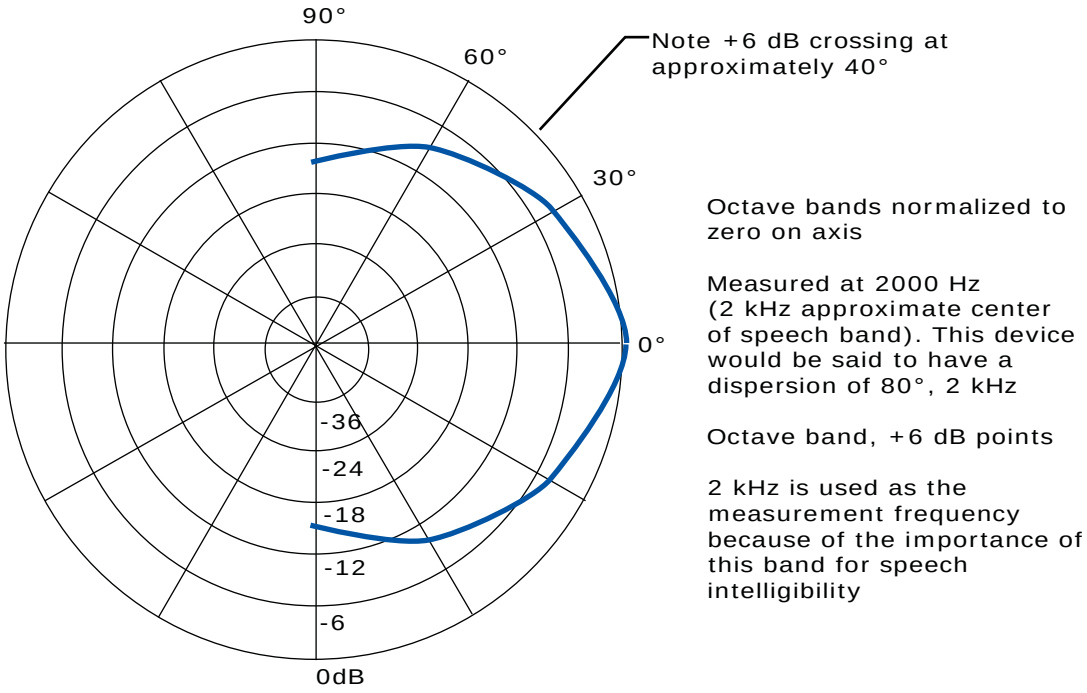
The distributed loudspeaker system will employ multiple loudspeakers separated by some distance from each other. Placing loudspeakers in the ceiling above the audience area commonly does this.

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Program Audio Design Considerations, continued

To begin a layout, the designer must first know how much area each of the selected loudspeakers will cover. The loudspeaker polar pattern directivity information provided by the manufacturer is used to create an elevation section view of a loudspeaker and the pattern. This allows the creation of the circular area that each unit will cover (see Figure 17.6).

Figure 17.6
Loudspeaker dispersion polar plot



dB = Decibel
Hz = Hertz
kHz = Kilohertz

Two measurements must be quickly determined:

- Loudspeaker coverage angle
- Listener ear level

By referencing the polar pattern information, the designer can find the angle at which the target highest frequency is 6 dB below the on-axis level. As an example, this might be at 40 degrees off axis, which would provide a full 80 degrees of coverage for that frequency.

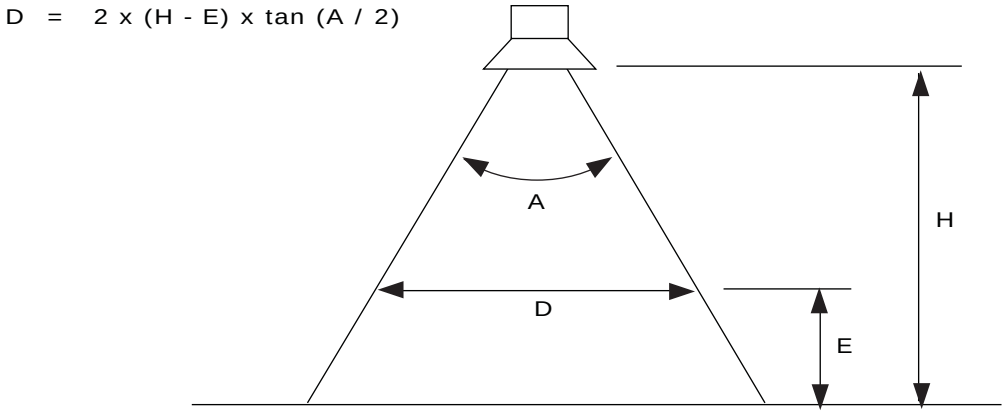
Program Audio Design Considerations, continued

Next, the listening ear height must be determined, particularly the highest level. If the design is a multipurpose room where the audience may be standing for some presentations and seated for others, the design should be made for the standing audience. The size of the coverage circle with the same loudspeaker can be dramatically different with a low ceiling and a standing audience as compared to a higher ceiling and a seated audience.

The diameter of the circle representing the coverage of the loudspeaker (see Figure 17.7) will then be found using the following formula:

$$D = 2 \times (H - E) \times \tan (A/2)$$

Figure 17.7
Loudspeaker coverage formula



A = Coverage angle of the loudspeaker
D = Diameter of the coverage circle
E = Listener ear height above floor
H = Loudspeaker height above floor

As an example, if the loudspeaker provided 80-degree coverage, the ceiling height is 3.7 m (12 ft) and the audience is seated (ear level of 1.2 m [4 ft]), the following would determine the coverage circle diameter:

$$D = 2 \times (12 - 4) \times \tan (80/2)$$

$$D = 2 \times (8) \times \tan 40$$

$$D = 16 \times 0.839$$

$$D = 13.4 \text{ ft or a radius of } 6.7 \text{ ft}$$

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Program Audio Design Considerations, continued

Speech Reinforcement Distributed Loudspeakers

With a public address (PA) system, the listeners do not necessarily see the talker; many times they are just listening to announcements. In speech reinforcement situations, the listeners see the talker and are able to hear the talker's remarks with natural sound, regardless of their listening distance. To achieve uniform sound distribution, hot spots must be avoided. This requires that an ample number of loudspeakers located overhead be used so that circular patterns of sound overlap at the hearing level.

For optimal distribution of the full range of important frequencies, overlap of as much as 50 percent in adjacent loudspeaker distribution patterns is recommended. The lower the ceiling, the more loudspeakers are required, and vice versa.

While some manufacturers' data shows cone angles up to 120 degrees, such wide dispersion is not optimal for speech. Speech intelligibility depends on the uniform ear-level coverage by the higher frequencies and these tend to beam in smaller cone angles. For example, when good articulation and intelligibility are not important in background music systems, the loudspeakers may be placed much farther apart.

Tables 17.2, 17.3, and 17.4 respectively show distances between ceiling loudspeakers with:

- 50 percent overlap at the plane of a seated listener's ear (1.5 dB variation).
- 30 percent overlap at the plane of a seated listener's ear (3 dB variation).
- 0 percent overlap at the plane of a seated listener's ear (6 dB variation).

Table 17.2
Distance between ceiling loudspeakers (50 percent overlap)

Loudspeaker angle of coverage	8'6"	9'0"	9'6"	10'0"	10'6"	11'0"	11'6"	12'0"	12'6"	13'0"	13'6"	14'0"	14'6"	15'0"
60°	2'7"	2'10"	3'2"	3'6"	3'9"	4'1"	4'4"	4'7"	4'11"	5'2"	5'6"	5'9"	6'1"	6'4"
70°	3'2"	3'6"	3'10"	4'2"	4'7"	4'11"	5'3"	5'7"	6'0"	6'4"	6'8"	7'0"	7'4"	7'8"
80°	3'9"	4'2"	4'7"	5'0"	5'6"	5'11"	6'4"	6'9"	7'2"	7'7"	8'0"	8'5"	8'10"	9'3"
90°	4'6"	5'0"	5'6"	6'0"	6'6"	7'0"	7'6"	8'0"	8'6"	9'0"	9'6"	10'0"	10'6"	11'0"
100°	5'4"	6'0"	6'7"	7'2"	7'10	8'4"	8'11"	9'6"	10'2"	10'9"	11'4"	11'11"	12'6"	13'2"
110°	6'5"	7'2"	7'10"	8'7"	9'3"	10'0"	10'9"	11'5"	12'2"	12'10"	13'7"	14'4"	15'0"	15'9"
120°	7'10"	8'8"	9'6"	10'5"	11'4"	12'2"	13'0"	13'10"	14'9"	15'7"	16'6"	17'4"	18'2"	19'1"

Program Audio Design Considerations, continued

Table 17.3
Distance between ceiling loudspeakers (30 percent overlap)

Loudspeaker angle of coverage	8'6"	9'0"	9'6"	10'0"	10'6"	11'0"	11'6"	12'0"	12'6"	13'0"	13'6"	14'0"	14'6"	15'0"
60°	3'7"	4'0"	4'5"	4'11"	5'3"	5'9"	6'1"	6'5"	6'10"	7'3"	7'8"	8'1"	8'6"	8'11"
70°	4'5"	4'11"	5'4"	5'10"	6'5"	6'10"	7'4"	7'10"	8'4"	8'10"	9'4"	9'10"	10'3"	10'9"
80°	5'3"	5'10"	6'5"	7'0"	7'8"	8'3"	8'10"	9'5"	10'0"	10'7"	11'2"	11'9"	12'4"	13'0"
90°	6'4"	7'0"	7'8"	8'5"	9'1"	9'10"	10'6"	11'2"	11'11"	12'6"	13'4"	14'0"	14'8"	15'5"
100°	7'6"	8'5"	9'3"	10'11"	10'11	11'8"	12'5"	13'4"	14'2"	15'0"	15'10"	16'8"	17'6"	18'4"
110°	9'0"	10'0"	11'0"	12'0"	13'0"	14'0"	15'9"	16'0"	17'0"	18'0"	19'0"	20'0"	21'0"	22'0"
120°	11'0"	12'2"	13'4"	14'7"	15'10"	17'0"	18'2"	19'4"	20'7"	21'10"	23'0"	24'3"	25'6"	26'8"

Table 17.4
Distance between ceiling loudspeakers (0 percent overlap)

Loudspeaker angle of coverage	8'6"	9'0"	9'6"	10'0"	10'6"	11'0"	11'6"	12'0"	12'6"	13'0"	13'6"	14'0"	14'6"	15'0"
60°	5'3"	5'9"	6'3"	7'0"	7'6"	8'0"	8'9"	9'3"	9'9"	10'6"	11'0"	11'6"	12'0"	12'9"
70°	6'3"	7'0"	7'9"	8'6"	9'0"	9'9"	10'6"	11'3"	12'0"	12'6"	13'3"	14'0"	14'9"	15'6"
80°	7'6"	8'6"	9'3"	10'0"	11'0"	11'9"	12'6"	13'6"	14'3"	15'0"	16'0"	16'9"	17'5"	18'6"
90°	9'0"	10'0"	11'0"	12'0"	13'0"	14'0"	15'0"	16'0"	17'0"	18'0"	19'0"	20'0"	21'0"	22'0"
100°	10'9"	12'0"	13'0"	14'6"	15'6"	16'9"	17'9"	19'0"	20'3"	10'6"	22'6"	22'9"	25'0"	26'3"
110°	12'9"	14'3"	15'9"	17'0"	18'6"	20'0"	10'6"	22'9"	24'3"	25'9"	27'0"	28'6"	30'0"	31'6"
120°	15'6"	17'3"	19'0"	20'9"	22'6"	24'3"	12'6"	27'9"	29'6"	31'3"	32'9"	34'6"	36'3"	38'0"

1 m = 3.3 ft
10.3 mm = 0.406 in

Another consideration with distributed loudspeakers in speech reinforcement is the use of mix/minus. By keeping open microphones out of the signal feeding a loudspeaker in the vicinity of these microphones, PAG can be increased. This mix/minus method is often used in conferencing systems.

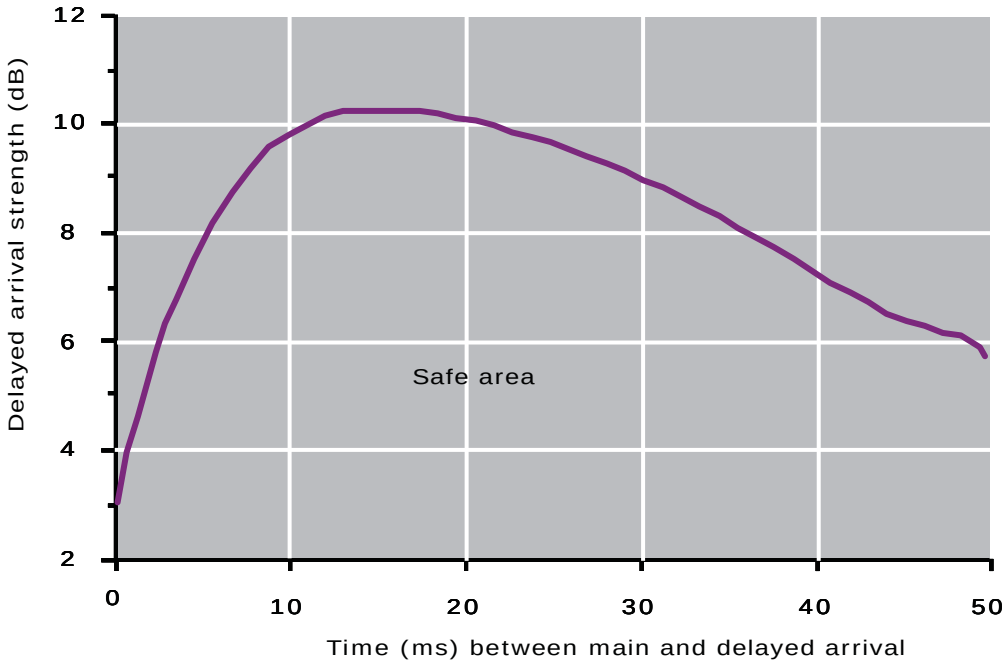
A similar but simpler technique in rooms with low ceilings and distributed loudspeakers is to zone the loudspeakers and simply turn off (or down) the row of loudspeakers directly above the open microphones. This is often referred to as a head table location and some rooms can be set up for multiple head tables with simple attenuators for each location.

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Localization

An important consideration with both program and speech is localization, also known as the Haas effect (see Figure 17.8). Localization is important as the listener's attention is drawn in the direction of the first audio heard. In the case of a presenter, it is important for the audio to appear to the listener as though it were coming from the stage as opposed to coming from some loudspeakers above the listener's head. Similarly, a video presentation should have the accompanying audio appear to come from the screen area.

Figure 17.8
Haas effect



dB = Decibel
ms = Millisecond

The Haas effect is a psychoacoustic effect that describes how two identical sounds from two sources, one farther away than the other from the listener, are actually perceived as one sound coming from the direction of the source that arrives first at the listener's ear.

The Haas effect can actually be used to the advantage of the audio system designer by delaying the signal going to the loudspeakers closer to the listener than the primary loudspeakers. With ceiling delay loudspeakers and the main cluster in an auditorium, the delay can be very slight, approximately 20 milliseconds (ms) in addition to the normal delay required, and allows the secondary signal to be increased up to 10 dB while still retaining correct localization.

Signal Distribution Systems

Introduction

The core of the AV system is the signal distribution and switching system. When looking at a one-line diagram of an AV system in its entirety, the signal distribution is usually shown at the center of the drawing, the figurative heart of the system. The signal distribution system consists of:

- All inputs, connections, and source devices.
- Switching, processing and distribution electronic devices.
- Connection to all output or end- point destinations.

From this viewpoint, the signal distribution system encompasses not only the electronic equipment but also the signal transport cables that support all of the signal types required in the system. In short, the signal distribution makes the system function.

As described in previous chapters, AV components operate over a wide variety of signal types, which usually require different cable types. The system is the correct interconnection of devices with the correct signal traversing from one component to another over the correct cable type for that signal and distance.

A very wide range of solutions for the system or the interconnection of devices is available, with great changes occurring with the increased use of digital signal formats.

The readability of system drawings, also known as one-line diagrams or signal flow drawings, should be taken into consideration during the design. While many approaches can be used for system drawings, a common convention is to place source equipment on the left side of the page and the output or destination devices on the right side. This way, the drawing is read from left to right.

Signal Type Separation

A first step to sorting through the various cable requirements is the fundamental approach of separating each signal type, grouping the types together, and providing the supporting electronics for the required signal type and quantity.

The first step is to determine the number of inputs for each signal type for the system, including any future or anticipated connections or growth factor. An AV system typically consists of audio with video; audio with red, green, and blue horizontal sync vertical sync (RGBHV); and audio-only signals. Having a greater number of audio sources than video signal types is not uncommon.

Since connecting an audio-only device to a video-only device with any meaningful result is impossible, the interconnection of electronic components is limited to the available signal type inputs and outputs.

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Signal Type Separation, continued

Once signals are separated into signal types, the designer needs to understand how these may connect to the system. Different signal types are generally treated differently. For example, viewing several RGBHV computer signals simultaneously is usually difficult or not necessary and, therefore, the signal just has to be switched to the required location. This is similar for playback video sources or audio sources. However, multiple microphones are often used simultaneously and expected to be heard operating simultaneously; therefore, a multiple microphone mixer is required.

NOTE: RGBHV signals and video signals connect to their respective switching devices, while the stereo analog audio signals connect to common audio switcher. Each maintains its own signal path according to the signal type from input, through switching, to output or destination. Such typical configurations are fully scalable through the size of the switcher. Switcher configurations with 8, 16, 32, 64, or 128 inputs are fairly common, albeit more expensive as size increases.

Many manufacturers have combined the signal types into a common product to provide a single set of electronics to handle all of the signal types. Audio can follow video when a video signal is selected in switching. Most video and RGBHV switchers have a version with audio follow capability. Since RGBHV and video signals are very similar in format, they can be combined into a common chaise.

Lastly, for very small systems, the switching equipment is incorporated into the display device for a complete one-box solution.

Signal Distances

The correct cable type and connectors are essential to the success of the system. Each signal type has a limit to the overall cable length that can be used. To extend that limit, a number of different strategies are available to the designer, including.

- Amplification.
- Signal conversion.
- Transport conversion.

Amplification

Signal amplification is the primary means of addressing signal degradation due to the limited cable length. The amplifier is placed at the location of the signal source and drives the signal to the destination. Computer interfaces are essentially amplifiers, albeit with greater capabilities of functions. Examples of amplifiers are found for virtually every signal type. Some amplifiers include signal equalization capability to optimize signal performance.

Signal Distances, continued

Signal Conversion

Video signals can convert from radio frequency (RF) to video to RGBHV. Signals also can be converted from analog to digital and reverse. In the audio design, an audio device can convert a microphone level signal to a line level signal that can operate over a greater cable distance with less susceptibility to interference. Audio systems also can convert a signal from a line level signal to an amplified signal for the purposes of driving a loudspeaker.

Transport Conversion

In some examples, the signal format does not support the required distance or operate in the system's cable topology. In this case, the signal is converted to an alternate format. For example, video signals on a coaxial cable are limited in distance by the cable type and strength of the signal. A common solution to this problem is to convert the signal to light and transmit the signal through an optical fiber cable.

Similar conversions to video through unshielded twisted-pair (UTP) cable also are available but without the performance provided by optical fiber cable. Audio signals operate in similar fashion, although audio can operate over greater distances than video signals. One important development is the use of audio and video signals as packets signals on data networks. This design solution converts the audio and video signals to a signal format compatible with data network transport standards. At this point, the signal is treated as data and subject to the limitations of data signal transmission. An excellent example of this is Internet protocol (IP) videoconference systems, where video, audio, and control signals are configured into packet data and use the digital network for signal transport.

Matrix Routing Switchers

Matrix routing switchers provide for connection of multiple inputs to multiple outputs. The principle of signal separation must be followed in this process to achieve meaningful results. The designer should specify the size of the matrix to support the number of inputs and outputs and some growth or future expansion considerations. Matrix devices are generally sized in groups of fours.

Matrix routing switchers also function as distribution amplifiers (DAs). Just as a DA provides connection of a single signal to multiple outputs, the matrix provisions for the same capability with added ability to select the input and output connections electronically.

Cost and signal performance are the main reasons matrix routers are not used in applications for distribution. Large matrix routers are expensive and, in very large systems, generally the most expensive system component.

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Matrix Routing Switchers, continued

The following three considerations should be taken into account with the selection of matrix routing switchers:

- Digital video signals generally require a different switcher function known as reclocking. The reclocking of the digital video allows for nearly unlimited regeneration of the digital video signal in support of multiple destinations without signal degradation. Thus, the bandwidth limitations of analog routers are not evident in the digital environment with this capability.
- Some manufacturers provide matrix routers with internal signal transcoding capability so that, for example, an analog National Television System Committee (NTSC) signal input is internally converted to digital and, thereafter, handled as a digital signal in the system.
- The emergence of newer signal types such as digital visual interface (DVI) and high definition multimedia interface (HDMI) is resulting is new switching and distribution products that support these signal types.
- The principles of matrix routing also apply to audio signal.

Signal Conversions

The last element of signal distribution is the conversion of signals to a different format. The purpose of signal conversion is to create compatibility of signals for connection to devices, switching and routing, or specialty transmission.

Audioconferencing Systems

Introduction

Reviewing the possibilities for the setup of a working conferencing environment, a number of aspects should be considered, including the conference:

- Type (e.g., audio, video, Web-based, or a combination).
- Objective.
- Duration.
- Dynamics (e.g., the level of interactivity between the participants and the roles of participants).

When people engage in remote interaction only through voice, they may become distracted and occupy themselves with alternative stimuli. Video adds a sense of connection and improves the attendee's recollection of the meeting events.

Web conferencing also is a part of communication environments, more often as an enhancement instead of a core communication tool. The majority of our communications is verbal in nature, requiring a specific level of intelligibility and interaction.

Audioconferencing

The goal of audioconferencing is to enable two mutually distant groups of people, referred to as the local and remote talkers respectively, to communicate with fast interaction and allow both parties to speak and be heard at the same time, as if they were physically in the same room.

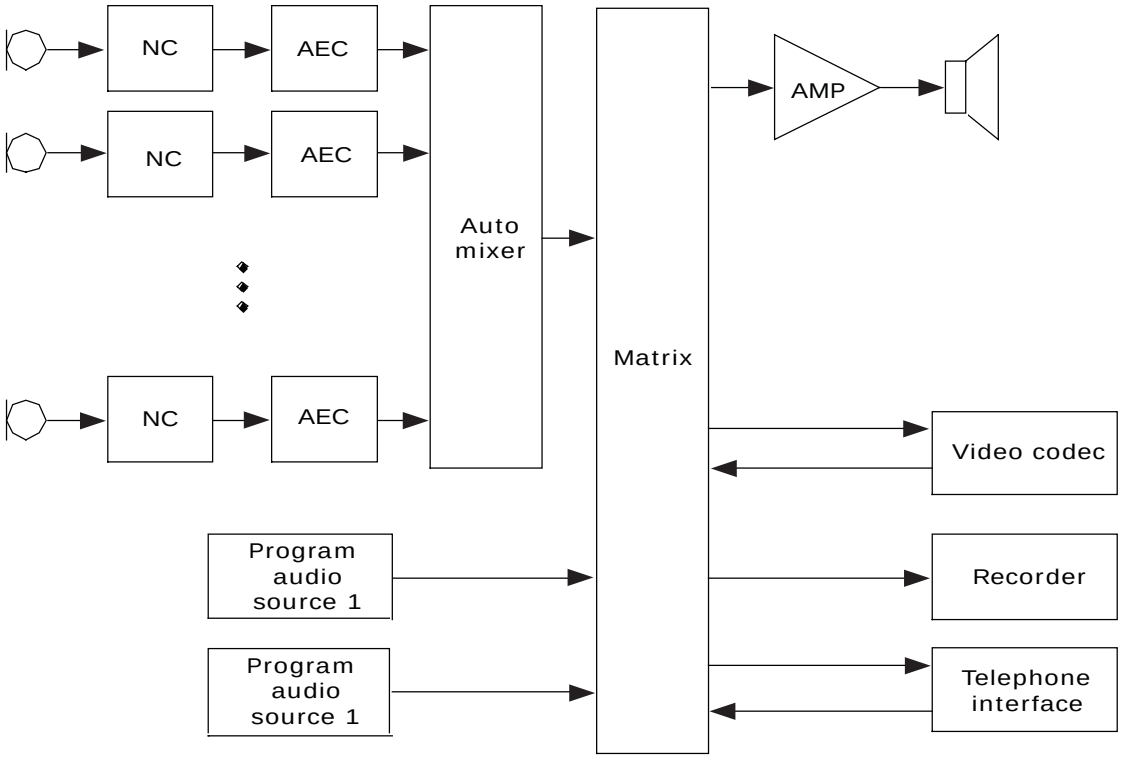
Figure 17.9 shows a typical solution for audioconferencing (or audio for videoconferencing) that consists of:

- Local microphones and loudspeakers.
- An acoustic echo canceller (AEC) and noise canceller.
- Automatic microphone mixers.
- Matrix mixers.
- Telephony interfaces.
- Video codecs (optional).
- Program audio (e.g., compact discs [CDs], digital versatile discs [DVDs], or videotapes).

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Audioconferencing, continued

Figure 17.9
Typical audioconferencing system



AEC = Acoustic echo canceller
AMP = Amplifier
NC = Noise canceller

This type of configuration would be installed in each of the rooms conferenced together.

One of the audioconferencing challenges is that the loudspeaker audio is not only heard by the local participants but also by the local microphones. In the absence of an AEC, the loudspeaker audio is sent back to the remote participants, who as a result hear a delayed echo of their voice.

Many of the challenges in audioconferencing arise from microphone selection and placement, loudspeaker placement, and balance between the architectural and aesthetic design of the room on the one hand and the audio quality requirements on the other. Compromising audio quality in favor of aesthetics reduces the quality and intelligibility of meetings.

In small conference room spaces, a tabletop conferencing telephone is often an adequate solution for audioconferencing and provides an all-in-one package that is easy to deploy and provides good sound quality in the many room environments.

Large Room Environments

The typical room environment introduces ambient noise (e.g., from heating ventilating, and air-conditioning [HVAC], outside noise, projectors, and computers), in-room reflections of the audio (i.e., multipath audio), and constraints on microphone and loudspeaker positioning.

Conference rooms should be designed to a noise criteria (NC) 30 standard. An NC 30 rating corresponds to approximately 40 decibels A-weighted (dBA) SPL of background noise, leaving about 30 dB of SNR for normal talkers (70 to 77 dB SPL at 1 m [3.3 ft]). A lower NC rating further improves the quality of the audioconferencing system by increasing intelligibility and reducing listener fatigue; however, it also increases the overall cost of the room build-out. For an audio system to have good intelligibility, the signals heard by the local talker should be at least 25 dB above the background noise level.

The surfaces in the room including walls, ceiling, and furniture, affect the quality of the conferencing system. Hard surfaces increase the amount of reflections in the room, causing multiple versions of a local talker's audio signal to be heard by the microphones and for multiple versions of the remote talker's signal to be heard in the local room.

Multiple versions of mutually delayed signals cause noticeable comb filtering effects. Such effects filter out particular frequencies depending on the time separation of the multiple signal versions, degrading the signal quality. Once comb filtering filters them out, the frequencies cannot be restored by equalization.

Often, the conference room location is selected due to the view or convenient location. However, the location of a potential conference room should be evaluated to ensure it is not directly underneath a building's HVAC units or near other environmental noise sources such as shipping rooms, loading docks, copy rooms, network operations centers, and other such rooms, to ensure that the outside noise sources are minimized.

Microphone Selection and Placement

The types and locations of microphones have the largest impact on the audioconferencing quality. Microphones translate the acoustic signals from the local talkers into electrical signals that can be processed and sent to remote participants.

Microphone Fundamentals

Most microphones used in conferencing systems are electret microphones. The design of electret microphones has allowed a large variety of sizes and shapes and excellent audio quality.

Microphone Selection and Placement, continued

Directional versus Omnidirectional Microphones

Electret microphones may be omnidirectional or directional in their pickup pattern depending on how the electret microphone element is physically mounted within the microphone enclosure.

Omnidirectional microphones pick up sounds from all directions around a microphone (i.e., a 360-degree pick up pattern), while directional microphones are designed to pick up signals in the pickup zone of the microphone and to reject signals outside the pick up zone.

Directional microphones are most often used in conferencing systems due to the:

- Rejection of the background noise.
- Reduction of reverberation/multipath.
- Rejection of the audio from the loudspeakers.

Directional microphones also increase the gain-before-feedback in sound reinforcement applications due to the increased rejection of the loudspeaker signal when it is directed toward the rear of the directional microphone.

Highly directional microphones like shotgun microphones are typically not used in conferencing due to the extremely narrow pickup pattern. If the talker moves out of the narrow pick up pattern, the talker's voice is significantly attenuated, sounding to remote listeners as if the talker faded out.

Boundary Microphones

Boundary microphones use the surface on which the microphone is installed and the proximity of the microphone element to the boundary surface to minimize the amount of phase cancellation that occurs when audio strikes the boundary. The resulting microphone configuration has a higher sensitivity. The pickup pattern of the microphone becomes half-spherical as the sounds below the boundary are not picked up. For example, if an omnidirectional microphone is placed on a boundary, the pattern becomes hemispherical. A cardioid microphone placed on a boundary becomes a semicardioid pattern with the sound below the boundary not picked up by the microphone.

Critical Distance

A distance from the microphone where the reverberant sound field and the direct sound field from the local talker are equal in intensity is called the critical distance. If a microphone were placed farther than the critical distance away from the talker, the resulting speech quality would be considered very poor, characterized by a bottom-of-the-barrel or muffled sound.

Microphone Selection and Placement, continued

The critical distance is a function of both the physical distance from the local talker to the microphone and the liveliness of the acoustics in the room. More reverberant rooms will have shorter critical distances, which underscores the requirement to place microphones as close to the talkers as possible. Increasing the gain on a microphone does not help reduce the critical distance as the reverberation and noise are amplified along with the local talker's voice.

The critical distance can be measured with an SPL meter and noise source. When the measured sound level does not drop by 4 to 6 dB for each doubling of the distance, the critical distance of the microphone from the noise source has been reached.

As a rule of thumb for omnidirectional microphones, the microphone should be no farther than 30 percent of the critical distance away from the talker. A directional microphone should be placed no farther than 50 percent of the critical distance.

If due to architectural constraints or room usage requirements the directional microphones must be placed farther than 50 percent of the critical distance, the users must either accept the resulting speech quality or increase the effective critical distance by moving microphones closer to the talkers, moving noise sources away from the microphones, lowering the level of the noise, and improving the acoustics in the room to reduce the amount of reverberation. Improving the acoustics in the room can be done by increasing the absorption of surfaces in the room (e.g., acoustic paneling, reduced HVAC airflow speed/noise, carpeted floors, curtains, and other absorptive surfaces).

Conferencing Microphones

While omnidirectional microphones seem like a natural choice for conferencing applications because fewer microphones would be required for a given number of participants, their 360 degree pickup picks up extra noise, room reverberation, and the remote audio from the loudspeakers. The result is that the signal picked up by the microphone in a conferencing environment sounds muddier and noisier than the signal from a directional microphone. For this reason, most installations use cardioid (directional) style microphones.

Gooseneck Microphones

In many boardrooms, gooseneck microphones are used and distributed around the table with one microphone per participant. Each of these microphones has a neck that takes the microphone off the table and brings it closer to the talker's mouth. In addition, these microphones have a directional pattern to further improve the rejection of the ambient noise.

NOTE: Some gooseneck microphones have the tendency of straightening out over time, so the microphone positioning should be checked periodically. If the microphone points at a loudspeaker, such change could pose a problem for a sound reinforcement application.

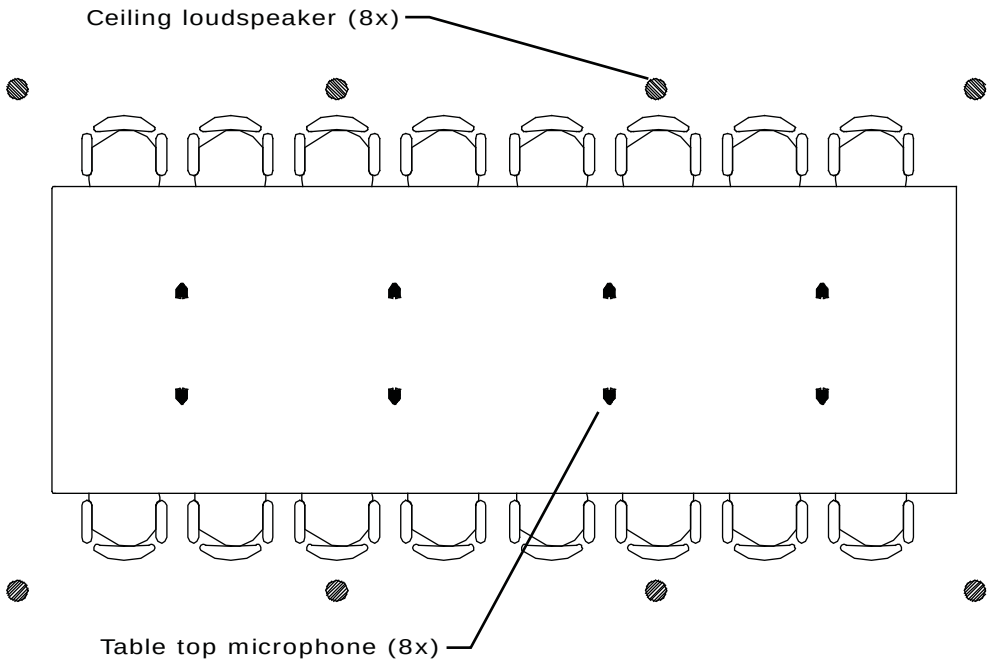
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Microphone Selection and Placement, continued

Tabletop Microphones

In many conferencing applications, boundary tabletop microphones are used and mounted at locations around the table (see Figure 17.10) and one microphone is typically used for every two participants.

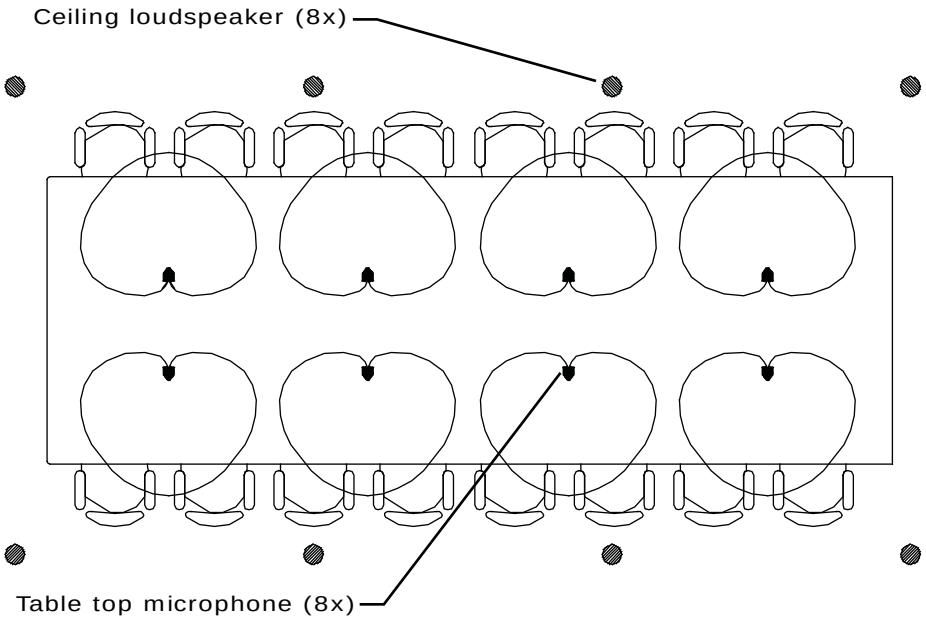
Figure 17.10
Typical conference room table with boundary tabletop microphones



Microphone Selection and Placement, continued

All of the participants seated at the table are well within the microphones pickup ranges (see Figure 17.11).

Figure 17.11
Conference room microphone pickup pattern



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Microphone Selection and Placement, continued

Noise Immunity

Cellular telephone systems often have transmission and reception frequencies in the 900 to 1800 megahertz (MHz) range. During a normal operation of these cellular phones, regular communication is maintained with the closest cellular towers for status as well as for signaling incoming data and telephone calls. For some Global System for Mobile Communications (GSM) style telephones, this signaling occurs at the rate of one 576 microseconds (µs) pulse every 4.6 ms, which represents a 217 hertz (Hz) signal.

Often in conferencing applications, cellular telephones are placed on the conference table in close proximity to the local microphones. Because these microphones often are not designed to be immune to the frequencies in the 900 to 1800 MHz range, the transmission and reception signals can be easily coupled into the microphone where it is rectified by the microphone's electronics and combined with the local microphone audio signal. When this happens, a noticeable beeping or chipping tone that sounds modulated, as if it were Morse code, is heard at remote locations. If this problem is present, the solutions are to move cellular telephones away from the microphones, turn off cellular telephones, or use microphones that have improved noise immunity to these high frequencies. Many manufacturers are now producing microphones with improved noise immunity.

Wireless Microphones

Wireless microphones are commonly used in conferencing applications, particularly for presenters. The advantage of wireless microphones is that they may be used anywhere within the room, depending on whether in-room sound reinforcement is used with that microphone. They also have the advantage of being closer to the local talker's mouth than a tabletop microphone.

A lavaliere style of wireless microphone is considered a better choice than a handheld wireless microphone for ensuring that the microphone stays a constant distance from the talker's mouth. This choice also minimizes the sound level variation to the remote participants in a conferencing application.

NOTE: The users of lavaliere microphone should be trained to attach the microphone in a way that prevents their clothing fabric from touching the microphone element wile speaking.

Handheld wireless microphones are not as effective as lavaliere microphones because they are often place placed on tables, used as pointing devices, or used in other situations that reduce the quality of the resulting audio signal.

Microphone Selection and Placement, continued

Wireless microphones use different methods of transmission that range from analog transmission over ultrahigh frequency (UHF) or very high frequency (VHF), to digitally encrypted transmissions over a 2 gigahertz (GHz) frequency band. Considerations for choosing a wireless microphone include the:

- Transmitted signal bandwidth (i.e., narrow or wideband).
- Latency introduced by the wireless microphone.
- Battery type and life (e.g., rechargeable or not).
- Reliable transmission distances.
- Cost.
- Freedom from interference.
- Use of encryption for securing the wireless channel.

Ceiling Microphones

In all applications, placing the microphone closer to the local talker results in a higher quality signal due to the improved SNR (i.e., the local talker is louder compared to the background noise) and a reduction in the size of the multipath signal compared to the original signal.

Most conferencing applications are a result of a trade-off among the usage of a room, the location and configuration of the furniture, and the maximum achievable audio quality. Rooms with movable furniture commonly do not have permanently installed microphones on the tables. Instead, microphones are often moved away from the participants and placed in the ceiling. The resulting signal picked up by the microphone includes significant additional noise sources (e.g., HVAC) that are closer to the microphone than the talker. In addition, the local talker's mouth is farther from the microphone, reducing the signal level picked up by the microphone. Any additional gain added to pick up the local talker's signal also amplifies the background noise, exacerbating the problem.

To set achievable expectations, the audio quality of a ceiling microphone should be tested in the target room as early in the design process as possible. This can be done simply by temporarily hanging a microphone from a ceiling with tape or some other temporary adhesive and running the microphone cable to a location acoustically isolated from where the microphone is temporarily installed.

With the use of a microphone amplifier and powered loudspeaker, the customer can listen to the audio quality and judge if it is acceptable before additional work is performed. More often than not, once the conference room users hear the resulting sound quality of ceiling microphones, they opt for tabletop boundary microphones or, at the very least, decide to place the microphones closer to the local participants.

Ceiling microphones should be installed away from HVAC, light fixtures, projectors, loudspeakers, and any other noise sources. If ceiling microphones are the only option, they should be hung from the ceiling close to the talkers, rather than flush-mounted. While aesthetically less appealing than a flush-mounted ceiling microphone, a hanging microphone moves the microphone away from any ceiling noise sources, including the loudspeakers that play the remote audio into the local room and closer to the talkers.

Microphone Selection and Placement, continued

If the ceiling microphone is close to the ceiling (less than 0.3 m [1 ft] from the ceiling) but not flush mounted, the same boundary effect that improves the sensitivity of flush-mounted microphones causes the microphone to pick up multiple delayed signal paths, unnecessarily degrading the overall audio quality of the system.

Ceiling microphones (hanging or flush mounted) should have no more than a half-spherical pick up pattern. In typical conference rooms with 2.74 m (9 ft) high ceilings, ceiling microphones are commonly hung 0.3 m (1 ft) or more from the ceiling over the conference table.

When planning the number of installed ceiling microphones, the designer should keep in mind that a ceiling microphone will cover approximately 9.3 square meters (m^2 [100 square feet (ft^2)]) of room space, depending on the critical distance of the microphones. For example, rooms that have very high ceilings (i.e., taller than 3 m [10 ft]) should only use ceiling microphones if they can be hung several feet from the ceiling.

Automatic Microphone Mixers

The role of the automatic microphone mixer is to limit the number of open microphones (NOM) or contributing audio at any given time to only the microphones associated with active talkers. By reducing the number of active microphones, the local speech that will be sent to the remote site is less reverberant and less noisy.

A significant reduction occurs in audio quality if all of the microphones are active all the time versus being processed by the automatic microphone mixer. This difference is particularly clear when ceiling microphones are used due to the high noise and reverberation levels associated with microphones that are farther away from the local talkers and above 50 percent of the microphone's critical distance.

Noise Cancellation

Room ambient noise caused by HVAC, projectors, computers, and the outside noise picked up by the microphones reduce the SNR at the microphones. This noise is then transmitted to the remote site along with the local talker's audio signal. The reduced SNR contributes to the lowered intelligibility of the remote audio and increased listener fatigue of the remote talkers.

Ambient noise should be eliminated or reduced through architectural means such as changing HVAC ductwork, moving microphones away from noise sources, and removing or dampening noise sources. If these approaches are not adequate or possible, an additional option is to process the microphone signal with advanced signal processing techniques that reduce the level of background noise while maintaining the quality of the local talker's voice.

Techniques for reducing the background noise picked up by the microphone range from simple noise gates to advanced digital adaptive filters. Noise gate techniques reduce the noise when the local talkers are not talking by suppressing the signal that is below a given threshold, but the noise is still going to be present when the local talkers begin to speak again. The gating of the background noise will sound unnatural at the remote site as the local talker speaks and then stops speaking.

Noise Cancellation, continued

More sophisticated techniques, such as adaptive filter techniques, are used successfully in audioconferencing applications. While not all adaptive noise reduction techniques (commonly referred to as noise cancellation) have the same performance, the objectives are the same:

- To identify the characteristics of the noise (e.g., broadband, such as HVAC noise, or narrowband, such as a whine from a mechanical source)
- To remove the noise signal from the microphone audio signal without any additional information about the noise

These techniques work best with noise that has stationary statistics (e.g., the noise signals may be random but the style of randomness is fixed, such as the noise from a fan source). As these techniques typically take several seconds to identify the characteristics of noise, they do not work well with impulsive noises such as clicks from pen tapping or paper rustling on a microphone. These systems are typically designed to work with speech signals and are not typically suitable for use with music.

As not all implementations are the same, the amount of residual noise or spectral artifacts introduced into the processed signal may vary largely. These artifacts may sound like chirps or other sounds and may be perceived to be worse in quality than the original noise.

These artifacts may be minimized by lowering the amount of noise cancellation provided. Typically, it can be adjusted from 0 to 15 dB or more. With current techniques, 5 to 10 dB noise cancellation can be achieved without significant distortion of the underlying local talker's signal, depending on the manufacturer.

Ceiling microphones benefit the most from noise cancellation techniques because these microphones are closest to the ceiling noise sources of HVAC and projectors. The noise cancellation can make an otherwise useless room useable. However, if ceiling microphones are swaying due to the air flow from nearby HVAC ducts, noise cancellation may not be able to completely remove that noise.

Acoustic Echo Cancellation (AEC)

In audioconferencing applications, acoustic echoes occur because an open-air acoustic path exists between the local loudspeaker and the local microphone.

Speech originating in either the local or remote room is transmitted over a communications network to the other room where it is amplified and reproduced by the local loudspeaker (see Figure 17.11). The output of the loudspeaker (or multiple loudspeakers) fills the local room and, from many paths of reflections, reaches the microphones in the local room. In the absence of an AEC, this acoustically-echoed version of the remote talker's audio is transmitted back over the network to the originating room and reproduced by the loudspeaker, where it is perceived as an acoustic echo.

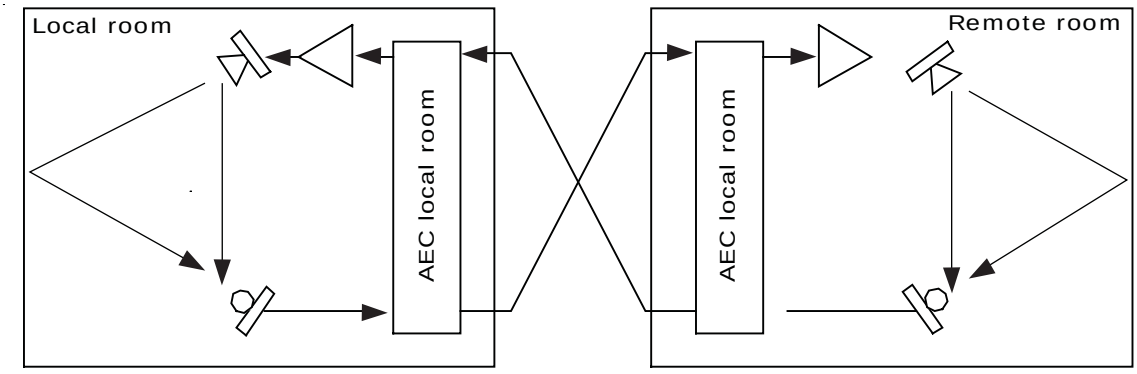
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Acoustic Echo Cancellation (AEC), continued

Acoustic echoes degrade the quality of speech communications because echoes of one's speech are subjectively irritating to the person speaking. In fact, if the period between the time a word is spoken and the time its echo is heard is more than 300 ms, the echo will actually cause most talkers to stutter. In addition, echoes can overload communication circuits, resulting in a feedback condition called howling. If, by the combination of loudspeaker volume and microphone sensitivity and positioning the echoes are louder than the originating speech, the teleconferencing equipment or the network itself can reach an overload.

An AEC in the local room will remove the echo of the remote talker's voice so it will not be sent back to the remote talkers. Just as an AEC is used in the local room to prevent echoes from being sent to the remote participants, the remote site would have a similar audioconferencing solution to prevent the local talker's audio from echoing back from the remote room (see Figure 17.12).

Figure 17.12
Two connected rooms and their acoustic echo cancellers



AEC = Acoustic echo canceller

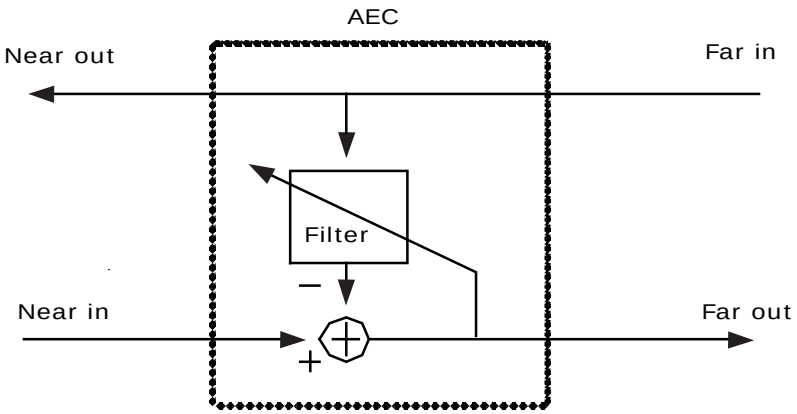
Acoustic Echo Cancellation (AEC), continued

The sophisticated part of an AEC consists of an adaptive filter that is nearly continuously adapting to adjust to the changes in the echoes caused by the changes in the room (e.g., participants moving around).

Figure 17.13 illustrates an AEC system with an adaptive filter at its center. The signals associated with an echo canceller are commonly referred to as:

- Near-in signal—The local microphone audio (both local talker and the echo of the remote talker).
- Near-out signal—The signal played into the local loudspeaker so that the local participants can hear the remote participants.
- Far-in signal — The signal sent from the remote side.
- Far-out signal—The local talker audio with the acoustic echo removed and sent to the remote participants.

Figure 17.13
Typical acoustic echo canceller with two input signals and two output signals

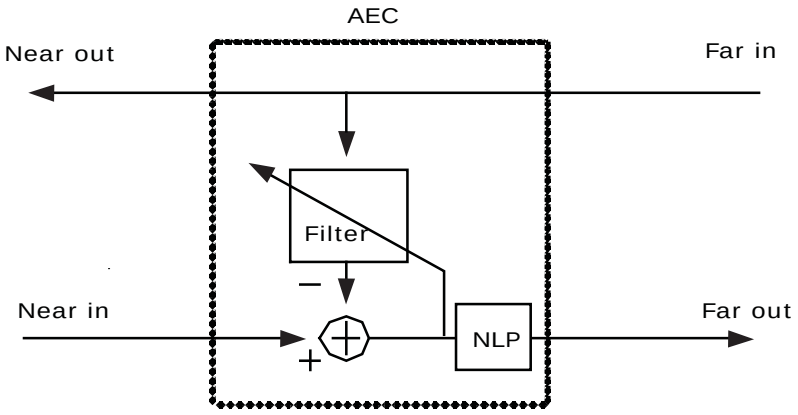


AEC = Acoustic echo canceller

Acoustic Echo Cancellation (AEC), continued

The performance of the AEC is often improved by adding nonlinear processing, sometimes referred to as center clipping, after the adaptive filter on the far-out signal (see Figure 17.14). The nonlinear processing removes low-level artifacts that result from imperfections of the adaptive filter (e.g., when it is not completely adapted).

Figure 17.14
Acoustic echo canceller with nonlinear suppression



AEC = Acoustic echo canceller

AECs typically have user-adjustable controls for the amount of nonlinear processing, allowing the processing to be more aggressive (i.e. larger suppression) or less aggressive (i.e., lower suppression). More aggressive suppression reduces the occurrence of residual acoustic echoes to the remote site, but possibly at the expense of introducing some clipping of the first syllable of the local talker's audio during transitions from the remote people's speech to the local people's speech. Aggressive suppression also may vary the level of the transmission audio signal based on whether both the local and remote talkers are speaking at the same time. With less aggressive suppression, the system can be made to appear more full-duplex at the expense of having some residual echo transmitted to the remote site if the AEC is not fully converged.

Reference

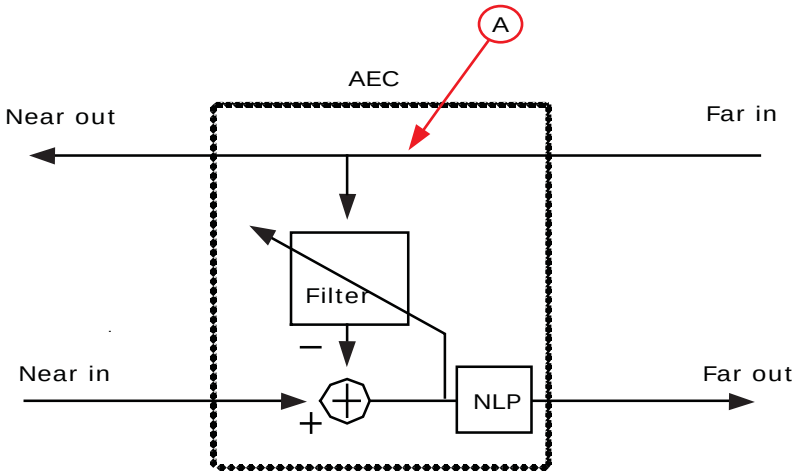
The reference provides the AEC with the information for selecting the signal to be cancelled from the room (see Figure 17.15). The echo canceller reference is usually a combination of audio from the remote sites, including telephone and videoconferencing audio and any program audio sources. Microphone signals are typically not included in the AEC reference signal.

Acoustic Echo Cancellation (AEC), continued

To cancel echoes, the original source signal (e.g., the remote audio) must be part of the echo canceller reference. Generally the reference is the original signal played by the loudspeaker system (see Figure 17.15) before it generates echo in the local room.

If the reference signal is significantly different from the signal played out of the loudspeaker (e.g., due to dynamics processing), the echo canceller may not be able to cancel the echo signal because it is not recognized as being the same as the reference signal, causing a persistent residual echo to be sent to the remote site. The local echo canceller treats this signal as a local talker. Dynamics processing or other nonlinear signal processing should not be applied on the loudspeaker signal as that will distort the echo signal substantially from the signal the echo canceller is expecting to see for the echo canceller reference. If dynamics processing is required, the signal should be processed before it is used as the echo canceller reference.

Figure 17.15
Acoustic echo canceller reference as indicated by signal A



AEC = Acoustic echo canceller
NLP = nonlinear processor

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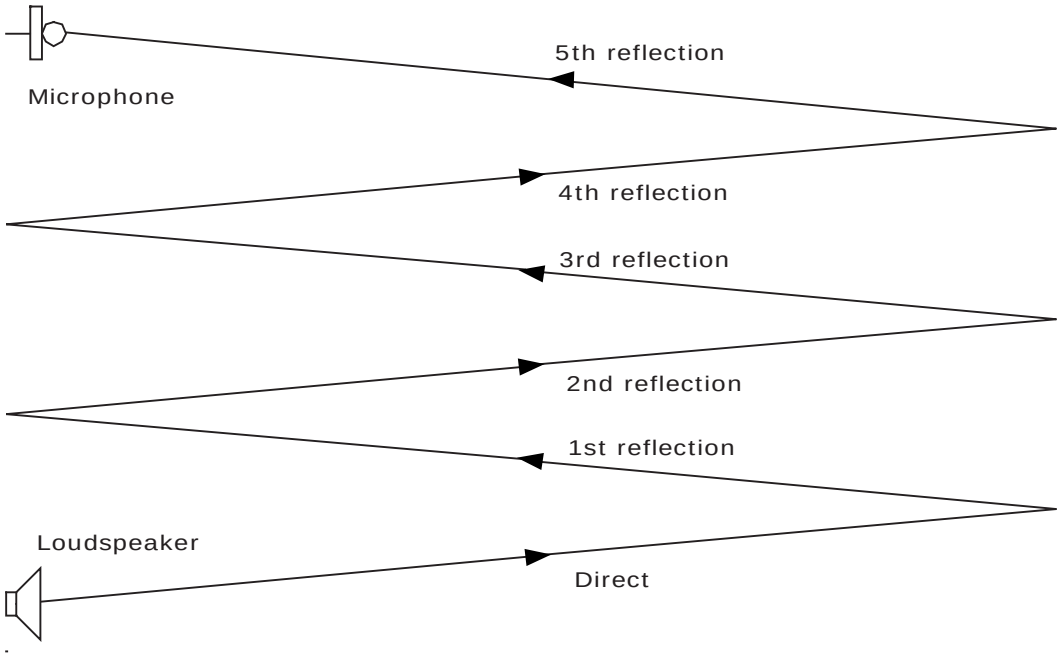
Acoustic Echo Cancellation (AEC), continued

Tail Time

The tail time of an echo canceller is the amount of time the echo canceller can still recognize a signal as an echo from the remote talkers' speech and not interpret that signal as speech from a local talker.

All echo cancellers have some upper limit, called the tail time or tail length, after which they do not recognize the echo signal as a version of the reference signal and consequently cannot remove the echo from the room. The tail time is measured in ms, although it can be interpreted in terms of distance. It should be greater than 100 ms for medium sized rooms or greater than 200 ms for larger rooms. If the room is lively, the length of an echo path may be longer than expected making the room appear acoustically larger than it is physically (see Figure 17.16).

Figure 17.16
Acoustic echo and multiple reflections



Acoustic Echo Cancellation (AEC), continued

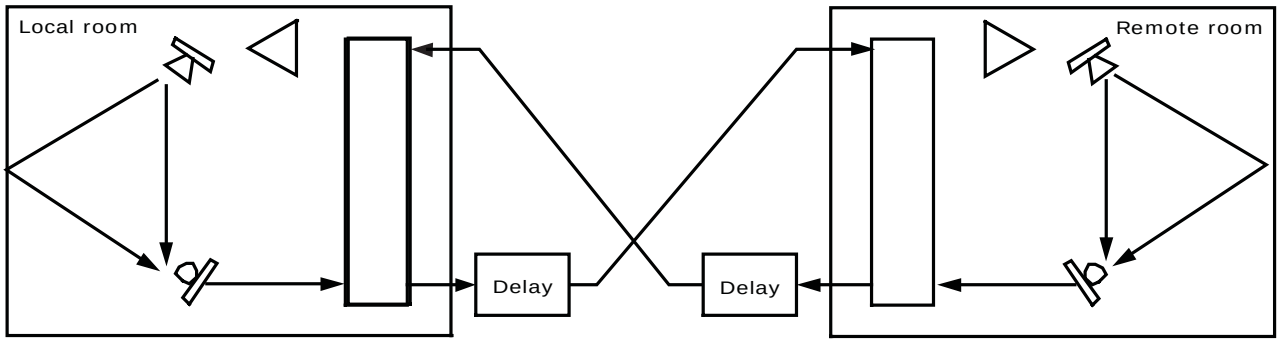
Transmission Delay

In all communication networks, a combination of processing latency and network latency delays occurs when the local signal is heard in the remote room and conversely when the remote signal is heard in the local room. Numerous studies have shown that when delay is added to an echo, the perceived communication impairment caused by the echo is increased.

Processing latency is due to the selection of algorithms, the speed of the underlying processors, the implementation of the algorithms, and the method of collecting the audio from the analog-to-digital (A/D) converter and sent to the digital-to-audio converter (D/A) in a digital system.

In some cases, such as in videoconferencing systems, delay may be intentionally added to the audio signal to compensate for the delays inherent with video signal processing to maintain audio and video lip synchronization (see Figure 17.17). Network transmission delay is limited by the speed of electrons, or the speed of light with satellite and microwave transmission, in a network and any other data processing or handling that may occur as the data is transmitted through the network. Networks may require a hundred milliseconds or more to transfer audio from one site to anoother.

Figure 17.17
Two rooms connected through network with inherent delay



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Acoustic Echo Cancellation (AEC), continued

While the delay in a network increases the perception of echoes, it does not affect the performance of the AEC in either the local or the remote rooms.

The AEC is concerned only with the audio as it enters the room and reflected in the room and picked up again by the local microphones. The echo canceller does not distinguish whether the signal from the remote talkers takes 1 ms or 10 hours (h) to be received; it is concerned with the audio once it reaches the AEC and is picked up by the local microphones. Only the perception of residual echoes is influenced by the transmission delay. For example, an echo that is heard with 5 ms delay will not be objectionable at all, while the same echo heard with 500 ms delay will render interactive communications impractical.

Echo Return Loss (ERL)

An echo canceller's performance is measured by how well it can reduce the echo signal present at the microphone. The natural reduction of the echo signal due to the physical separation of the loudspeakers from the microphones is commonly referred to as echo return loss (ERL) and is measured in dB.

ERL (see Figure 17.18) is the ratio of:

$$20 \log (A/B)$$

Where:

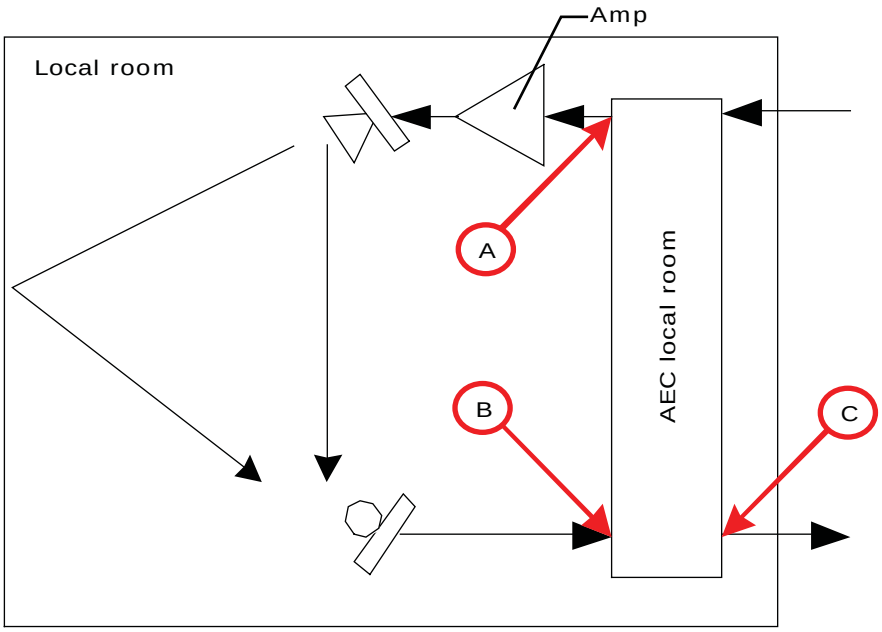
A = Signal that is sent to the loudspeaker amplifier

B = Signal picked up by the microphone

Acoustic Echo Cancellation (AEC), continued

Echo cancellers commonly have a minimum required ERL for proper operation. ERLs below the minimum will slow or prevent an adequate convergence of the AEC. Typical values for ERL with which an AEC can operate are from -6 dB and higher with –6 dB characterizing a more robust AEC. An ERL of –6 dB means that the echo is 6 dB louder at the microphone than the reference signal at the AEC.

Figure 17.18
Echo return loss and echo return loss enhancement



AEC = Acoustic echo canceller

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Acoustic Echo Cancellation (AEC), continued

While a high positive ERL means there is a natural reduction in the amount of echo present at the microphones, a significant amount of echo will be sent to the remote site if the signal does not undergo any further processing.

The enhancement of the ERL due to the presence of an AEC is referred to as the echo return loss enhancement (ERLE).

ERLE (see Figure 17.18) would be the ratio of:

$$10 \log (B/C)$$

Typical values for ERLE are 15 to 25 dB based on the algorithm performance. The total echo loss is ERL + ERLE (before the application of nonlinear processing/suppression) typically ranges from 15 to 40 dB depending on the room gain structure (ERL) and the performance of the AEC algorithm. Nonlinear processing will provide additional echo suppression to remove residual echoes when the echo canceller is in the receive state (i.e., only receiving audio from the remote site).

For some echo canceller manufacturers, the term ERL is replaced with an equivalent term of conferencing room gain. The conferencing room gain is the reciprocal of ERL or defined as:

$$20 \log (B/A) = -20 \log (A/B)$$

Lower room gain (equivalently higher ERL) in this case will improve the echo canceller's performance.

Multichannel versus Single Channel Acoustic Echo Cancellation (AEC)

The highest quality audioconferencing solution is the one in which each microphone has its own AEC and noise canceller (see right of Figure 17.19).

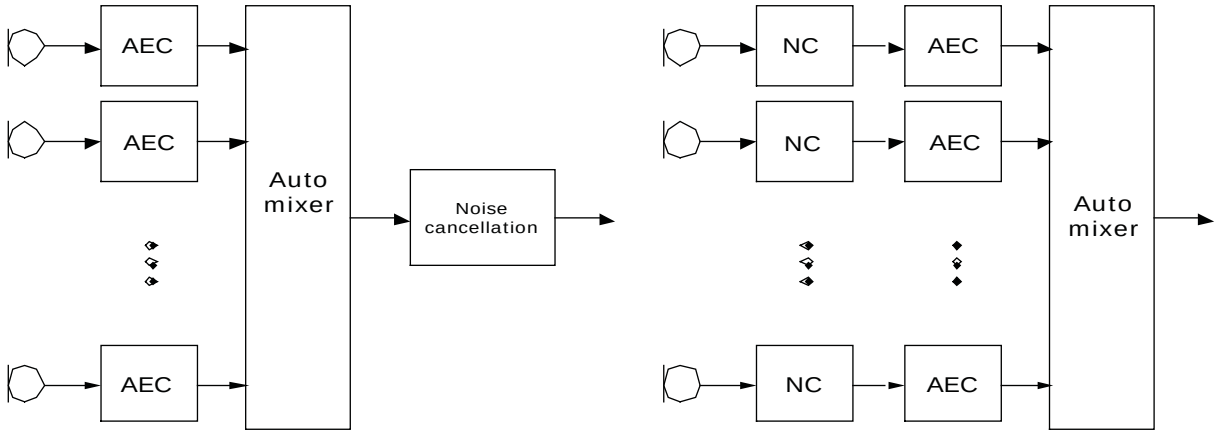
Each microphone picks up different background noise levels and possibly types of noise based on their proximity to different noise sources (e.g., projectors, HVAC vents, lighting fixtures).

If each microphone is processed independently, only the noise and echo affecting a particular microphone will be removed from that microphone signal. This minimizes the likelihood of residual artifacts from the noise and echo processing on the underlying signal.

If the microphones are first summed together and then the noise processing is performed (see left of Figure 17.19), each local talker's voice will be processed by the same noise reduction algorithm to remove noise regardless of whether that noise was incident on that particular microphone.

Acoustic Echo Cancellation (AEC), continued

Figure 17.19
Noise cancellation after automixing (left) and individual noise cancellation (right)



AEC = Acoustic echo canceller
NC = Noise criteria

Similarly, with respect to the AEC, processing the signals independently is better because each microphone has its own acoustic view of the room and sees an acoustic echo that is different from the other microphones.

If multiple microphones are mixed into a single AEC, as each microphone becomes active with respect to its automatic microphone mixing algorithm, the AEC must reconverge to the echo path from the microphone that becomes active.

The performance of the AEC will degrade as the number of open microphones that feed into it is increased. Multiple microphones should only be fed into a single AEC if the ERL is high—equivalently, the room gain is low (e.g., in acoustically well treated room or when microphones are physically separated from loudspeakers or their gating).

Muting Microphones

When muting microphones in an audioconferencing system, muting the microphones in the signal chain after the AEC has processed the local microphone's audio signal is considered the best option. This allows the AEC to continue adapting to the changes in the room, keeping the AEC converged even though the microphone is muted.

If the microphones are muted in the signal chain before the AEC, the AEC will not be able to adapt as there will be no signal present while the microphones are muted. Once the microphones are unmuted, the AEC may have to reconverge to the any new echo paths. This may result in a momentary acoustic echo to the remote site until the AEC reconverges.

Acoustic Echo Cancellation (AEC), continued

Volume Control

If the gain on the loudspeaker amplifier is increased, the ERL will decrease and the room gain will increase, meaning that a stronger echo will be present at the input of the microphones. The echo canceller will need to work harder to remove the echo. If the amplifier is turned up too high, sometimes by as little as 6 or 10 dB, the AEC will not be able to operate properly. This may result in persistent residual echo under low ERL or high echo situations.

To adjust the volume of a local room properly, the sources feeding into the echo canceller or the far-in signals should be adjusted or, if that is not practical, at least the echo canceller reference should be adjusted as the loudspeaker level is corrected to match the amplifier adjustments. Under these conditions, the ERL remains relatively fixed, allowing the echo canceller to continue operating properly.

Troubleshooting Guidelines

In the event that a configured conferencing system has acoustic echoes heard by the remote participants, the most important step in troubleshooting is to mute signal paths and determine when and if the echo is removed. If the echo goes away when the local microphones are muted, the local echo canceller is causing the echo issue.

The most common reason for acoustic echo is that the ERL of the room is not high enough to allow the AEC to properly adapt to the remote audio. This is usually solved by reviewing the gain structure and turning down the amplifier and increasing the gain of the signals that make up the echo canceller reference.

The next most common reason for echoes is that the echo canceller reference does not contain all of the remote audio sources, allowing one or more remote audio sources to be interpreted as local speech by the echo canceller and consequently sent to the remote participants.

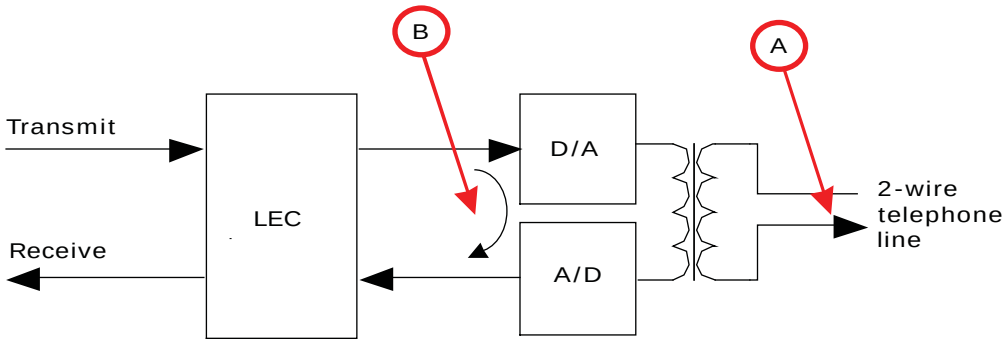
Telephone Hybrid

To use the audioconferencing system, the local signal has to reach the remote participants and vice versa. While only supporting 3.5 kilohertz (kHz) of audio bandwidth, the public switched telephone network (PSTN) provides the most common and reliable real-time communication network for audioconferencing.

In the conference room, PSTN is accessed by a pair of conductors that carry both the transmit and receive signals. When interfacing external equipment to the PSTN, the transmit and receive signals should be separated. This is the task of the telephone hybrid, also known as a 2-wire–to–4-wire converter (see Figure 17.20).

Telephone Hybrid, continued

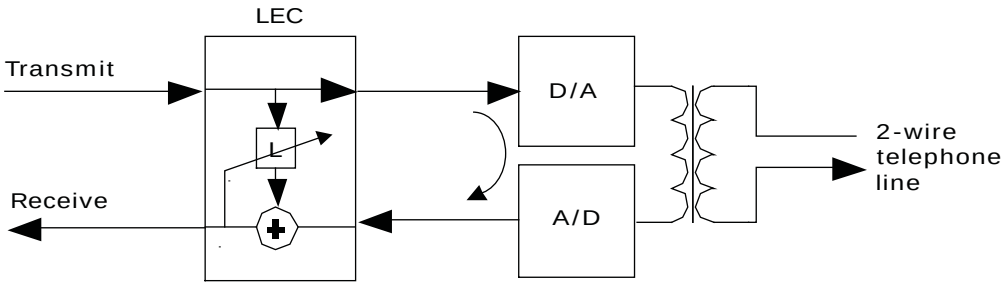
Figure 17.20
Telephone hybrid



A/D = Audio-to-digital converter
D/A = Digital-to-audio converter
LEC = Line echo canceller

The telephone hybrid circuit that interfaces the 2-wire PSTN network to the separate 4-wire transmit and receive uses a LEC (LEC [similar to the AEC]), to remove the line echo (signal B in Figure 17.20) caused by the imperfect signal balancing of the transmit and receive circuits onto the 2-wire network (see Figure 17.21).

Figure 17.21
Line echo canceller



A/D = Audio-to-digital converter
D/A = Digital-to-audio converter
LEC = Line echo canceller

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Telephone Hybrid, continued

This imperfect balance means that, when a transmit signal is sent to the telephone line, some leakage or coupling of the signal back to the receive path occurs. This leakage is heard as a return echo of the local talker's speech. This is the same echo, commonly referred to as side-tone, heard on a telephone handset when speaking into a telephone. The side-tone echo provides feedback to the local talkers about the loudness of their speech and the working condition of the telephone line.

While side-tone is desirable while talking on a handset, it is not desirable in a conferencing application. As the line echo or side-tone is mixed together with the audio from the remote telephone talker's speech, the line echo is played into the room over the same loudspeakers in the local room used for hearing the remote talkers. The line echo sounds like an echo of the local talker's speech with a short delay.

If the signal in the room is loud enough and the loudspeaker-to-microphone coupling is significant (i.e., low ERL), the line echo may cause acoustic feedback in the room as the local talker's audio is played back into the room, picked up by the microphones, reflected off the telephone line interface, and played back into the room. Since the telephone signal is part of the AEC reference signal, the AEC will try to echo-cancel the side-tone and prevent its sending to the remote side and hence causing more side-tone. However, it may not completely cancel the signal as the system will be in doubletalk (i.e., the echo canceller will detect both the local talker's speech and the side-tone interpreted as the remote talkers' speech). This prevents the AEC from converging properly, degrading the conferencing experience.

The LEC is an adaptive filter that uses the transmit signal to adapt and remove the line echo that appears on the receive side of the LEC. Similar to the AEC, some nonlinear suppression to remove residual echoes may be present when the LEC is not fully converged.

The LEC typically adapts when transmit audio is present without receive audio (i.e., just the local talkers are speaking). The contrast is the AEC, which typically only adapts when remote audio is present and the local talkers are not talking.

Due to the variation in performance of telephone lines across the world, telephone hybrids have a country code setting required to properly interface the hybrid to the local telephone line characteristics. If the telephone hybrid settings do not match the communications network's settings, the performance of the telephone hybrid is degraded and may pose a violation of the local telecommunications regulatory requirements.

Loudspeakers

Loudspeakers and the amplifier driving the loudspeakers in the local room allow the local conferencing participants to hear the remote audio. The loudspeakers can be wall-mounted, ceiling-mounted, or even table-mounted, although they are most often installed in the ceiling of the local rooms.

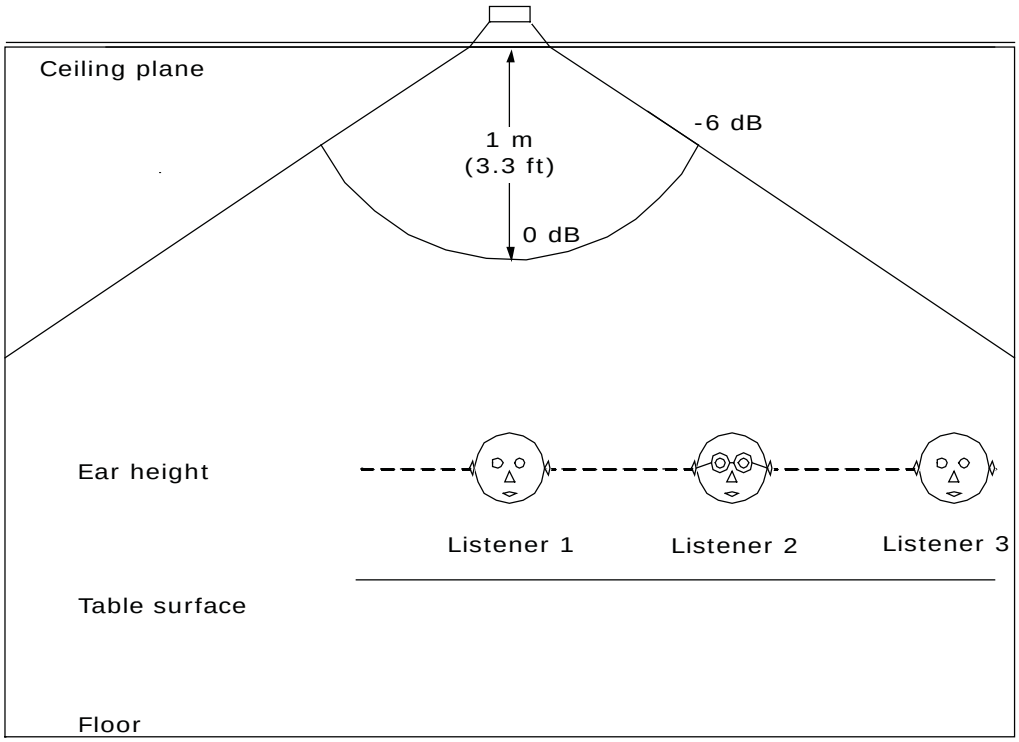
Just as microphones are characterized by their pickup pattern, frequency response, and sensitivity to sound, loudspeakers are characterized by their frequency response (e.g., 80 Hz to 20 kHz), power capacity (e.g., 40 to 80 W), sensitivity (e.g., 86 dB SPL at 1 m [3.3 ft]), and nominal coverage angle (e.g., 130 degrees).

The loudspeaker coverage angle is defined by the angle where the loudspeaker levels are within 6 dB of the on-axis level. Figure 17.22 shows a typical coverage angle for a ceiling-mounted loudspeaker and illustrates that the listeners farther away from the loudspeaker axis will receive less sound than the listeners directly below the loudspeaker. In this figure, not only are listeners 2 and 3 farther away from the loudspeaker than listener 1 and receive less audio due to the inverse square relationship, they also receive less audio from the loudspeaker due to the inherent 6 dB difference, as stated by the manufacturer, between the off-axis response and the on-axis responses of the loudspeaker.

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Loudspeakers, continued

Figure 17.22
Loudspeaker coverage angle



dB = Decibel
ft = Foot
m = Meter

While this example shows a single loudspeaker and multiple participants, most rooms require multiple loudspeakers to provide enough coverage so that the remote audio can be heard at a comfortable level by all of the participants regardless of where they are sitting.

Loudspeakers, continued

Numerous rules govern the number of loudspeakers and the amount of power required for specific room sizes, which can be determined using the software designed for that purpose.

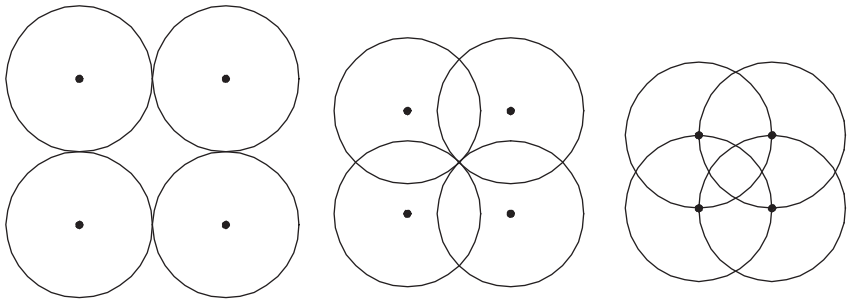
One rule is that the typical ceiling-mounted loudspeaker has a coverage area of approximately 9.3 m^2 (100 ft^2) at the ear level assuming a 2.74 m (9 ft) ceiling, shown in Figure 17.23 as a radius of about 1.7 m (5.5 ft).

Depending on how close the loudspeakers are clustered, different levels of audio are heard by local participants. Clustering the loudspeakers farther apart (about 3.4 m [11 ft] in this example) will cover a larger area but have some significant level variation depending on where the listeners are. Clustering the loudspeakers closer together will increase the overlap and reduce the level variation heard by the listeners based on their position in the room.

While tighter clusters minimize the level variation, they also increase the cost of the system because more loudspeakers are required to cover a particular area.

Another rule for loudspeaker positioning is to distribute the loudspeakers not farther than twice the distance from the ceiling to the listener's ear level. In a conference room with 2.74 m (9 ft) high ceilings and seated listeners' ears about 1.1 m (3.5 ft) above the floor, this corresponds to a 1.7 m (5.5 ft) loudspeaker separation. If the listeners will be standing, more loudspeakers are required to effectively cover the room as the loudspeaker pattern will not cover such a large area closer to the listener.

Figure 17.23
Loudspeaker coverage patterns with varying degrees of overlap



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Loudspeakers, continued

Distributing the loudspeakers in the ceiling allows all of the participants in the room to hear the sound clearly. If only a single set of loudspeakers is located in the front of the room, the audio in the back of the room may sound reverberant and muddy, with reduced intelligibility for the local participants.

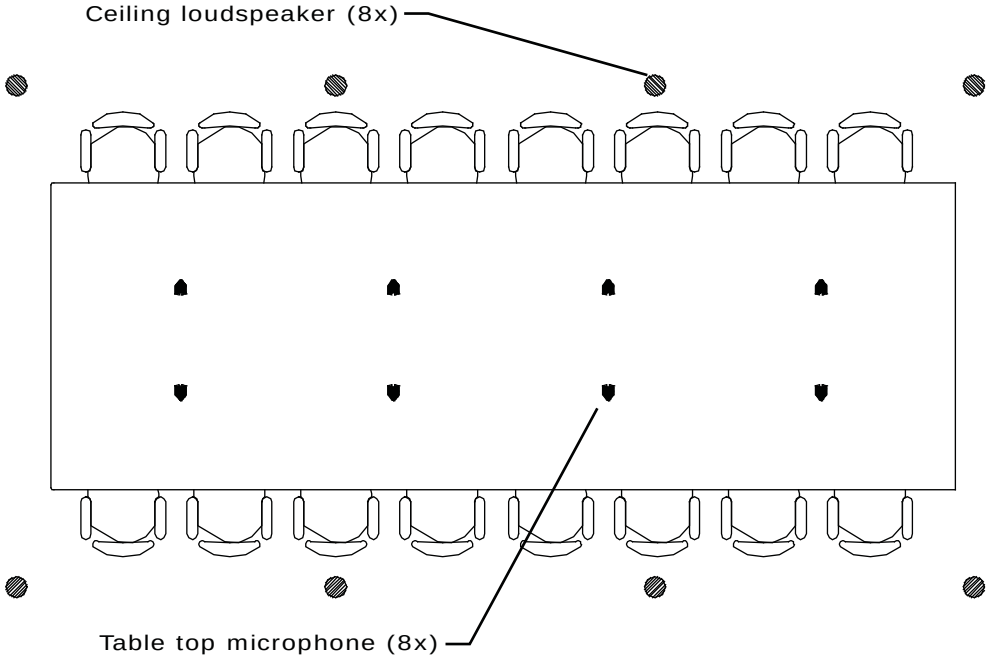
Similar to a microphone's critical distance, loudspeakers also have a critical distance where the reverberant sound field is equal in intensity to the direct sound field. If only a few loudspeakers are used (e.g. at the front of a room), the listeners near the critical distance will not receive an intelligible signal as listeners closer to the loudspeakers. Distributing the loudspeakers throughout the room generally helps to ensure that all of the listeners are well within the loudspeakers' critical distance.

In many audioconferencing rooms, separate loudspeakers are used for program audio (e.g., videocassette recorder [VCR] or DVD) to maintain the stereo separation of the source material in the room. A subwoofer also may be used for this media, although subwoofers are typically not required for audioconferencing due to the limited range of low frequencies produced by the typical talker.

Loudspeaker Zoning and Placement

Ceiling loudspeakers should be positioned so the sound field from the loudspeaker encompasses the participants' seating locations. This typically means that the loudspeakers are positioned outside the table perimeter to allow the coverage of the participants and any potential areas of overflow seating as shown in one possible layout (see Figure 17.24). As discussed in an earlier section, the microphones should be placed as close to the local participants as possible to minimize the amount of background noise and reverberation.

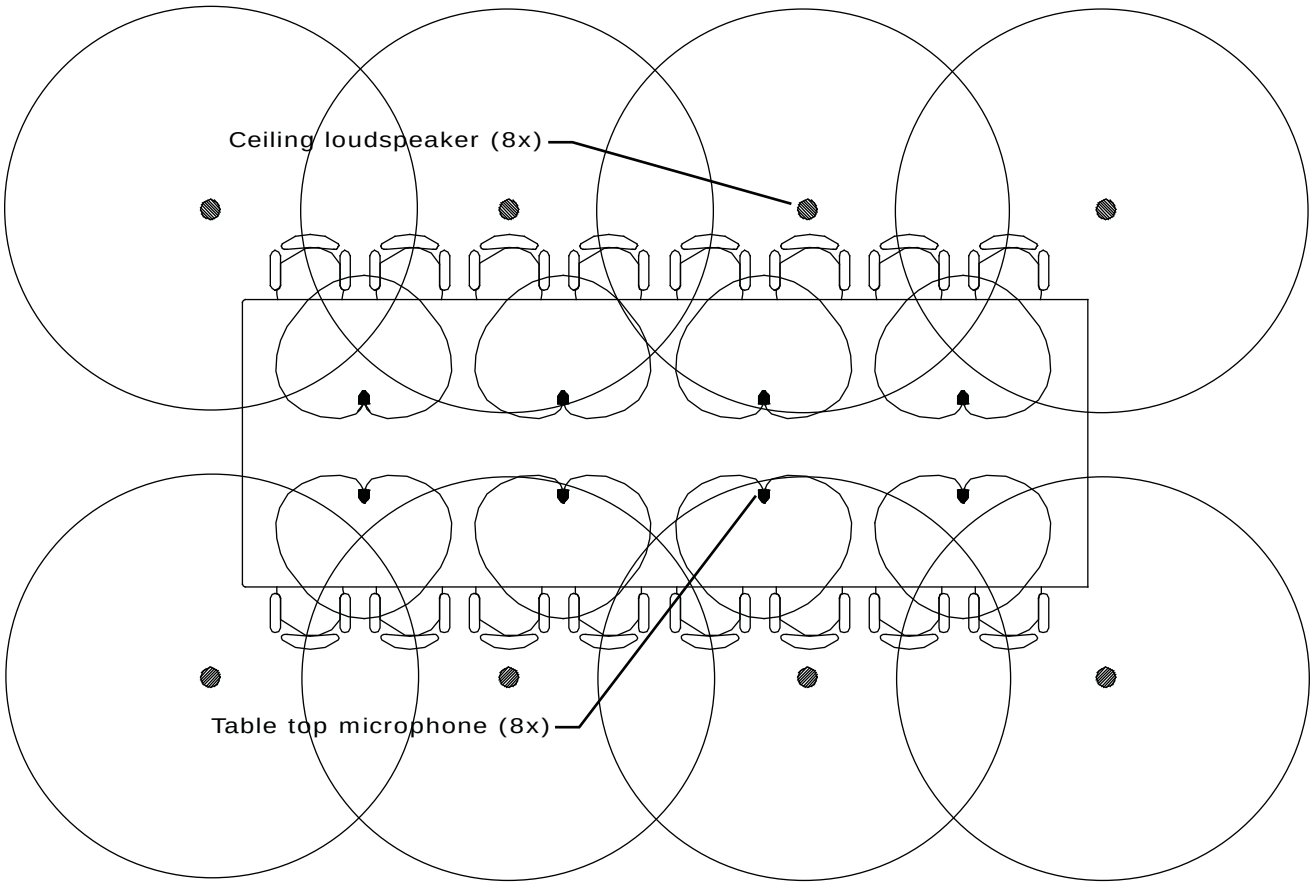
Figure 17.24
Conference room with loudspeaker and microphone placement



Loudspeakers, continued

Figure 17.25 shows the same room as in the previous figure with the directional microphone pickup patterns and a loudspeaker pattern overlaid.

Figure 17.25
Microphone pickup and loudspeaker coverage patterns



The microphones are at the periphery of the loudspeaker coverage pattern (to maximize the ERL of the room). While the area over the center of the table does not receive complete coverage, both the seated participants and any overflow seating for extra participants receive adequate audio coverage.

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Loudspeakers, continued

Loudspeakers Power

Once the locations of the loudspeakers have been determined, the next step is to determine how much power is required to drive each loudspeaker to achieve the required level at the listeners. Loudspeakers have a power rating that is expressed in dB SPL at 1 m (3.3 ft). This specifies how much sound is created at 1 m (3.3 ft) from the loudspeaker assuming 1 W of power is applied to the loudspeaker.

For example, a loudspeaker rated at 86 dB SPL 1 W/m requires 1 W to generate 86 dB SPL at a distance of 1 m from the loudspeaker. In a normal room, the loudspeakers are approximately 2 m (6.6 ft) above the participant seated directly underneath a loudspeaker, resulting in 80 dB SPL at the listener's location with 1 W of power. As normal speech conversations are in the 70 to 77 dB SPL range, this level of sound would be more than sufficient for playback for a listener located directly underneath a loudspeaker, assuming background noise in the room (e.g., an NC 30 style room) is not substantial. As mentioned previously, having a sound system at least 25 dB above the ambient background yields excellent intelligibility.

To compute the power requirements for each of the distributed loudspeakers, the desired SPL at the listeners' ears (e.g., 85 dB SPL) should be taken, additional SPL added to compensate for the distance from the loudspeakers (e.g., 6 dB for a doubling of distance), and the loudspeakers sensitivity (86 dB SPL) subtracted, as follows:

85 dB + 6 dB – 86 dB = 5 dBW

This is the power in decibels referenced to 1 W (dBW). The inverse log is used to convert this result back to watts. In this example:

5dBW = 10 log (needed watts / 1W)

0.5 = log (needed W / 1 W)

0.5 = log needed W

3.16 = needed W

The result is 3.16 W required for each loudspeaker.

Loudspeakers, continued

Once the power requirements for the loudspeakers have been calculated, they should be added up and used as the baseline for the size of the amplifier required to drive audio into the room. The designer should keep in mind transformer losses of approximately 1 dB for each loudspeaker and choose an amplifier at 25 to 50 percent larger than the sum of the required loudspeaker power. This will allow some headroom for additional loudspeakers or louder transient signals.

Spatial Directionality

In videoconferencing applications, the remote audio commonly comes from a location close to the display screen to give the perception that the remote audio is coming from the remote participants shown on the video screen. In this situation, when the room is larger than 6.1 m (20 ft) in length, reinforcement of the front loudspeakers with additional ceiling loudspeakers distributed through the room would fill the room with sound without losing the perceptual directionality associated with the front of room display device.

To maintain the perception of the audio coming from the front-of-room display device, the reinforcement of the ceiling loudspeakers can be delayed slightly (e.g., 1 ms for each foot of separation) from the front loudspeakers and can be attenuated by approximately 6 to 10 dB from the level sent to the front-of-room loudspeakers.

Microphone and Loudspeaker Placement Considerations

Once loudspeakers have been placed through the room to achieve good sound coverage and microphones have been placed through the room to provide good sound pickup, the placement of the microphones relative to the loudspeakers should be double-checked to ensure the ERL of the conferencing system has not been compromised in the process.

If loudspeakers are placed in the microphone's direct pickup pattern, the ERL will be reduced and residual echo will more likely be sent to the remote participants. The configuration software with the audioconferencing product usually provides a tool where the ERL can be checked to ensure it is within the recommended operating range for that particular audioconferencing device (typically 0 to 10 dB and above). If the recommended ERL is exceeded, the gain structure will have to be reviewed, ensuring the loudspeakers are not pointed directly into the pickup pattern of the microphones or lowering the gain on the microphones.

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In-Room Reinforcement

Sound reinforcement may be desirable if the listeners cannot easily hear the other talkers in the room. The objective of this type of sound reinforcement, sometimes referred to as mix-minus system, is to augment the local speaker's voice so that local listeners still have the perception the audio is originating from the local talker.

One of the keys to making a system of this type stable and work reliably is properly setting user expectations and perception. It is critical that the users do not expect audio levels similar to a paging system or PA system.

Paging and PA systems are designed to broadcast a single voice loudly, overcoming background noise, side conversations, and inattention to deliver important messages. The sound levels generated by these systems are louder than required by the participants to subtly reinforce the voices and maintain the perceptual directionality so the local listeners' attention remains focused on the talker and not on the loudspeaker.

Voice reinforcement or enhancement is supposed to be just that—reinforcing the level of the talker to improve intelligibility. In a properly configured and calibrated mix-minus system, the best way to find out if the system is functioning properly is to disable it and see if the local participants notice the resulting loss of intelligibility. If they do, then the system is set correctly.

The reinforced levels should never exceed conversational speech levels (i.e., 70 dBA SPL at the listener's ear) or the result may become unstable, creating residual echoes to the remote listeners due to low ERL or even generate very loud acoustic feedback in the room with the loudspeaker audio coupling into the local microphones.

A mix-minus system is typically required when the room is large enough that the local speakers' audio drops below 60 dBA SPL when heard by the farthest listener in the room. Based on normal speech conversation levels of 70 to 77 dBA SPL, this roughly corresponds to listening approximately 20 to 25 feet away from the talker. Another way to view this issue is as a critical distance issue. If the local listeners are farther away than the critical distance from the local talker, some form of mix-minus system may be required for adequate intelligibility.

In-Room Reinforcement, continued

For rooms smaller than 6 m (20 ft) by 6 m (20 ft), the voice-lift application is really not necessary and is just beginning to provide some benefit. Just as adding gain to a microphone to try to compensate for a critical distance issue does not work, adding sound reinforcement to compensate for a noisy room does not work well either. The microphones that pick up the noise will reinforce that noise into the room, adding to the noise rather than facilitating the hearing. The correct approach would be to remove the noise and make the room useful in all applications.

The designer must carefully plan microphone and loudspeaker locations so that the system stays acoustically stable while providing the necessary pickup of local talkers and reducing the effective acoustic distance of the listeners.

First, the designer should consider the number of zones or areas of independent loudspeaker playback. A zone is most often sized close to the largest room size that does not require reinforcement or about 37 m^2 (400 ft^2). For example, a 6 m (20 ft) by 12 m (40 ft) room would require two zones. Long and narrow boardrooms often require this type of voice reinforcement application.

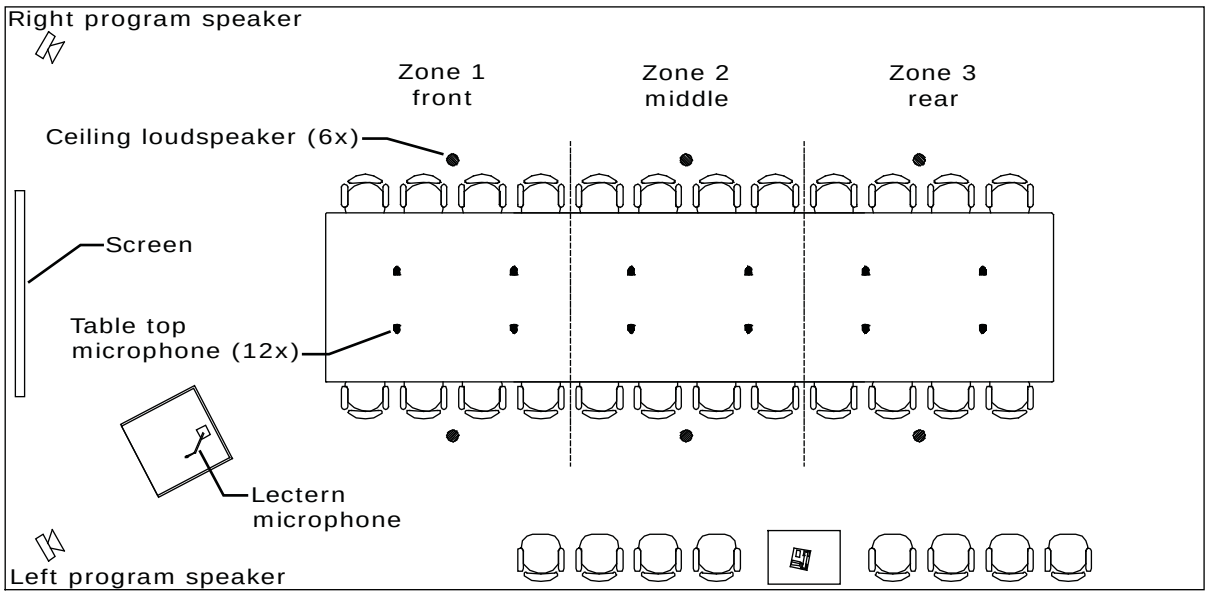
Once the zones are planned, the microphone locations are selected within the zones. The concept is to locate microphones and loudspeakers in such a way that each zone is completely independent in level and mix. This way, microphones from a given zone are never played into the loudspeakers associated with that same zone (mix/minus) and are sent at increased levels to zones further away. The inverse square law calculated results drive the required level settings in the reinforcement system—the zones twice as far typically have a 6 dB level or higher. To support zoning, a multichannel amplifier must be used so each loudspeaker zone can receive separate loudspeaker signals.

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In-Room Reinforcement, continued

Figure 17.26 shows a three-zone room that could reinforce the microphones in zone 1 into zone 3 and vice versa.

Figure 17.26
Three-zone room



Two general concepts are often used in mix-minus systems: NAG and PAG (see the related section describing these concepts previously in this chapter). These calculations can be performed using a few different online tools and quickly help to determine the sound levels that can be tolerated within a room. For the room to be acoustically stable and for safety reasons, the NAG must be less than the PAG.

In-Room Reinforcement, continued

Occasionally the PAG can be slightly improved with equalization, feedback eliminators and microphone/loudspeaker directionality improvements, but those are usually limited to less than 6 dB total improvement. Placing microphones as close as possible to the local talkers and minimizing the number of active microphones help to control NAG/PAG.

Ceiling-mounted microphones present particularly difficult sound reinforcement challenges due to their close proximity to loudspeakers (i.e., decreasing PAG) and their long distance from the local talkers (i.e., increasing NAG). The use of ceiling microphones and sound reinforcement must be carefully designed with conservative levels of reinforcement, large separation of zones, and limited volume control range to ensure that the resulting room is stable. In situations where ceiling microphones and loudspeakers must be used with the added requirement of in-room reinforcement, the design and installation should be carefully considered and executed..

In a room that has sound reinforcement with inappropriately high gain settings, side conversation can be heard by most if not all participants.

IMPORTANT: The key to success is setting the appropriate performance expectations with the end user and it is the responsibility of the conference room designer to set that expectation.

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Videoconferencing Systems

Videoconferencing systems present some unique challenges to room designers, including the:

- Need for controlled lighting different from standard office light.
- Integration of audioconferencing requirements into a video room.
- Cameras and displays' point of view.

The intent of this section is to give the reader usable information that would allow a successful system deployment.

Room Setup

Room Size and Location

A videoconference room should be larger than a similarly populated basic meeting room. The attendees have to be spaced apart so the far-end viewers can more easily see and differentiate those attendees.

The physical location of this type of conference room should be driven by the needs of the organization and some of the unique videoconferencing criteria. The videoconference room must be located and furnished in a way that allows uninterruptible presentations and conversations.

First, the designer should try to keep away from windows and exterior walls. Controlling the light entering the space is critical to the video quality rendered from the space. Exterior walls allow sirens, truck noises, and other distracting sounds into the space. Therefore, the designer should consider an interior room with ready access to the public spaces in the building.

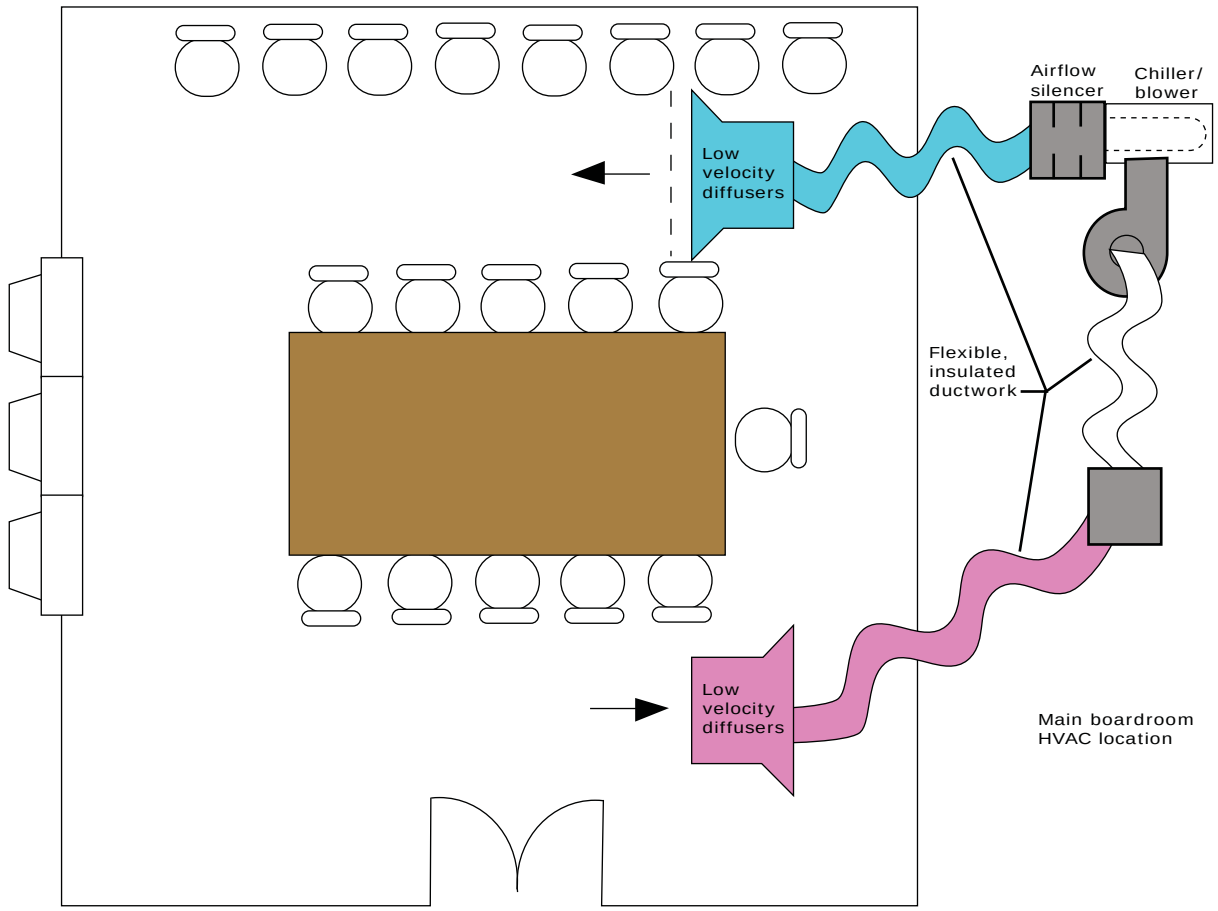
Heating, Ventilating, and Air Conditioning (HVAC)

In this type of conference space, the heat load surpasses the typical capabilities of HVAC systems. The designer should plan for the excess heat load, especially if the conference equipment is planned to remain constantly powered. An auxiliary local cooling circuit should be made available for night and weekend temperature control.

The designer should coordinate with the HVAC installer to create a remote system to the conference room (see Figure 17.27). Adding an excess length of flexible, insulated ducting to the standard airflow paths and arranging the excess ducting in series of S bends helps to reduce both the noise from the mechanical equipment going into the room and the voices from the room going into the plenum space.

Room Setup, continued

Figure 17.27
Remote heating, ventilating, and air conditioning for videoconference room



HVAC = Heating, ventilating, and air conditioning

When reviewing the power distribution in a future videoconference room, the designer should defer to local electrical codes for the following:

- The video can be sensitive to ground and phase differences. A scheme that takes the room power feeds from a common phase and ground point should be used.
- The videoconference room should be isolated from the devices that impose a harsh transient loading on the power.

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Room Setup, continued

Building and Infrastructure

Local building codes dictate the rules for wall construction. The room should be built with low NC as a goal. NC 30 guidelines are recommended for videoconference room needs. Wall construction techniques may include a double layer of gypsum board as the interior wall, with offset stud internals and deck-to-deck coverage.

As with any other infrastructure project, attention should be given to access points (APs), cable pulls, and conduit runs. A videoconference room has much more cabling and signal routing than a standard environment, so preplanning is recommended. Often, cables are pre-manufactured with over-molded ends attached. Some of these cables are not conducive to field termination, so oversized conduit runs may be required.

Furniture Layout

One of the objectives of videoconference room design is to make the space amenable to an interactive event and encourage a rapport with the remote connection while maintaining the sense of connection between the people in the local videoconference room.

Often, the primary consideration is given to the remote connection, ignoring the local interactions. This may lead to extremely specific, immersive rooms where a video display might be located at the edge of a conference table and special mirrors are used to enable eye contact. These system designs work well for their intended purpose, a face-to-face electronic meeting, but not with larger numbers of participants. Another downside is if the remote site does not use the same technology or video equipment orientation, the perspectives are distorted and the experience may be degraded.

Unless immersive design is specifically required, the designer should select a general-purpose environment. A trapezoidal table with the wide-end closest to the video display nearly always provides the most satisfactory solution. Variations include the horseshoe (or U), the oval-egg, and V designs.

The designer should try to avoid the traditional long, narrow, boardroom table in any video-enabled space. From the view at the far-end, the scene will always appear to be a difficult picture to watch, especially with the unavoidable obstruction of participants' faces. Camera operation also is compromised by this layout.

Camera-Friendly Finishes

Videoconference systems are specifically programmed devices. Standards-based communications work best with specific colors and finishes. For example, a medium gray with a blue tint is the best choice for the wall detected by the system. All of the other walls can be painted to meet an aesthetic objective. Finishes should be satin or flat.

Tabletops can cause reflections and color changes. A neutral color with satin or flat texture should be maintained for the conference table.

Displays

Types, Technologies, and Purposes

The display type must match the intended usage and room aesthetics. For example, large CRTs are not the preferred solution in smaller spaces. Many alternative display types are well suited for videoconferencing, including LCD, plasma, rear-projection displays and, as the least favorable choice, front projection displays.

Placement

Video displays require space. Cameras may be collocated with the far-end image displays. Lighting for video is somewhat directional.

Using the standard rules from the presentation field invariably leads to mounting the displays too high for videoconferencing interactions. Since the display location determines camera location, the errors can multiply. Cameras must be collocated with the far-end display to provide a sense of eye contact.

Aesthetic considerations (e.g., visual symmetry) need to be put aside for these systems to generate a real sense of connection. The AV designer should try to keep the lower visible edge of the far-end display visible to the farthest seated participant. This enhances the sense of remote connection, and eye contact becomes more natural.

Importance of Display Type

Front projection screens, although standard in presentation rooms, do not work well in interactive video rooms. They are almost completely at odds with the required light levels for high quality videoconferencing.

Captive technologies are considered the best choice for the conference video. They include direct-view CRT, LCD, plasma, and rear-projection implemented as a dedicated projection room or in a convenient box.

Display type determines sensitivity to effects such as burn-in (common in plasma and CRT displays) or light washout (retro-boxes).

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Displays, continued

The designer should ensure the displays support the input connection type required by the videoconference system. The system may use:

- High density (HD) 15 video graphics array (VGA) connection.
- Luminance/chrominance (Y/C) S-video.
- Composite video.
- Digital visual interface (DVI).

No vendors of videoconferencing equipment currently use HDMI or similar, but that may change with product cycles. Migration toward high definition (HD) technologies will probably drive this connectivity need.

Personal Computer (PC) Graphics

Display technology designed for personal computer (PC) graphics is often included with the higher-end conference-suitable displays. The typical PC graphics resolution is standard extended graphics array (XGA) or 1024 by 768.

Higher resolutions, such as super extended graphics array (SXGA) at 1280 by 1024 and wide extended graphics array (WXGA) at 1280 by 768, also may be used. The project key is to budget sufficient funds for a capable display system that will not become obsolete before it is fully depreciated.

Camera Technology

Camera Specifications and Terminology

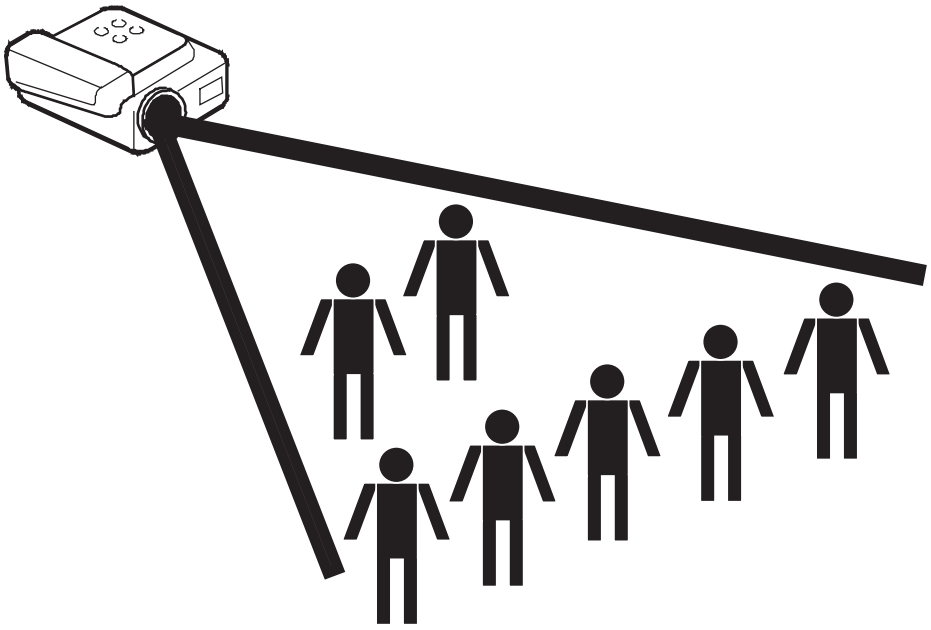
Cameras used for videoconferencing are derivatives of consumer video camcorder cameras. The reasons for this were the reduced costs of manufacturing and the highly competitive variety of camera technologies. Today, most of the available cameras have similar features with the major differences being mounting type, controls, and overall style.

For the most part, camera specifications have little relevance in the videoconference environment. However, the designer should be concerned with the specifications that can make a difference in the perceived quality of a typical conference.

The field of view (FOV) of the lens is an important measurement because it helps to determine how much of the room is visible (see Figure 17.28). This is usually specified as an angle at widest zoom setting. Anything valued higher than 65 degrees FOV is subject to significant optical distortions (e.g., curvature at the image edges eventually extending throughout the image as the FOV gets bigger). The ratio of optical zoom (e.g., 8:1, 10:1, or 17:1), combined with the FOV number will give the usable range of the camera views.

Camera Technology, continued

Figure 17.28
Field of view



The speed of the lens (f) gives an idea of how the camera will respond under normal lighting conditions. It is a measure of the ultimate light-gathering capability of the lens, combined with the optical efficiencies of the selected lenses and coatings. The depth of field is directly related to the speed of the lens combined with the light sensitivity of the imager. All this relates to core lens technology, where the iris or light-level regulator gets smaller as the light level increases. This makes the camera act more like a pin-hole camera, with the image always in focus and the depth of field essentially infinite.

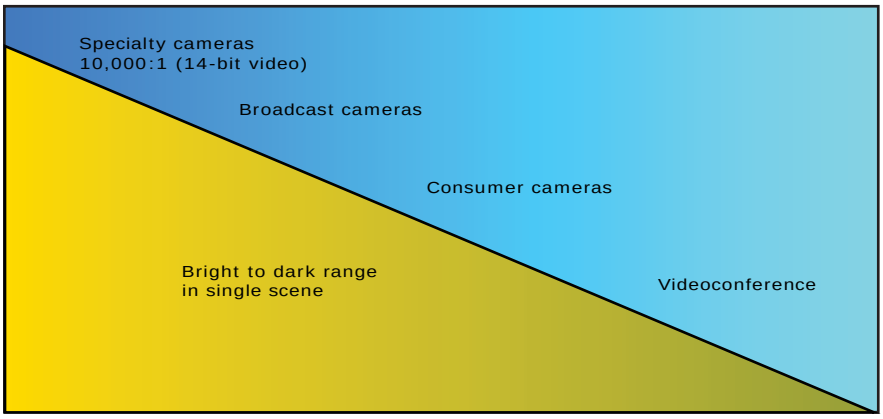
Cameras do not have an unlimited ability to accept light, especially over a single scene. This is regulated by a combination of the electronics resident in the camera, the lens, and the imager. Most cameras used in videoconferencing systems are digital and use 10-bit processing. A 10-bit system has a bright-to-dark range of 1024:1 for all numerical values. A 10-bit system would limit the potential performance of the camera to resolve about a 1000:1 difference from brightest to darkest elements in a given image.

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Camera Technology, continued

Figure 17.29 shows types of cameras by bright-to-dark range.

Figure 17.29
Camera bright-to-dark ranges



Pan-Tilt-Zoom (PTZ) Assemblies

A typical fixed camera position may be substituted in some cases by a pan-tilt enabled camera. The generic term for such things is a pan-tilt-zoom (PTZ) assembly.

Many videoconference system manufacturers include one of many PTZ camera types. The differences between the cameras are usually not obvious. PTZ cameras vary in the speed and smoothness of the pan and tilt. Mechanical noise, physical size, electrical connections, and mounting locations are other factors to consider.

Auto-Pointing Technology

A special type of PTZ assembly includes auto-pointing or follower capability.

The follower systems have relied upon IR technology to allow a sensor array in the PTZ to find and follow an IR beacon worn by a person; however, such a system is really limited to one user at a time and then the beacon is transferred to the next person.

An advanced design of the follower system auto points and zooms based on the sound location. This type of design cannot follow a voice but points the camera to the current talker. As such, this type of auto-pointing camera can relieve the system operator of the burden of re-aiming the camera whenever a new talker is engaged.

Camera Technology, continued

Camera/Video over Category 5 Cable

Video can be moved around a conference room in a number of ways, and the current popular method involves category 5 cabling and video drivers designed for such purpose. If this type of distribution is considered, the AV designer should select a vendor that specifies camera support in category 5 designs.

Harmonizing the paths for control, video, and IR return is time consuming. Selecting an optimized solution may be the best choice even if it is more expensive. Such a solution may include one to two category 5 cables, remote powering, mounting brackets, adapters, and appropriate camera support.

Lighting

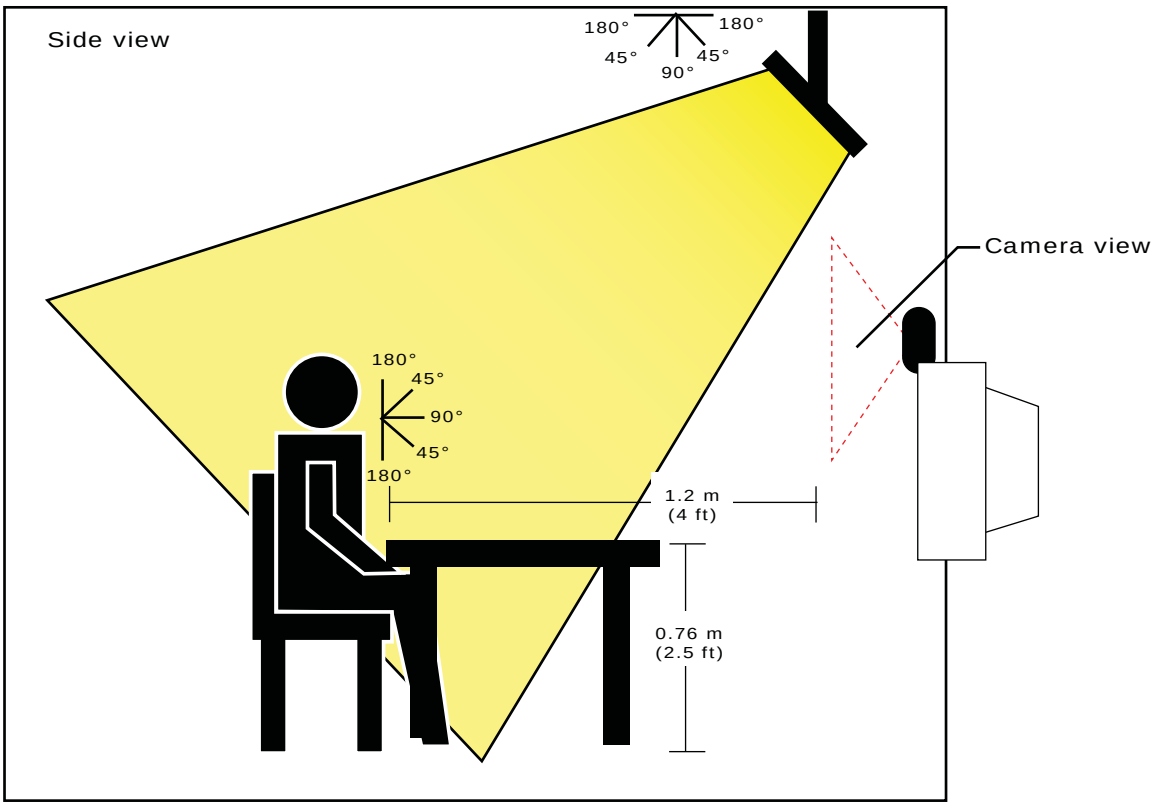
To work within the limitations of current camera technology, the designer should understand that light levels translate into depth-of-field or the distance range of the scene that appears simultaneously in focus. More light equals greater depth of field. Greater depth-of-field equals sharply defined objects or persons within that view, which gives an impression of a higher video quality.

The typical camera used for videoconferencing operates extremely well at 753 lux (70 fc) measured at the subject. Figure 17.30 shows a typical videoconference light setup.

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Lighting, continued

Figure 17.30
Videoconference light setup



ft = Foot
m = Meter

Lighting, continued

Cameras do not tolerate:

- Glare—Reflections off shiny table-tops, highly polished millwork, corrective eyewear, or glossy hair products compromise video quality. The lighting should be well controlled and perhaps indirect to avoid the possibilities of glare. Also, shadows cast as a result of too much direct down-light can make a meeting participant appear tired or inattentive.
- Wide differences in light level—The typical camera has a dynamic range of about 1000:1 from brightest to darkest in a given scene. The usual dynamic range of a videoconference system is around 200:1. Therefore, lighting is very important. Dimmable systems do not benefit a videoconference room, unless the dimming function is locked-out during a video event.
- Lighting color variations—All of the lighting elements should maintain the same color-temperature. Lamps must be replaced at the same time in a given room to keep the same color control. Different types of lamps (e.g., fluorescent and incandescent) should not be mixed. Also, the mix of outdoor and indoor light can lead to the unpleasant side effect of having one side of a person's face appear blue from sunlight and the other side red from incandescent light. Drapes and blinds can be used to prevent this problem. Vertical blinds look better on camera than do horizontal blinds. The vertical lines give the camera an object to focus on, while the horizontal blinds interfere with the camera's scanning nature.

A camera's view is two-dimensional. Therefore, the designer must specify a type of lighting that would create a sense of separation between the background (e.g., walls) and the foreground (e.g., people). A level of wash on the viewed wall can enhance the scene rendered to the far-end.

Codecs

A codec is a small but critical piece in a videoconferencing system.

A codec:

- Takes the analog audio and video signals and converts them into digits.
- Processes the derived digits to reduce the amount of data.
- Allows the transmission of the data to a different location over a network.
- Decompresses the data.
- Assigns the data to the audio or video decoder, which turns it back into analog signals for listening and viewing.

Interoperability standards define the playback or decoder side of processing while manufacturers work to enhance the compression or coding side of processing for an improved perceived signal quality.

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Codecs, continued

The performance of a videoconferencing system is most often governed by the processing capability of the equipment. At any given data rate, the system's ability to effectively compress the video is determined by the speed of arithmetic processing. If a system has the capability of performing several hundred million arithmetic operations per second, the video quality will be good. If, however, the system is capable of several billion arithmetic operations per second, the resultant video quality can be extremely good to near-broadcast quality due to the equivalent algorithms.

For the highest quality at low (128 to 384 kilobit [Kb]) data rates, the designer should select a codec with the capability to perform several billion operations per second. The decoder side of the processing is relatively easy; therefore, the source of the video determines the perceived viewing quality.

Audio/video synchronization is related to this capability. When the processing is insufficient to hold up the frame rate, the perception is that the audio is out of sync. This does not really happen because of a constant delay associated with audio and video. The dropping of video frames video appear as if it is not moving along with the audio. However, as soon as the motion decreases, the synchronization appears correct again. This lack of sync is reduced using lower bit-rate audio algorithms such as G.728 (16 Kb channel rate), which allows more of the network bandwidth to be used by the video processing.

The coder can be tested by directing the camera controls to zoom in on a complex image and then zoom out. The processing is assessed through this fast moving of the image pixels in opposite directions at the same time. If the image degrades or freezes, the coder's processing capabilities are limited.

Application features pose a level of challenge in codec selection. The designer should consider:

- Microphone inputs.
- Auxiliary camera capability.
- Computer graphics capability.
- Number and type of displays supported.
- Ease of control.
- Communication network interfaces.
- Upgradeability and expandability.

Features can be easily confused with performance and, consequently, a mistaken assumption can be made that if the feature set matches, then the performance must match. This is far from the typical case. Personal use computer-based conference systems that include identical features to the higher-cost group-use systems are available, yet their performance is significantly lower than that of the group-use systems.

Integration with Room Audio Systems

Videoconference system manufacturers provide microphones that are often adequate and should be used. Rooms that can use a videoconference system manufacturer's microphones are rooms that:

- Do not require additional sound reinforcement.
- Have a good balance between telephone call audio and video call audio.
- Are not used as audio-conferencing only rooms.
- Are considered value engineered.

Quality will be adequate under appropriate environmental circumstances, but as the demand for quality increases or the room characteristics become more challenging, videoconferencing integration with an installed audio system is considered.

The conference room designer should ensure the user expectations are at level with reality. The designer also should maintain the best possible practices in the deployment of the technologies to exceed those expectations.

All typically deployed conference room audio is a compromise. If all participants could wear personal microphones and use in-ear monitors, the audio could be nearly perfect; however, this scenario is highly unlikely.

Working within the budgets and aesthetic constraints involves compromise, but the designer should try to avoid over promising the system performance based on manufacturer's demo or specifications sheets.

Communications Network Interface

The primary means of network access for videoconferencing is integrated services digital network (ISDN). Two basic ISDN variations for videoconferencing are:

- Basic rate interface (BRI).
- Primary rate interface (PRI).

BRI consists of two user channels of 64 Kb each delivered over a single copper pair similar to a regular telephone line and was originally intended to supplant plain old telephone service (POTS).

PRI contains either 24 or 32 channels of 64-Kb service and is delivered over two pairs of copper wire.

The interfaces are different, often optional, and incompatible. Connections require the correct interface or they will not work.

Multiple channels of BRI are often collected together and operate as a single higher speed connection in a process called inverse multiplexing. Typically, up to four BRI circuits are linked together to provide 512 Kb/s connectivity.

Some limited deployments of other types of circuit switched digital networks are still available, such as Switched 56 (Kb/s) and some proprietary private branch exchange (PBX) based access, but they require specialized equipment.

Communications Network Interface, continued

The circuit-switched networks also may include somewhat specialized serial interfaces, such as:

- International Telecommunication Union-Telecommunication Standardization Sector (ITU-T) standard V.35.
- Electronic Industry Alliance (EIA) standard RS-449 or RS-530.

These interfaces use a dialer technology called RS-366 dialing to place calls. It is a rudimentary type of data interface that presents one digit at a time to the network then waits for acknowledgement before proceeding. It can be slow but extremely reliable. These types of interfaces are usually used for government installations where special data encryptors are used to secure the transmission path from unauthorized listeners.

Although primarily used by government agencies for their special needs, these interface types also can be used for connection to satellite, microwave, and other radio links, as well as to legacy network termination equipment. They might be considered universal interfaces.

The current trend is to migrate toward IP communications, often in a mistaken belief that communication costs would be reduced to near zero and that all connectivity issues would disappear.

Almost every videoconferencing system comes from the factory with an IP interface built in as a basic configuration. However, substantial challenges arise from maintaining and servicing firewall technologies, quality of service (QoS), and indirect addressing. In addition, such configurations may require separate network servers because of the currently limited integration and interaction between information technology (IT) and videoconferencing technologies.

Almost all the installation difficulties are network communications related whether basic connectivity or call routing.

Control Systems

In environments where the videoconference system is a pre-packaged device or where a minimum of peripheral tools is required, the manufacturer's remote controllers may be useful. Manufacturers hire teams of human-factor specialists to ensure that their remote control devices are intuitive and simple to use.

If, however, a variety of devices require remote controllers, managing more than two remotes may not be practical.

With more complex conference rooms, the designer should consider a control system that simplifies the users' efforts. When specifying the control page designs, the designer should focus on casual users because they benefit most from the simplicity.

Control Systems, continued

Control Tools

Several manufacturer-specific management tools are available at different price points and capabilities. The purpose of these tools is primarily to facilitate the maintenance and configuration of the deployed systems without a physical contact by administration personnel. Control tools allow tasks such as remote conference system logins, local address book updates, latest firmware downloads, and the power-up configuration resets. With six or more conference endpoints or any number of endpoints in different geographical locations, companies make savings through remote management tools. This is especially true if all the systems are connected using an IP network.

When considering these tools, the designer should ensure that the manufacturer's statement about a product's functions and interoperability with other manufacturers' products is true before placing a purchase order (PO).

International Telecommunication Union-Telecommunication Standardization Sector (ITU-T) Standards and Rules

One of the most important requirements of business videoconferencing is that a given system can interoperate with any vendor's videoconference system. That has been accomplished through international standards. Technical proposals are submitted through ITU-T by various interested parties, a study group (SG) is formed, the proposal is reviewed and often modified, and, if found appropriate, ratified as a standard.

Videoconferencing falls under several network specific standards, including:

- H.320, covering ISDN or generic circuit-switched communications.
- H.321, covering asynchronous transfer mode (ATM) networks
- H.323, covering IP networks
- H.324, covering regular telephone modem networks

All of these umbrella standards encompass a variety of other, lower-level, standards that mandate the techniques of call setup, communication layer assignments, video compression, and audio compression.

The standards that concern the business application the most are H.320 and H.323. The most important sections of these standards cover the audio and video compression technologies.

In video, the current standard is the H.264 family of compression algorithms pre-defined specifically for the playback side. Older systems and systems claiming full compatibility also must be compliant with H.261 and, optionally, H.263, H.263+, and H.263++.

International Telecommunication Union-Telecommunication Standardization Sector (ITU-T) Standards and Rules, continued

The H.264 standard was based on Moving Picture Experts Group (MPEG) 4, but the conferencing working group (WG) branched away from the core working group and added features and functionality optimized for interactive systems. Sometimes H.264 is referred to as MPEG 4 part 10. No audio codec is associated with this subset of MPEG 4, although advanced audio codec (AAC) is often used. The biggest noticeable difference between H.264 and other video codecs is the improvement in real video quality.

All of the available video compression algorithms entail signal loss but can maintain effective compression ratios of up to 500:1 and more.

The audio side is a little more complex. The variety of available algorithms ranges from G.711, which is compatible with basic digital telephony dating from 1962, to G.722.1 annex C and beyond. Some of the audio compression schemes are well suited to both voice and music (G.722) while some are designed for voice only (G.723).

The audio compression is lossy but the acceptable compression ratios are 25:1 at the most. Best compression systems allow audio of near CD quality. More important is the quality of the audio data recovery as the data passes through standard telephony channels. Many available non-ITU compression systems (e.g., AAC, MPEG layer 3 audio [MP3], Windows® media audio [WMA], and similar) are designed for a robust data channel (e.g., hard-drive or local memory) and fail when that data-stream is corrupted. This often leads to severe popping, odd noises, and other types of sonic debris. Almost all the ITU approved audio compression systems treat data loss in some way so the noise does not become a part of a typical videoconference experience.

The H.320 and H.323 standards compliance requires the H.261 video codec and the G.711 audio. Optional are the H.263, H.263+, H.263++, and H.264 video codecs. On the audio side, G.711 is required with G.721, G.722, G.722.1, G.722.1-annex-C, G.723, G.728, and G.729 as optional. AAC and low-delay AAC (AAC-LD) are not part of the ITU recommendations but of the MPEG4 standard.

In the end, the designer should ensure the videoconference systems adhere to the ITU standards, and that the required features are covered by those standards. The key term is standards compliant and not standards-based as they relate to equipment selection.

Industry Trends

High Definition Television (HDTV)

To make best use of the typical conference room layout, a wider aspect ratio may seem like a sensible option. However, current interoperability standards do not fully define a 16:9 image end-to-end. Also, many studies have shown that some of the HDTV formats have more resolution than one's eyes can absorb

HDTV consists of several different scan rates and line counts, all of which are considered standards and none of which are cross-compatible. Fortunately, most of the vendors of conferencing technology who have made proclamations of HDTV support have chosen a common format. That format is 720 horizontal scan lines displayed progressively (720p) with a 16:9 aspect image.

A subset of the H.264 video compression algorithm allows HDTV compression but the interoperability has to be managed by various manufacturers. Backward compatibility is the key issue. Some vendors offer HDTV capable videoconference equipment with limited or no backward compatibility, which makes interoperability with other systems problematic.

New Technologies

As of the publication date of this manual, an ITU SG is forming to determine the next generations of software compression technologies.

Currently listed as H.265, the SG results are slated for publication and ratification sometime in the 2008 to 2010 time frame. In the meantime, annexes will be added to the current H.264 to ensure it does not fall behind in compatibility and functionality as the market demands become apparent.

IMPORTANT: The designer should be wary of manufacturers claiming that their products are H.265 ready because the algorithm functions are yet to be determined.

Codecs

Digital signal processing (DSP) power continues to increase. Programmers continue to improve audio and video data compression techniques so that new generation HDTV codecs and hardware platforms can offer big improvements in connectivity, control, and performance.

Technologies that enable person-to-person (P2P) communications but are not practical with larger groups include:

- PC communication packages.
- Embedded technologies from operating system (OS) manufacturers.
- Low-cost Web cam technologies.

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Industry Trends, continued

The technique for including many different sites into the same call event is multipoint bridging or multipoint control unit (MCU) technology. The current costs of an MCU far exceed the combined costs of the included endpoints. Such communications applications require a host server to enable the links, which generates an additional infrastructure cost. Furthermore, many of the applications cannot operate in an open network.

Telecommunication Connectivity

Service Providers (SPs)

The majority of business video communications is still carried out using ISDN as the connecting network type. ISDN BRI is the dominant connection.

In North America, a BRI connection requires additional equipment that is not considered part of the telephone company's responsibility must be provided by the user. A device must be installed to terminate the telecommunications company network and translate from the single copper pair to the standard ISDN BRI interface (i.e., S/T interface) of separate transmission and reception pairs. This device is known generically as a network termination type 1 (NT-1).

An NT-1 is required for each BRI drop. In most countries, an ISDN BRI is delivered by the telecommunications company as an S/T interface on 2 copper pairs.

A BRI has two user data bearer (B) channels each at 64 Kb/s and one delta (D) signaling channel at 16 Kb/s.

Making the codec compatible with the ISDN circuit requires several pieces of information, including:

- Service profile identification (SPID).
- Switch type.
- Directory number (i.e., ISDN telephone number).

This data will make the conference system identifiable to the ISDN network and enable call traffic.

The ISDN with higher capacity is the PRI, delivered on T-1 facilities in North America and E-1 facilities in the rest of the world.

The T-1 version delivers 23 B channels and 1 D channel running at 64 Kb/s, while the E-1 has 30 B channels and 2 D channels (one for the user and one for the telecommunications company) 64 Kb/s. E-1 and T-1 both use two copper pairs as the physical layer, one pair for the transmission side and one pair for the reception side.

Telecommunication Connectivity, continued

Often a termination device called a channel service unit (CSU) is required. CSUs terminate and condition the network drop and provide some test capabilities back to the telecommunications company. On the videoconference side, a data service unit (DSU) is used. CSU and DSU are most often part of the same box, referred to as a CSU/DSU.

Ordering a PRI is different because it almost always comes through the commercial side of the telecommunications company but without the option packages available on the BRI. The designer should check with the specific video equipment manufacturer for the PRI requirements, often referred to as provisioning, because they differ by manufacturer and application.

Higher bandwidths are available with different delivery systems. Optical fiber, coaxial, and satellite cable can be used for increments of T-1/E-1 connectivity up to the T-3/E-3 level (45 or 60 Mb/s). Telecommunications company-provided synchronous optical network technology (SONET) usually starts at the optical carrier (OC) 3 level (155 Mb/s) and is available up to OC-192, which is large and can be expensive.

One of the top considerations when purchasing networks from alternative carriers at data rates above normal circuit-switched service levels is the ability to get off the network easily.

Bandwidth

In considering the bandwidth required for videoconferencing, the designer can try to determine the total network loads.

For circuit-switched systems, the required data rate is divided by 64 Kb/s to obtain the required number of B channels. North American PRI uses 23 B channels, while other countries' PRIs have 30.

Telecommunications companies always plan for oversubscription of their provided networks. This practice originates from basic telephony, where the simultaneous call capacity of the central office (CO) is significantly lower than the total number of attached subscribers. The typical rule of thumb is to allow access to 20 percent of the subscribers at the same time.

Unless the PRI is specified as 100 percent utilization, the telecommunications company may provision the CO to only allow 5 channels of access in the United States or up to 6 channels of access in Europe without considering the PRI's intended usage. The designer should specify the need for all channels to be available for 100 percent utilization.

For IP systems, the required data rate is the required call rate plus approximately 20 percent overhead for H.323 (and then doubling if the system is on a simplex network). Hence, a 384 Kb/s call would be 461 Kb/s (i.e., 384 + 77) on a full duplex network. If the network is an older style simplex type, where only one side can transmit at a given time (e.g., wireless fidelity [WiFi]), the rate is doubled to 922 Kb/s for the preceding example.

Telecommunication Connectivity, continued

Network Loading Rules

In calculating the network loading allowed in an IP environment, the designer normally uses the 70 percent rule. The realistic network capacity is only about 70 percent of the advertised capacity. This allows statistical errors to occur and accounts for data collisions, data loss, and retransmitted data packets.

Videoconferencing is similar to streaming technology. To prevent the degradation of other users' experience on the network, a 30 percent loading should not be exceeded. On a 100 Mb/s network, for example, the conferencing traffic should not exceed 21 Mb/s (30 percent of 70 Mb/s). If the company is running a voice over Internet protocol (VoIP) application, which also is considered a type of streaming traffic, it must be included in the calculations.

Internet Connectivity

Many companies opt for a T-1/E-1 access to the Internet through an Internet service provider (ISP). This option constitutes a shared resource of a maximum capacity of 1.544 Mb/s in the United States through which Web browsing, e-mail, online auctions, and videoconferencing traffic must flow. Since the upper limit for network loading is 30 percent for video, the best practices capacity of T-1 would be 463 Kb/s or one video call.

If Web browsers and e-mail traffic are not considered important, the T-1 network can be used for videoconferencing with a 3-call limit at a call-rate of 384 Kb/s plus overhead, which would leave no headroom for any other service type.

Protocols

Types of Protocols

All IP networks that use communications have a host protocol. Some protocol versions are optimized specifically for a telecommunications application and include:

- Session initiation protocol (SIP) and live communications server (LCS).
- Simple customer control protocol (SCCP) and call manager.
- H.323 and a software-based PBX and communications control server.

SIP is a new and open protocol that places the requirement for intelligence into the endpoints. The network's task is to recognize the protocol and allow it to pass cleanly. SIP was designed by the Internet Engineering Task Force (IETF) for universal connectivity with expansion and enhancements in mind. All connections are initiated in a way that makes them firewall friendly and opens up near limitless possibilities for call controls. SIP also enables vendor-free telecommunications networks' gaining user freedom of choice.

Protocols, continued

SCCP is a Cisco proprietary communications protocol but also one of the most widespread throughout the world. SCCP requires strict networking device compatibility. All of the endpoints and edge devices must intercommunicate with the core processing elements, which then allocate bandwidth and determine call routing paths.

Operating a universal device on an SCCP network may be challenging due to the complexity of the SCCP interactions. Typically the network would need to be segmented running a universal, H.323 or similar, subnet and an SCCP-enabled primary net. Deploying specific technologies in such an environment may be difficult but is feasible with the proprietary technical support. H.323 networks do exist and are relatively universal but mostly cannot offer useful features like call waiting and call forwarding. The network load imposed by the H.323 applications is significant.

Internet Protocol (IP) Communications Systems

Locally, the IP network is laid out in a series of sections. Each of these sections may be serviced by a router or switch that links back to a server that can be the administrative management point for the entire network. Traffic over these sections is often full bandwidth and full duplex.

Computers can operate with a configuration and addressing scheme known as dynamic host configuration protocol (DHCP). This allows unique addresses and setups to be automatically installed on the computer as required. Since the computer most often initiates all of the required communications and the fact that the remaining network devices do not recognize its address does not pose a problem.

However, a videoconference system using a VoIP telephone would not be able to receive calls without a technique called network address translation (NAT). This technique allows the external sources to see a specific address on a company's network while hiding other addresses.

Quality of Service (QoS)

QoS is an informational header that can be applied to IP data traffic to assign a measure of priority and precedence to that data. If the network is configured to regard the QoS headers, videoconference and VoIP data can be assigned higher priority than e-mail or print jobs, enhancing the communications path for a better user experience. Unfortunately, the public Internet does not support QoS. Once any IP communication traversing the public Internet reaches the destination IP network, it is relegated to a print job for priority.

Data loss and corruption are two other difficulties that arise in the IP world and most manufacturers embed a measure of resilience to these effects. Elastic data buffers and data error concealment routines are typical techniques used to reduce the artifacts of IP network transmission.

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Protocols, continued

Simple Network Management Protocol (SNMP)

Simple network management protocol (SNMP) allows remote hierarchical views into the abyss of the network and its connected devices so that troubleshooting, error logging, maintenance, and configurations can all be managed remotely. This is a standard tool for the IT professional, and its availability is expected for any and all devices attached to the local IP network. When one is choosing equipment and technology to deploy on an IP network, take into consideration the needs of that support person, and ensure the tools required for the remote management and administration of that equipment are available. If not SNMP, then something similar to allow the access required.

Multipoint Control Unit (MCU)

In a typical call scenario, two sites may be discussing an idea and needing an additional input from a third party. The call cannot progress until they receive the pertinent information from the third party. The solution could be to send an instant message (IM), make a telephone call, send a fax, or bridge in the third party.

A bridge is a device that allows multiple parties to participate in the same call, with all of the parties enabled to see and hear the site talking. The industry name for this technology is multipoint control unit (MCU). It has embedded technology that allows many sites to hear each other in a common call and optionally contains technology that may allow:

- All of the sites to see each other at the same time or separately.
- The connection of mixed calls (i.e., voice only and video in the same call).
- The connection of different capability calls (e.g., ISDN with H.261 video at 384 Kb/s with IP H.264 at 768 Kb/s and a desktop system with quarter H.263+ at 256 Kb/s with a caller on a cellular telephone).

This last combination uses a technology called full transcoding that does not depend on the call type, video algorithm, audio algorithm, data rate, or network type.

Some MCU devices are very limited in their real capabilities and can only manage to connect calls of exactly the same type and transport, which is typical of the built-in MCU available in a videoconference system.

The more advanced MCU devices have a nearly unlimited capacity capable of hosting several hundred to thousands of calls simultaneously and are able to be collocated without difficulty at a telecommunications company's CO. However, the network load from an MCU can be substantial depending on its physical location and intended use, so the AV designer should carefully plan an MCU deployment.

Protocols, continued

Conferencing Integration with Voice over Internet Protocol (VoIP) Call Managers

VoIP is quickly becoming the telephony migration of choice. As this technology is deployed, the technical support providers are finding difficulties with firewalls and outside network access. These issues can be resolved using the border controller and firewall gateway technologies.

Sometimes a network engineer finds a flaw in the fundamental layout of an IP network that becomes apparent only when burdened by the constant data delivery requirements of VoIP. For a VoIP system to duplicate the capabilities of a traditional PBX, a level of intelligent control must be present on the network. This feature is referred to as call manager or communications manager.

Many call manager systems are proprietary and require a compatible desk set along with the core application protocol. This means that the videoconference system intended for such a network may require an isolated network segment that uses a different protocol and has reduced features compared to the desk telephones.

Another issue might arise if the videoconference system requires a POTS line for any voice conferencing. In this case, the project may require an analog telephone adapter (ATA). This device resides on the VoIP network and provides a measure of POTS connectivity. Unfortunately, the ATA design was intended for devices like fax machines, so the voice quality may not meet the customer's expectations.

Communications Infrastructure

Structured Wiring and Telecommunications Inside Plant

In ISDN deployments, using the preinstalled structured wiring may cause problems. Telecommunications company applications are backward compatible with antiquated wiring practices.

Category 5 wiring has the impedance of 110 ohms. Telecommunications company circuits typically have 600 ohm impedance. The difference can lead to reduced distance limits, data errors, and loss of service on ISDN installations. If any of these problems arise, they can sometimes be solved by terminating the network wiring with a 110 ohm resistor at the punch block nearest to the NT-1 or the conference system, whichever is the end of the run.

Communications Infrastructure, continued

Private Branch Exchange (PBX) Applications and Central Exchange (Centrex) Services

Providing the communications through a PBX is sometimes difficult for the videoconference system because the ISDN presentations do not necessarily match that of a CO. Subtle problems with the communications may result. The designer should collect all of the application information for technical support, including:

- PBX type and revision.
- Software revision.
- Telecommunications card type and revision.
- ISDN provisioning details.

Many times, when a PBX is specified for a company installation, the designers underspecify the system power supplies. This is often done as a cost savings, but it means that any analog telephone circuits may be operated with a low loop current. The low current tricks the connected telephone device into registering that it is located kilometers (miles) from the telephone switch and applying extra processing and gain to compensate for the nonexistent distance. The result can be signal overload, excessive gain, and, sometimes, random call disconnect. If the basic telephone interface shows signs of problems, the first place to test is the analog line loop current.

Sometimes, telecommunications companies provide PBX functions but host them at the CO. This is often referred to as central exchange (centrex) service or hosted PBX. The users are exposed to telephone functions similar to those of a PBX, including:

- 4-digit internal dialing.
- Call transfer.
- Call waiting.
- Voicemail.
- Dial 9 for outside.

The only real consideration for videoconferencing is the probability of adding a 9 or some other prefix to access the outside line. In some parts of the world, all ISDN BRI services are centrex in nature, so the telecommunications company partitions their CO switches to enable an easier management of the ISDN environment.

Communications Infrastructure, continued

Network Components

Hubs, routers, bridges, gateways, and servers are components of the basic IP network. Transition devices, referred to as edge devices, connect to the public Internet or to a private IP wide area network (WAN). Other devices and applications relevant to videoconferencing are firewalls, border controllers, gateways, and gatekeepers.

Firewall

Firewall is a relatively simple application that prevents unrequired communications from slipping through the company connection into the public Internet or other IP networks. Firewall also may limit the use of videoconferencing technology by blocking the incoming communications.

Firewall normally has a single open AP, often designated port 80, available to hypertext transfer protocol (HTTP) or Web browser traffic. Other ports may be opened from the inside to allow transfer of information as replies come back through the same port that initiated the request. The ports are closed as soon as the request terminates, preventing unwanted data traffic. H.323 mandates ports for specific aspects of conferencing (e.g., 1720 is for call setup). However, not all firewalls recognize H.323, so the request will not be honored.

Border Controller

A border controller can reduce the interruption factors of firewall application by allowing an easy traversal of the designated communication traffic through the firewall blockade. Typically, these devices operate by working in cooperation with the existing, and creating their own additional, firewall, while allowing the opening and closing of access ports based on the need of the terminal devices. ITU recommendations that govern these operations are H.460 and H.461. IETF recommendations for firewall compatibility also should be consulted.

Gateway

A gateway for videoconferencing has a significantly different purpose than one intended for IP networks, although the function is similar. Gateways typically link one network topology to a different topology.

In an SCCP network, a network gateway would be required to interconnect an H.323 segment with the rest of the SCCP network. In videoconferencing terms, a gateway is a network transition device that allows:

- Outside access to an IP conference system from an ISDN network.
- ISDN dialing access from the IP conference system.
- Crossing the firewall as a firewall gateway.

Built-in gateway devices in certain types of videoconference systems allow call-by-call IP or ISDN choices or both on the same call. Different levels of standalone gateways can manage from 3 BRI to dozens of PRI connections.

Communications Infrastructure, continued

The majority of videoconference connectivity is through ISDN. New deployments of video technology are often designed around IP. If gateway is left out of the design, a gateway service can be ordered from a network provider or, on a call-by-call basis from a bridging service provider (SP).

Gatekeeper

To make the dialing easy for the users, a software application called a gatekeeper is required. This application may be:

- Incorporated into a soft PBX package.
- Part of a network management system.
- A server-based program.

A gatekeeper acts as a traffic director on the IP network. It can manage bandwidth allocations, limit overall conference traffic on the network, and provide alias dialing (i.e., access to an endpoint through an e-mail address or some other substitute for the actual IP address).

Sometimes, the gatekeeper can manage NAT difficulties. Advanced versions include provisions for dialing plan definitions such as least-cost call routing plans, E.164 (i.e., extension) dialing, and gateway management.

Gatekeepers are the best value method of IP-based video communications network management, because with the correct settings they ensure a high-quality experience for all network users. The designer should consider the inclusion of a gatekeeper into the deployment of videoconferencing over an IP network, especially if there is a gateway involved.

Control Systems

Introduction

AV systems generally include remote control systems. A remote control system, as described in Chapter 16: Control Components, consists of a processor and control panels with the primary purpose of integrating the operation of various devices onto a single control surface. Through a touch screen control panel or a fixed button control panel, various device functions are available to the system user, including:

- System power on and off.
- Device power on and off.
- Display device source selection.
- Audio volume controls and mute function.
- Room status configuration (i.e., combined or divided).
- Room lighting control.
- Window treatment controls.
- Projection screen raise and lower.
- Camera controls (e.g., PTZ and focus).

The range of control functions is far more extensive than this listing. This listing, however, reveals the importance of a control system to the overall system design.

The control system is essential to operating larger systems and, in many examples, it defines how the system is designed. For example, display devices usually have several signal inputs, commonly RGBHV and some form of video. When the operator selects a new source to the display device, the device requests the information about the type of the routed signal, and the correct input on the display device is selected. At the time the user selects a source signal for the display, the control system also tells the display device to select the correct input for the signal type of the source. The two-step function allows the AV system to maintain the RGBHV and video signals required in the system as separate routing. This simple control system function eliminates the need to convert signals to a common format prior to connection to the display system.

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Introduction, continued

A more complex scenario is a divisible room configuration. A conference room with an operable wall can be divided into two spaces, each with a display and audio playback functions. In the divided mode, each room division operates separately and independently, whereas in the combined mode both divisions operate as a single entity for all control functions. Typically the system needs to accomplish a number of tasks to change the room from a divided mode to a combined mode, as follows:

- A common audio signal is connected to each room division's audio system. Thereafter, the audio control of each division operates in unison and the room appears to operate as a single entity.
- The control of room lighting or window treatments operates both room divisions systems simultaneously.
- Video or RGBHV signals are routed to the display system in each room division so that the same image is shown on each display system.

Through a single button press on the control panel, a number of signal routing and control function routing changes occur within the system connections to reflect the room configuration status. To accomplish this result, the system connection of audio and video signals is premised on the control system providing this level of coordination and reorganization.

In the foregoing examples, the audio and video systems design is based on the ability of the control system to impact the audio and video configuration. Therefore, a control system is considered a significant driver of the audio and video system design.

One approach to establishing the design parameters of the system is to determine the acceptable control functions the system needs to support and specifying devices and interconnections that support the control function required. This apparent reversal of thinking is a valid design approach where the control system functions and actions are identified in advance of the audio and video system design so that the audio and video systems are designed to meet the functional requirements.

Control System Conceptual Differences and Graphic User Interface (GUI) Design

The AV remote control system is a unifying factor in the overall use and operation of the AV system. The variety of control panel types and sizes provide the designer with many options for structuring the control system and elements of the audio and video systems operated by the remote control system.

One important question for any control system design is the concept of what is controlled by a single button function. The control system has the capability to embed a number of functions within a single button toggle or press. In some situations, the AV system may be better operated when each control parameter is an individual button press, with buttons organized in a logical manner. The AV designer should select a solution that fits the specific control system scenario.

The common factor in all control systems is that the user has access to a control surface with the necessary AV system functions. The control surfaces range from discrete fixed button devices through touch screen control panel to Web pages with connection to the control system over network connections. That surface is known as a graphic user interface (GUI). GUI design possibilities are basically endless as each AV system has unique operational and function requirements.

One of the GUI design considerations is the level of control for each button press. A button press is the action taken by the user to interact with the control surface (i.e., a directive) with the intention of initiating a control function and the corresponding action by the control system when that directive is initiated.

For example, a person walks into a room and flips a light switch, expecting that the light will turn on. In contrast, the switch initiated a number of functions, such as turning the lights on, ceiling fan on, TV to a specific channel, and the air-conditioner on. A single directive may have two possible consequences, one a single event or action occurs (e.g., the lights turn on) or multiple events occur (e.g., TV, fan, air conditioner turn on).

In the previous example of a divisible conference room, a GUI page could show two buttons for selection of room status: divided or combined. By selecting or depressing one button, the multiple reconnections and control system setups would occur with the result that, until a room configuration selection occurs again, the room would operate in the divided or combined mode.

A further example is the raising and lowering of a motorized projection screen. In one design example, the screen lowers only when the projector powers on. However, a different display projector may be required and the customer may wish to lower the screen and not to turn on the installed projector. Incorporating the screen lower function into the projector power on button, the independence or separation of devices is negated. In some situations, having separate buttons for each AV system function is desirable. The one button–one function requires a greater knowledge of buttons but provides for greater flexibility.

The true challenge of the control system GUI is to find the correct balance of button functions and AV system functions that meet the customer's expectations for operational flexibility and simplicity.

Overhead Paging Systems

Introduction

Overhead paging, sometimes referred to as a PA system, allows users the ability to broadcast voice messages or audio programming across a network of loudspeakers that are typically mounted on walls or in the ceiling. In many systems, loudspeakers and horns may be accessed individually, in logical groups (i.e., zones), or all at once (i.e., all call). This type of system may have the capability to provide background music, time tones, night ringing, alerting tones, one-way and/or talkback paging, to any or all zones in the system. A PA system can be accessed through a telephone system or may have a dedicated microphone or console.

NOTE: This section discusses telecommunications and fire alarm applications of overhead paging.

Paging systems may be accessed from standard telephones, with or without being connected to a telephone system, or from CO lines. Some systems use dedicated and keyed (e.g., push-to-talk) microphones or a dedicated console; however, using telephone access is more common in modern systems.

The voice page is made from a telephone by dialing a code or pressing a button and making an announcement. Many places of employment are now required by governmental authorities to have systems specifically for emergency and safety announcements. In addition to an emergency life safety system, the building paging system is often used for emergency and routine announcements. Stop and start work tones, background music, and personnel tracking are all considered to be common uses of a building PA or paging system.

The paging equipment is connected to the loudspeaker distribution system in the building. Loudspeakers may be flush mounted in the ceiling, suspended from the ceiling, or wall mounted. Horns are often mounted on walls, racks, poles, and I-beams or suspended from ceilings. Larger buildings or multi-building campus applications may have multiple zones for the paging system. The audio paging cable runs typically return to the nearest AV room, which allows for easier maintenance, troubleshooting, and system changes.

In addition to one-way paging, other features of overhead paging systems can include:

- Two-way talkback paging (i.e., talk, then listen for response from loudspeaker).
- Multiple zones (i.e., areas to be paged separately [e.g., office and factory]).
- Group call (page multiple areas/zones at once).
- All call (page all areas/zones at once).
- Background music.
- Night ringing.
- Time clock or class change tones.
- Alert or alarm tones.
- Battery backup.
- Override input.

Types of Paging Systems

Two main technologies employed in paging systems are:

- Centrally amplified systems.
- Distributed amplified systems.

With both systems, the voice page may be accessed by a microphone or a telephone. The voice signal is amplified and broadcast over the loudspeakers and/or horns.

Centrally Amplified System

The centrally amplified system is so named because the line level signal received from a telephone system or the low level signal from a microphone is first amplified and then fed at a higher level through various types of cable to loudspeakers and horns.

Two types of amplifiers and loudspeakers that can be used in a centrally amplified system are:

- Constant current.
- Constant voltage.

The constant current systems are more common in smaller installations and require more consideration in design because the loudspeakers need to be balanced, based on load rating, typically 4 or 8 ohms.

Systems requiring more than a few loudspeakers are typically better served with a constant voltage design, which provides a voltage of up to 140 V (i.e., typically 25, 70, or 100), eliminating the need to calculate and balance loads. The constant voltage system is more common in modern installations and can be easily expanded.

With the centrally amplified system, one or more amplifiers are usually mounted in racks and connected at the headend equipment to amplify the voice or audio signal. This amplified signal is then transmitted out to loudspeakers and horns through different types of cable.

In both constant current and constant voltage systems, the cable is usually 18 American wire gauge (AWG) [1 mm (0.039 in)] or larger, and may be shielded to prevent emissions (e.g., alien crosstalk) of the higher voltage level signals into other lower voltage level voice and data systems. In some localities, conduit may be required due to the voltages (70 or 100 V). Verify this requirement with the local authority.

Distributed Amplifier System

Distributed amplifier systems typically connect to the telephone system using a control unit located at the headend equipment. The control unit sends a lower voltage level voice signal, along with a direct current (dc) voltage (i.e., typically 24 V) through two-pair twisted-pair cable to the loudspeakers. Each loudspeaker or horn contains a separate amplifier circuit and volume control where the voice signal is amplified.

Types of Paging Systems, continued

Distributed amplifier systems also may use voice grade or data grade cabling, allowing the designer to integrate the design of the PA system into the structured cabling network. However, some systems allow daisy chaining of voice grade cable, providing a more efficient installation. The designer must determine which cable design is most practical for the facility being designed.

Both distributed amplified and centrally amplified systems offer advantages. The designer should consider both types of systems when evaluating a facility for overhead paging.

When deciding on which type of technology to use, there are several considerations, which include:

- Cost.
- Cable type.
- Future expandability.
- Interface requirements.
- Source requirements.
- AV room or rack space availability.
- Facility type.

Loudspeaker Selection and Placement

The reproduced direct sound should be as low as possible. Direct sound is sound that travels directly from a loudspeaker to the listener. Rooms with hard surfaces (e.g., marble or concrete floors, painted plaster walls, high ceilings) can cause reverberant sound that is reflected from a surface (e.g., wall or floor) to the listener. A high level of reverberated sound could cause the direct sound to be unintelligible. In contrast, rooms or areas with carpeting, suspended ceilings, furniture, and wall covering typically have more absorption, and may require higher output levels or additional loudspeakers.

An ideal distribution system is accomplished by locating the loudspeakers in a way that provides even coverage at the lowest wattage possible. This is called a distributed loudspeaker system. A properly designed overhead paging system will provide an SPL for the voice page that is at least 6 dB, but no more than 20 dB above the ambient noise level.

If the 6 dB level is not followed, the voice pages:

- May be lost in the ambient noise of the room.
- Will be unintelligible.

Loudspeaker Selection and Placement, continued

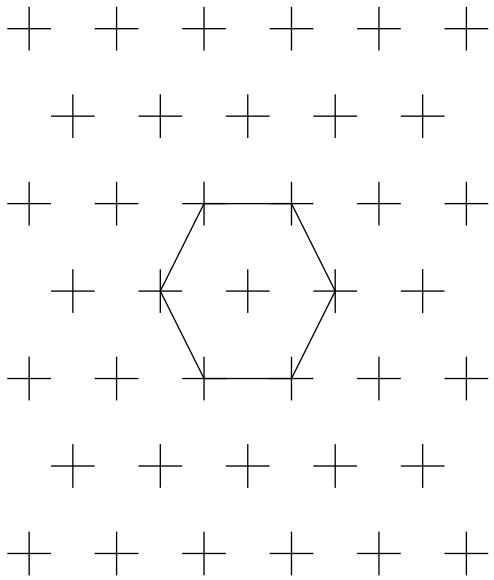
If the 20 dB ambient noise level is not followed, the paging will be far too loud in areas closest to the loudspeakers and horns.

In some systems, highly directional horn loudspeakers are used to direct the sound toward the listener and away from areas (e.g., walls) that may cause reverberation of sound to occur.

Loudspeaker Distribution Patterns

The two most common loudspeaker distribution patterns used by designers are the hexagonal and the square (see Figures 17.31 and 17.32). The hexagonal is the preferred pattern because it provides the most uniform coverage.

Figure 17.31
Hexagonal loudspeaker pattern

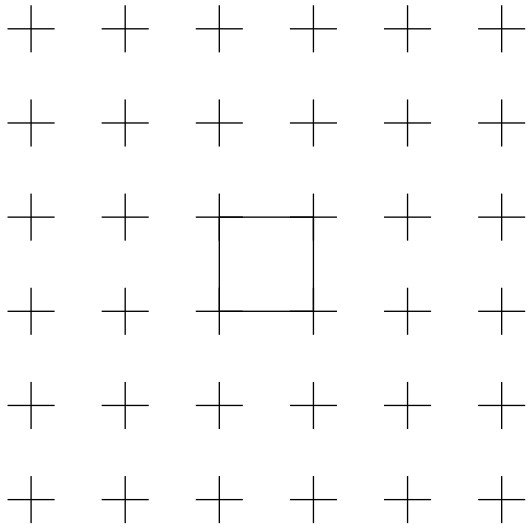


Hexagonal spacing

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Loudspeaker Selection and Placement, continued

Figure 17.32
Square loudspeaker pattern



Square spacing

Ceiling Loudspeakers

In areas with less than 70 dB noise level, the distance between ceiling loudspeakers in a row should be approximately twice the ceiling height.

In areas with a noise level greater than 70 dB, the distance between loudspeakers should be decreased.

Loudspeaker Selection and Placement, continued

Wall-Mounted Loudspeakers

In some installations, ceiling-mounted loudspeakers are impractical due to premises structures that prevent the loudspeakers from being properly mounted. In these installations, using wall-mounted loudspeakers may be necessary.

For appropriate sound coverage, wall-mounted loudspeakers should be mounted 2.4 m (8 ft) to 3.7 m (12 ft) above the floor. Wall-mounted loudspeakers should not be directed toward each other.

Hallway Loudspeakers

For heavy traffic hallways, use ceiling-mounted loudspeakers placed along the center of the hallway 2.4 m (8 ft) intervals whenever possible. Place the first loudspeaker 2.4 m (8 ft) from the end of the hall and work toward the other end. Place a ceiling loudspeaker at hall junctions. In a normal traffic hallway, place loudspeakers at intervals equal to twice the ceiling height.

Where ceiling loudspeakers cannot be used, use wall-mounted bidirectional loudspeakers placed at intervals of approximately 8 m (26 ft) on alternating sides of the hallway. Place the first bidirectional loudspeaker 6 m (20 ft) from the end of the hall and work toward the other end.

Horn Loudspeakers

Horn loudspeakers (i.e., horns) have a directional projection pattern and are appropriate for use in environments with more than 70 dB of noise. The loudspeakers may be installed indoors or outdoors, or where larger areas must be covered by each loudspeaker. Horns commonly have a higher power rating than ceiling-mounted loudspeakers.

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Loudspeaker Selection and Placement, continued

The area that can be covered by a horn depends on:

- Ambient noise level (i.e., consistent or varying noise level).
- Mounting height.
- Angle of projection.
- Obstructions or racks.

One 15 W horn mounted 5 m (16 ft) above the floor and adjusted to a 60-degree angle of projection will cover the areas shown in Table 17.5 under the given noise levels.

Table 17.5
Area covered by horns

SPL of Ambient Noise	m^2	ft^2
Up to 74 dB	372	4000
75 to 89 dB	232	2500
90 dB and above	112	1200

dB = Decibel
ft^2 = Square feet
m^2 = Square meters
SPL = Sound pressure level

NOTE: In ambient noise levels above 100 dB, coded tones or strobe lights may provide an alternative to standard paging. Many paging controls can activate these devices.

Loudspeaker Selection and Placement, continued

Loudspeaker Phasing

When more than one loudspeaker is used in an area, it is important that the loudspeakers are phased correctly to reduce cancellations. Phasing refers to whether the diaphragms of two or more loudspeakers are moving inward or outward at the same times. Loudspeakers are in-phase when their diaphragms are moving inward or outward at the same time—loudspeakers are out-of-phase when their diaphragms are not moving inward or outward at the same time. Out-of-phase loudspeakers reduce the overall sound volume and quality in an area.

Feedback

Feedback is an unwanted oscillation or tone that quickly grows in loudness. Feedback occurs when the sound from a loudspeaker reaches a microphone or telephone handset and is louder than the person speaking. To protect against feedback, do not locate ceiling loudspeakers directly above telephone sets or external microphones, or point horns toward telephone handsets used for paging. In applications that require paging from a telephone near a loudspeaker or horn, a digital store and forward message unit that records the page then broadcasts it after the user disconnects from the system, is usually required to completely eliminate feedback. This is a system accessory that is installed with the headend equipment.

Constant Voltage System Design

Constant voltage is called thus because all transformers on the line have the same voltage applied to them. The taps selected on the transformers then may supply differing amounts of power to the individual loudspeakers.

Constant voltage should not be assumed to mean that the amplifiers deliver a constant signal to the distribution line.

An amplifier does this only when being driven to its full rated power output by a constant sine wave signal. In actual use, the amplifier's output voltage:

- Varies with the audio signal.
- Is usually much less than the maximum power rating.

Generally, there are two systems typically used. The most common is called a 70 V system because the maximum voltage out of the amplifier at full power is 70 V. The other system is called a 25 V system for the same reason. Some countries use 100 V and 140 V systems.

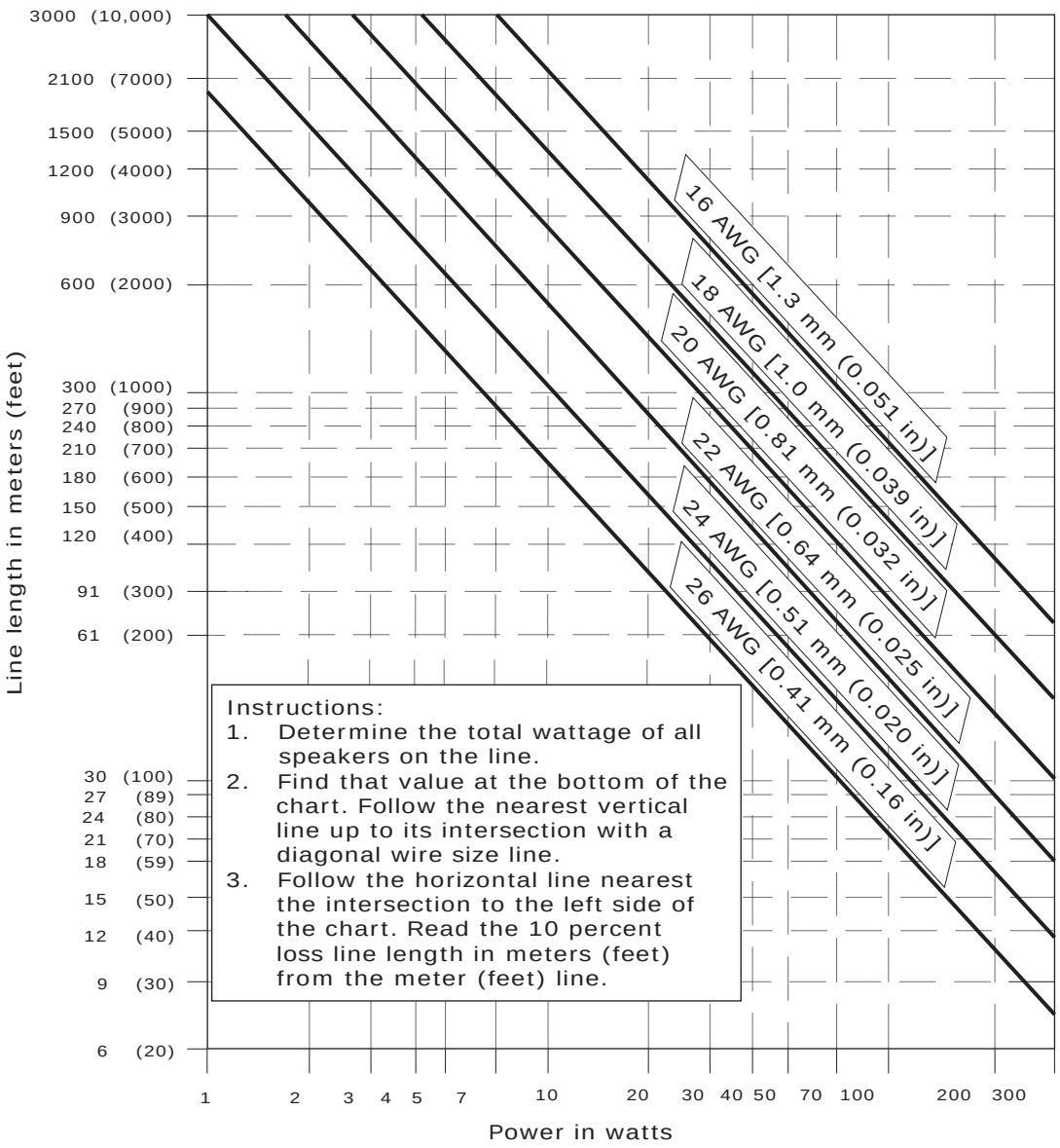
In a 70 V distribution system, a 5 W signal can be transmitted over 1520 m (5000 ft) on 20 AWG [0.81 mm (0.032 in)] with a power loss of only 10 percent. In a 25 V system, the 5 W signal can be applied over more than 183 m (600 ft) of 20 AWG [0.81 mm (0.032 in)] with a 10 percent power loss.

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Constant Voltage System Design, continued

Figure 17.33 is based on 10 percent line losses in a standard 70 V distribution system using different line lengths and signal strengths.

Figure 17.33
70 V loudspeaker line loss



AWG = American wire gauge
in = Inch
mm = Millimeter

NOTES: This chart is based on a line loss of 10 percent. Line lengths for a 5 percent loss can be detected by multiplying the 10 percent length by 0.5. The line lengths double for a 20 percent loss.

A 70 V line can be run eight times farther than a 25 V line for the same loss.

Constant Voltage System Design, continued

At the time the 25 V and 70 V systems became standard, the 70 V system was selected because with 3 dB regulation, the output voltage never exceeds 100 V peak, even under no-load conditions. This allowed 70 V systems to meet the electrical codes for class 2 open wiring, meaning that their loudspeaker lines could be installed without conduit. In most areas, the loudspeaker lines for a 70 V system can still be installed without conduit. However, some areas now require conduit for the loudspeaker lines. In these areas, 25 V systems are permitted to be installed without conduit.

IMPORTANT: Carefully check all applicable local and national codes before planning to use open wiring. Consult the local authority having jurisdiction (AHJ) for further clarification concerning local requirements.

Voltage step-down transformers are used at each loudspeaker to convert the 25 V or 70 V signal to a much lower voltage. These transformers are called impedance-matching transformers. These transformers provide various taps that allow the power to each loudspeaker to be individually adjusted during installation. The tap values may range from 1/8 W to 20 W for most paging applications, up to 200 W for some loudspeakers.

Loudspeaker-matching transformers are not 100 percent efficient. The transformers introduce a certain amount of power loss into the system, and affect the system's overall frequency response. In addition, transformers introduce a small amount of distortion.

The efficiency of the transformers falls off at high and low voice frequencies, thus affecting the overall frequency response. The electrical characteristics that cause the frequency loss also tend to introduce distortion into the system. This is especially true in the lower (i.e., bass) frequency range, where actual transformer impedance tends to fall off rapidly. Because the impedance falls off so rapidly, the line presents a much lower impedance to the amplifier at these lower frequencies. In severe cases, the impedance reduction may actually overload the amplifier in this frequency range, usually resulting in an unclear or "muddy" sound.

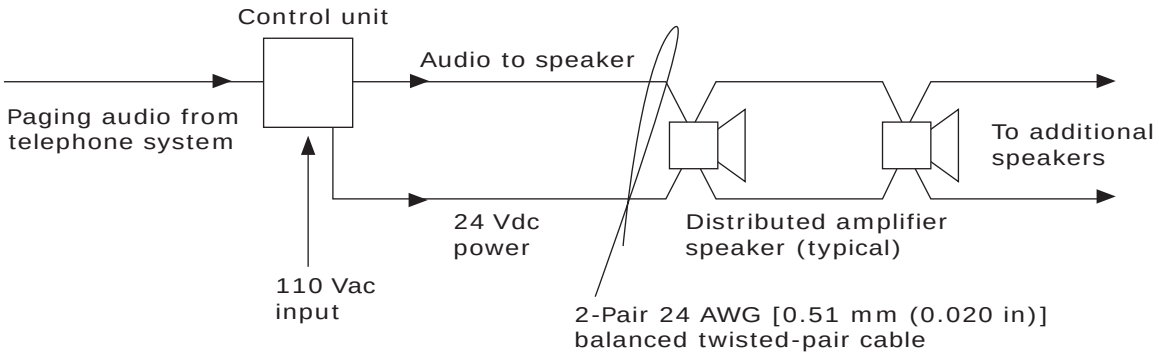
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Distributed Amplifier System Design

A distributed amplifier system (see Figure 17.34) places amplifiers away from the central distribution point. Small amplifiers are placed directly on the loudspeaker-mounting frame (e.g., ceiling loudspeakers) or inside the housing (e.g., horn type loudspeakers).

Systems come in various configurations with more advanced systems providing power, audio, and data over a multipair cable. Simpler systems may just have distributed amplifiers with basic line level audio feeding each amplifier. In any of these distributed systems, cable loss and amplifier power calculations are essential to ensure a properly functioning system.

Figure 17.34
Distributed amplifier system



AWG = American wire gauge
in = Inch
mm = Millimeter
Vac = Volt alternate current
Vdc = Volt direct current

Central Amplifier Power Requirements

The power rating of the amplifier should be based on:

- The total sum of the tap wattages of each impedance-matching transformer on each loudspeaker.
- The total sum of the power lost in the loudspeaker distribution cabling.
- Power reserved for future growth.

Add an additional 25 percent to this number so that the amplifier will normally be operating at about 75 percent of its rated output.

Sound Masking Systems

Introduction

Sound masking systems are designed to provide a masking noise in spaces where conversation may be distracting or where confidentiality of conversations is important.

Many factors can affect the recommendation for the use of a sound masking system or the successful implementation of a sound masking system.

Companies have utilized the open office plan for years. Open offices offer a lower cost alternative to the traditional closed offices. The drawback of open offices can be the lack of speech privacy. Sound masking can help alleviate some speech privacy problems with an understanding of its capabilities and potential drawbacks.

In cases where an extremely high degree of privacy is required or a challenging architectural construction is encountered, the services of an acoustical consultant should be considered.

Care also must be taken to assess the customer's expectations. In addition to understanding the properties of sound waves, the AV designer should possess a good understanding of acoustics, including sound transmission class (STC), absorption ratings, noise reduction coefficient (NRC), and articulation class (AC).

Factors Affecting Sound Masking Systems

The major factors that affect a sound masking system include the office furniture orientation and absorption, rating, and the ceiling tile NRC. The ceiling is typically the largest contributor to the reduction of noise levels in the open office. An office with a drywall ceiling would not be a good candidate for a sound masking system since its absorption rating is very low.

Ceiling-mounted devices that reflect sound (e.g., light fixtures) have to be considered. The best environment for sound masking has no ceiling-mounted light fixtures. Indirect or task lighting is used in such cases.

The best sound masking systems are designed to provide a steady even masking level throughout the space. Therefore, unducted return air grates pose a problem because they can allow high levels of masking noise into the space. These need to be treated as part of the design process.

Another factor that affects the acoustics of the space and hence the effectiveness of the system are the wall finishes. Direct reflections into the workspace from hard wall surfaces like drywall or large windows should be avoided. If the furniture layout cannot be changed, the hard surface should to be treated.

The objective before masking noise is added is to have as quiet a space as possible. The measure of this noise level is NC. To have a masking system acceptable to those working in the space the NC should not be higher than 35. A sound level meter capable of measuring octave band sound levels should be used. For new spaces, the NC can be predicted but should be field verified.

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Sound Masking System Components

The basic electronics in a sound masking system are always the same but may have different configurations. The components include a(n):

- Masking noise generator.
- Equalizer.
- Amplifier.
- Loudspeaker.

Systems vary in size from self-contained masking units with all of the components to large systems with racks of amplifiers and associated equipment. Complex systems can incorporate paging and background music.

The masking generator generally provides pink noise to the equalizer. Pink noise has equal energy across the octave bands where it produces noise. The equalizer (EQ) is always a third octave device. The EQ should have high and low pass filters. A parametric equalizer may be used as well. An EQ remote controller is helpful in the tuning process. Amplifiers should have 70 V outputs. Since a masking system should never be turned off, the amplifiers should be of high quality.

Monitor panels should be included in each rack of equipment to ensure that all inputs and outputs are in service.

Masking Loudspeakers

Sound masking loudspeakers are typically a standard 203 mm (8 in) 70 V paging loudspeaker with some special hanging hardware. The hardware allows the loudspeakers to be located above the suspended ceiling and pointed up toward the roof or floor deck above the ceiling.

Masking loudspeakers may contain all of the required electronics to provide a masking sound. These are typically called self-contained masking units. They contain a noise generator, an equalizer, an amplifier, and a loudspeaker in a box. They are usually capable of operating on alternating current (ac) or dc power.

Loudspeakers are spaced according to the height above the floor. The designer should refer to the manufacturer guide when placing masking loudspeakers.

Loudspeakers may be placed in a suspended ceiling if placing the loudspeakers above the ceiling would be very difficult due to congestion above the ceiling. The loudspeakers will have to be placed much closer together because the masking sound will not reverberate in the ceiling plenum. Also, placing them close together will result in overlapping coverage, thus reducing dead spots.

Sound Masking System Enhancements

Different levels of masking may be required for different types of areas in a facility, including hallways, lobbies, and restrooms. Separate level controls will have to be provided for each of these types of areas. These controls should be located in the equipment cabinet serving that area.

When designing a sound masking system, the customer may request that the system be configured for paging and/or background music. Paging and background music are good enhancements to a sound masking system. These options require separate equalizers. Paging also requires higher sound levels than sound masking. Background music is not meant to be noticed but paging is meant to be heard.

These options may necessitate additional zones because paging and background music may not be required in all parts of the facility. Additional amplifiers will be required for each type of zone (e.g. masking with paging, masking with music).

Tuning Sound Masking Systems

Proper tuning is as important as selecting the proper equipment and design of the sound masking system. Once the equipment installation is verified according to specifications and operating properly, tuning can begin.

Because sound levels throughout the space will be measured by sensitive equipment, tuning has to be accomplished in an unoccupied space. All of the intended furniture has to be in place before the tuning can begin. Tuning can be a time-consuming, trial-and-error process. All building systems (e.g. HVAC) must be in operation during the tuning.

The required tuning equipment in the United States is an American National Standards Institute (ANSI) class 1, 1/3 octave spectrum analyzer and a high-quality flat response microphone.

A proper masking curve should be selected before beginning the tuning process. The selection of curves is extensive. Many companies start with a base contour and customize it as they gain experience. A curve that has been used for many years is the NC 40 curve. This curve has been found to have a level that is too high for some masking systems. The curve is generally customized to meet the specific needs of the space being masked.

The procedure involves setting the equalizer at the various frequencies required and adjusting them to match the required contour. This testing needs to be done throughout the space under tuning. If discrepancies are found in the readings, they need to be closely evaluated. Changes should be made carefully because adjusting one part of the system can change the masking contour in the overall space.

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Expected Privacy

Once the masking system is planned, speech privacy can be predicted. The articulation index (AI) is the metric used to predict speech intelligibility. AI denotes intelligibility with a two-decimal place number between 0.00 and 1.00. The lowest number, 0.00, denotes no intelligibility while the highest, 1.00 denotes perfect intelligibility.

AI is an inverse predictor of speech privacy. Perfect intelligibility (i.e., 1.00) would predict no speech privacy while no intelligibility (i.e., 0.00) would predict confidential privacy. Table 17.6 relates AI to speech intelligibility.

Table 17.6
Articulation index speech intelligibility

Selective Speech Intelligibility	Articulation Index	Subjective Speech Privacy
Excellent	0.75–1.00	None
Good	0.60–0.74	None
Fair	0.45–0.59	None
Poor	0.33–0.44	None
Bad	0.20–0.32	Marginal (0.20–0.30)
Bad	0.05–0.31	Normal
Bad	0.00–0.04	Confidential

Definitions

Marginal Privacy

Marginal privacy implies an environment where speech privacy is minimal. In this case, audible conversations are distracting and conversation eavesdropping is easy.

Normal Privacy

Normal privacy is typically the best that the designer can expect from a properly designed sound masking system in an open office. Normal privacy means that, while occupants are aware of conversations around them, they cannot discern the subject unless they concentrate on them.

Confidential Privacy

Confidential privacy is expected in some offices and conference rooms. When confidential privacy is present, conversations from adjacent rooms will not be intelligible.

Expected Privacy, continued

Total Privacy

Total privacy means that sound from one space will be inaudible in an adjacent space. This type of privacy is not possible with sound masking alone. Special construction techniques are required to achieve this level of privacy.

Predicting Speech Privacy

Predicting speech privacy is usually the responsibility of the acoustical consultant. The consultant will specify the materials and construction that will affect the privacy in the space. These may include ceiling, furniture, wall types, and layouts.

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Digital Signage Systems

Introduction

The concept of delivering a focused message to a specific audience at the specific time and location may include:

- Digital signage.
- Dynamic signage.
- Narrowcasting.
- Datacasting.
- Digital in-store merchandising.
- Electronic display networks.
- Retail television (TV).
- Captive audience networks.
- Out-of-home media networks.
- Digital media networks.
- Electronic billboards.

The use of dynamic digital signage (DDS) is spreading. It can be found in the streets of any metropolis, a high-rise building elevator, a sports arena, or TV advertisements.

Retailers use signage to coordinate their weekly specials from the newspaper and direct mail campaigns with onscreen in-store messaging. Others have a network of in-store TVs to promote national and local brands sold in the store. Movie theater owners use a satellite network of digital projectors to entertain and inform moviegoers before the feature film begins. Fast food operators employ digital menu boards. Grocery stores use strategically placed displays to influence customers' buying habits at the critical point of sale (POS). Corporations and government facilities implement DDS to motivate and train employees in the workplace. Even relatively innocuous locations such as a local bank or a doctor's waiting room are likely to have DDS to inform, educate, entertain, and promote products and services.

Markets

Technology sales to the DDS industry continue to rise. A unique aspect of DDS is its ability to serve a myriad of markets. To better understand this diversity of DDS, the AV designer should consider the ensuing case examples from around the world built for:

- Banking.
- Pharmacy.
- Medical institutions.
- Digital cinemas.
- Homeland security.
- Public spaces and conference centers.
- Grocery stores.

Rabobank—Ultrech, The Netherlands

Rabobank is made up of more than 1300 independently operated local banks throughout The Netherlands. In its Dutch home market, Rabobank Group has 1.3 million members, with 9 million business and private customers.

When Rabobank wanted to reach its customers more efficiently and grow new business worldwide, company officials chose a DDS network with plasma screens located in bank locations and next to the bank's automated teller machines (ATMs). Each plasma screen displays short focused ads about the bank's products and services.

Content is created and distributed to each bank location from a central location over an asymmetric digital subscriber line (ASDL) infrastructure.

T-Systems—Warsaw, Poland

T-Systems launched the first dynamic advertising network for Power Media. The network is composed of more than 220 plasma screens and placed in a third of all pharmacies in Warsaw.

The objective of the network is to sell branded ad space over the Pharmacy TV Channel. The broadcasts follow the pattern of a standard TV program, containing news, weather forecasts, events calendar, advice of the day, medical messages, and branded commercials advertising over-the-counter (OTC) drugs, cosmetics, dressing materials, and medical services.

Hospital de Clinicas Caracas—Caracas, Venezuela

Hospital de Clinicas Caracas, the most technologically advanced health institution in Venezuela, is the first to install a digital dynamic entertainment and advertising network. Fourteen HD plasma screens display entertainment and relevant health-related information to patients and patrons. The network is the first DDS of its kind to be installed in Latin America.

Markets, continued

Berkeley Cinemas—Auckland, New Zealand

Berkeley Cinemas rolled out the first cinema DDS installation in New Zealand. The driver for the project was the deployment of HD plasma screens in portrait and landscape mode, creating a cutting-edge cinema environment that enhanced the movie-going experience. The plasma screens, as well as a floating screen driven by a projector, provide relevant up-to-date content such as movie session times and prices, entertainment with movie trailers and previews, and advertising.

Cumbria Constabulary—Cumbria, UK

Managed by the Force Intelligence Section, Cumbria Constabulary installed a Telebriefing DDS system that provides real-time intelligence on wanted criminals and other critical crime-based information to officers each day. The Forced Intelligence Center distributes the intelligence to nine rural police stations across Cumbria. News, criminal alerts, new department processes, laws, and acts of parliament are compiled into the briefing content and distributed over the DDS system.

NorgesGruppen—Oslo, Norway

NorgesGruppen is Norway's largest trading enterprise. Its core business is grocery retailing and wholesaling. Through its chains, the group holds 34.8 percent of the Norwegian grocery market.

NorgesGruppen rolled out its first in-store digital signage network in its MIX chain. MIX contains 950 stores/kiosks with 100 of the MIX stores implementing two digital signage channels per store and the remainder implementing one channel. Due to the unique dynamic, real-time rendering of DDS, the content displayed at each store can be dynamically tailored to the local requirements of each store.

Business Models

Merchandising Model

In the merchandising model, the goal of the DDS network is to enhance brand awareness, establish brand identity, and entertain and persuade customers at the last mile of marketing, the POS, to purchase the brand. Digital signage has the power to influence the functional and emotional associations assigned to a brand, similar to advertising, packaging, store design, and point-of-purchase material.

Business Models, continued

The customer funds the network infrastructure and, given that this model is an extension of a company's branding strategy, displaying advertising of products not owned by the customer is the exception rather than the norm.

Advertising Model

In the advertising model, the customer or DDS network operator implements a digital signage network with the intention of selling the advertising space it represents. Software for proof-of-playback and invoicing is a vital part of this model. While customers derive ad revenue as an additional revenue stream, network operators derive revenue from maintaining hardware, advertising revenue, as well as content-related services.

The programming is a mix of advertising created for TV, advertising created specifically for the digital signage medium, and content supplied by media houses. Network operators provide content services such as modifying TV stock advertising to suit digital signage, developing promotion templates, and, on an ad-hoc basis, also including content creation.

The customer or the DDS network operator can fund DDS networks based on this model.

Customer-Funded Network

In this model, the customer owns the hardware—funded in turn by category captains and/or co-op partners—and sells advertising on the DDS network to its suppliers as an additional revenue stream. The retailer usually outsources the DDS network operation (network maintenance and media management) to a third party, paying a fee for the former service and partaking in a share of the advertising revenues.

Network-Operator–Funded Network

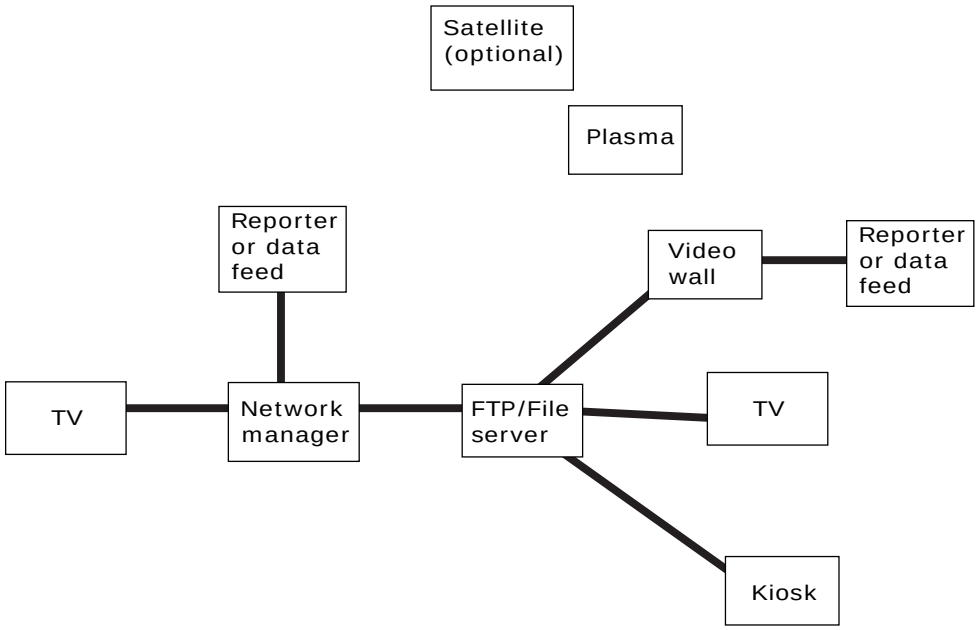
In this model, the DDS network operator leases space (e.g., a mall or theater), invests in the infrastructure, manages advertising sales and provides a share of the ad revenue to the real estate owner. The real estate owner is locked into a long-term contract with the DDS network operator when the latter owns the infrastructure on his premises. Also, such an arrangement allows DDS network operators to share a smaller percentage of the advertising revenue from the DDS network.

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Collaboration of Technology Providers

DDS networks, because of their configuration, require collaboration between industry technology providers (see Figure 17.35).

Figure 17.35
Collaboration of component technology



FTP = File transfer protocol
TV = Television

A successful DDS network is a collaboration among computer vendors, display manufacturers, infrastructure providers, software vendors, and system integrators that specify, install, and maintain the DDS network.

Computer Vendors

To effectively operate a DDS network, computer systems are required for the critical tasks of content creation, server operations, scheduling, distribution, and playback. These systems are typically Windows-based PCs, although some networks are operating on UNIX, LINUX, and MAC operating systems. Each system on the network is configured with specific components (e.g., disk space, memory, video cards, TV cards, and audio output) that fulfill the requirements of the specifications of the DDS network.

Collaboration of Technology Providers, continued

Display Devices

A typical DDS network employs some type of display component, including:

- Plasma screens.
- Liquid crystal display (LCD).
- Light-emitting diode (LED).
- Cathode ray tube (CRT) monitors.
- Projection devices.
- Interactive kiosks.

The decision to employ a specific type of display is dictated by application, location, budget, and preference.

Plasma Screens

Plasma screens are employed in a variety of sizes in DDS networks where video is a critical component of the message or cost sensitivity is an issue. Plasma screens, as with other flat-screen displays, have experienced a significant drop in pricing over the past few years, further driving the DDS marketplace. Because of the nonstop operation of DDS networks, commercial grade plasma screens have a burn-in life of approximately 66 000 hours. This characteristic of plasma screen technology should be considered when specifying a DDS network.

Typical applications of plasma screens are in retail and entertainment applications where a mix of video, text and graphics are combined to deliver a customer enticing advertisement.

Liquid Crystal Display (LCD) Screens

LCD screens, like plasma screens, have seen a significant drop in pricing over the past few years but are still considerably more expensive than its Plasma screen cousin. LCD screens are best employed where relatively static information is displayed and a requirement for reading text is significant. The crisp and bright nature of LCD screens lends themselves to DDS networks.

Typical applications for LCD screens are in corporate/government, education, public venues, hospitality, and transportation where screens display airport flight information, train schedules, museum information, hotels, community information, and campus information systems.

Light-Emitting Diode (LED) Screens

LED screens are typically used for outdoor applications including advertising billboards, sports arena scoreboards, strip signage, or advertising signage located on sides of buildings. This class of signage provides for a variety of sizes and resolution. The screens are modular in construction and link together to make any size screen necessary for a given application. Depending on the size and resolution of the screen the cost of implementation could reach into the millions.

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Collaboration of Technology Providers, continued

Cathode Ray Tube (CRT) Monitors

While waning in their appeal, CRT monitors are inexpensive alternatives to other display devices. CRT monitors are typically employed in in-store CRT networks, doctor's office networks, and some train and airport applications. CRT monitors display both static and dynamic content at a relatively low resolution. The public's comfort level with their home CRT sets makes CRT monitors a good choice for intimate applications like doctor's and hospital waiting rooms.

Projection Devices

Somewhat unique in their application, projection devices provide the ability to display messages or advertising over large areas without the constraints of other types of display technologies. They are employed in outdoor applications where the display may be the side of a building or a large screen.

In a more intimate environment, projection devices are used in store display windows where there is a requirement for the projection source to be invisible.

More recently, projection devices are combined with state-of-the-art radio frequency identification (RFID) technology in futuristic retail environments displaying ads for products of particular interest to a consumer at the POS.

Projection devices also are employed in education, conference facilities, and museums.

Interactive Kiosks

Interactive kiosks are used in a unique application for digital signage. Typically, interactive kiosks are employed in hotel lobbies, tourist centers, museums, convention centers, and other areas where people are seeking information (e.g., restaurant locations, directions, community attractions).

Interactive kiosks can be employed in two configurations:

- One-on-one person interactions (e.g., hotel lobbies, museums)
- Larger screens applications designed for displaying information to many people at a given time (e.g., wayfinders or schedules at convention centers)

Infrastructure Providers

An integral part of a DDS network is the system infrastructure. Most DDS networks are operated from a central location over a network infrastructure including local area network (LAN)/WAN, virtual private network (VPN), digital subscriber line (DSL), dialup, satellite or Internet/intranet. Cost-effective broadband availability is one of the tipping points that contribute to the popularity and success of DDS networks in the marketplace.

Collaboration of Technology Providers, continued

Most applications of DDS either use an existing network infrastructure or develop a unique infrastructure for the DDS network. Either way the IT department becomes an integral part of the DDS installation. The issues that affect the decision on how an infrastructure is configured are location, budgetary considerations, availability of infrastructure capability, and security.

Software Vendors

The component that binds the DDS network together is the software application. The marketplace is rich with software vendors that provide varying levels of DDS capability. However, software vendors tend to stratify between small network and large network deployments.

For a DDS network to exist, critical components that facilitate the network need to be present, including:

- Content creation.
- Scheduling and distribution.
- Playback.

Content Creation

A DDS network can be configured with the latest component technology but if the content is not appealing to the intended audience, the network is a failure.

To create the necessary content for a DDS network, graphic designers compile text, graphics, video, audio, live TV feeds, text crawlers, and animation from a myriad of sources to develop the compelling content that is intended to attract the attention of the consumer. To be successful the creation component needs to be easy to use, robust and employ assets generated from external sources such as, Adobe PhotoShop®, Adobe AfterEffects®, Macromedia Flash®, and other asset sources. The content creation package also requires the support of industry standards for text, graphic, audio, and video assets.

Scheduling and Distribution

The heartbeat of any DDS network and the next step in the software process is the scheduling and distribution of content over the network infrastructure. Network managers create a play list, schedule the content, and distribute the content to players located at display locations. Considerations like day-parting, player/screen selection, and playback sequence are all managed by the network manager.

Collaboration of Technology Providers, continued

Furthermore, in a robust network management environment, health checking through constant communications with players on the network ensures the screens are up and running and not displaying the dreaded black screen. In addition, for networks that are displaying advertising, network managers need to keep track of the frequency of the display loops and length of time each loop is played throughout a given parting cycle so audit records can be generated for advertisers.

As a playback loop cycle is scheduled to end, the network manager has to prepare and send the next loop cycle to the players and avoid any downtime between loop cycles. The interface between loop cycles should be seamless.

Playback

The business end of all DDS networks is the player. Each player is composed of a computer or set-top appliance that plays the content on a designated screen location.

For some DDS networks, the content is streamed across the network directly to the player appliance and played in real time. Because of a high degree of risk involved with network reliability caused by external or internal factors, streaming of content is typically not advisable.

However, for other configurations, the content is stored at player locations and is played from the computer or appliance at the screen location. This solution alleviates the risk taken when the content is streamed over the network.

As mentioned before, players are designed to operate nonstop with occasional scheduled maintenance breaks and system rebooting. This is vital to the health of the DDS network. Periodic preventative maintenance is required to ensure the intended benefit of the network is realized for the network operator.

Audio / No Audio

The decision to add audio content on a DDS network is dictated by the application and location. In general, audio is used to attract people's attention with the intent to inform or entertain.

For installations that are intended for audiences that move past a screen quickly (e.g., train or airplane schedules, advertising on walkways), the dwell time (i.e., the actual time a person is in the location of the screen) is not long enough to deliver an audio message. In another scenario, where the dwell time is longer but the environment does not lend itself to audio output (e.g., high ambient noise or designated quiet areas), audio is ill advised.

However, in scenarios where the dwell time is long and the environment lends itself to the audio output, audio can be employed effectively to attract a customer's attention and encourage them to connect with the message. Areas of interest might be retail stores, where consumers spend significant dwell time, and doctors' or hospital waiting rooms, where the waiting time is long and the audience can be entertained or informed.

Audio / No Audio, continued

One important consideration for employing audio as part of the DDS content is in locations like retail stores where the in-store staff listen to the same audio loop throughout the day. If the audio is repetitive, sooner or later the staff disables the audio. However, in the same environment, audio can become a training aid to the in-store staff by educating them on the intricacies of product benefits while they interact with customers.

Research should be done to determine the actual customer dwell time and develop appropriate ad loop times to attract the customer. In addition, changing the order of the ads in the loop cycle can mitigate the repetitive nature of the content.

Screen Mounting Locations

For the most part, the location of the screen in a DDS network is dictated by the market application. Different markets require different locations for the screen placement. To demonstrate some of the market applications, the following examples explain how screens can be placed for maximum viewer impact.

Retail

In most retail applications, screens are mounted as close as possible to the point of purchase. Because most of decisions to purchase are made in the last few feet of the product, screens that are located in the vicinity of the promoted product provide enticement for consumers to make the buying decision.

In most retail applications, DDS networks are subdivided into channels relating to specific departments in a store environment. Each store employs multiple channels (e.g., TV, audio, video, computer, and appliances). In each of these departments, focused advertising about the products and services is displayed.

To better attract the consumer's attention, screen placement and configuration are varied, including video walls, interactive kiosks, plasma/LCD screens hanging from the ceiling, or small LCD screens located at the shelf level, each designed to deliver a focused message to the consumer.

Entertainment

In entertainment venues including sports arenas, sports bars, concert halls, theme parks, and movie theatres, screens are strategically placed to present the visitor with advertisements for in-house products and services, movie trailers, ride information, or live sports feeds. The screens are typically located just above the crowd's eye level for maximum impact. The screens tend to be large plasma, LCD, or LED installations.

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Screen Mounting Locations, continued

Hospitality

In hospitality applications including hotels, cruise ships, resorts, and casinos, screens are placed in locations where visitors can easily interact with them. The screens employed for displaying messaging about amenities or restaurant menus tend to be plasma or LCD and for wayfinding, directions, and local attractions interactive kiosks are employed. The screens are located in lobby areas, walkways, restaurant areas, and, in some examples, hotel rooms.

Education

Educational campuses employ DDS networks to communicate with their students and faculty. Screens, usually plasma or LCD, are located throughout the campus and in each of the buildings providing student information, class schedules, faculty schedules, cultural information and news of the day. In many installations, the DDS network is connected to the campus infrastructure facilitating student message boards.

Interactive kiosks are available in bookstores and student centers for information on current events, cultural events, and wayfinding.

Public Venues

Public venues, including conference centers, government buildings, museums and public parks, are installing DDS networks to interact with the visiting public. The screens employed for indoor applications, typically plasma, LCD, or interactive kiosks, are located in walkways, meeting areas and restaurants. For outdoor applications like public parks or some museums, LED or weather-protected interactive kiosks are employed to provide visitors with directions to attractions and restaurants.

Security Issues

For most installations of DDS networks, control of the content and the network is located at some central location. Each of the servers, players and screens are controlled by this central location or control center. Security becomes and issue because the potential for an external force to invade the DDS network and display messaging that is not intended by the owner is always a concern. However, because most DDS networks operate on standard network protocols (e.g., transmission control protocol [TCP]/IP), tools and firewalls are available to protect the DDS network.

Another aspect of security is physical hardware protection. Components such as computers and display screens are high-value assets and the potential for vandalism or theft is critical to network owners. Mounting brackets and cabinetry are typically employed to protect the screens and computers from the vandalism and theft.

Enhancing Technology

The new DDS technologies can interact with consumers and identify the buying behavior of the consumer and deliver a focused messaged based on the consumer's interest.

The most prevalent of these technologies is RFID. RFID tags are placed on products that are scanned by sensors in the store environment. When a sensor identifies a product a consumer has chosen, a focused message can be displayed on the DDS screen that relates to that specific product. RFID technology also can connect to the store's POS system so inventories can be more effectively managed.

In the future, RFID tags will become an integral identifying technology, allowing retailers to provide products and services customized for each consumer who visits the store.

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Broadband Systems

Introduction

This section outlines the basics of broadband community antenna television (CATV [cable TV]) systems, master antenna television (MATV) systems, and private broadband satellite master antenna television (SMATV) systems.

CATV systems serve both rural and urban areas. They provide a large group of subscribers access to multichannel TV programming distributed over a regional area by a network of coaxial and optical fiber cable. For smaller or private MATV and SMATV cable systems, access to multichannel TV programming is provided to a much smaller group of users.

These systems typically serve the occupants of an office building, industrial facility, school, hotel, or hospital. In this case, the TV programming signals are distributed to the building's occupants through an intrabuilding network of coaxial or optical fiber cables.

Evolution of Community Antenna Television (CATV) Systems

In the past, TV reception was accomplished through an individual antenna that was normally placed on the roof of the home. This method, although popular, had many pitfalls. Broadcasting stations and antenna receivers were often too far away to receive adequate signals. Another area of concern was adequate reception of the signal when there were hills or mountainous terrain in the surrounding area.

In the late 1950s, a better system for TV reception was established—CATV (cable TV). With CATV, transmitting stations using microwave technology could transmit far outside their local area, allowing the signals to be picked up at distant receiving stations and then routed by cable to individual homes. This provided community TV systems with an expanded variety of program services.

The development of communication satellites enabled community systems to receive programs from around the world. The variety of available programming became great enough to be attractive to viewers in large cities, as well as the surrounding areas. At that point, CATV was no longer descriptive of the service and became the accepted nomenclature. In some geographic areas, cable TV has not been installed and may not be practical. In these areas, direct satellite reception provides the only means of receiving the array of stations.

Community Antenna Television (CATV) Architecture

CATV systems are designed to serve individual subscribers within a relatively large region or community, while private MATV and SMATV systems are designed to serve a smaller, restricted group of people, typically in intrabuilding applications. Even though the CATV, SMATV, and MATV system applications are different, their technologies and architectures have many similarities.

Community Antenna Television (CATV) Architecture, continued

The basic analog CATV system consists of two main parts, the headend or main station and the distribution system consisting of trunks, feeders, and drops to the subscribers. Collectively, they provide for the acquisition, processing, and distribution of the required CATV channel signals.

Common components found in a simple RF video distribution system typically include:

- Headend—The location of transmission equipment.
- Modulators—Convert composite or S-video signals along with corresponding audio signals into modulated signals on a carrier channel.
- Demodulator (or tuner)—Strips the baseband signals from the carrier, producing the composite audio and video.
- Combiners—Through multiplexing, combine the individual signals together with a carrier signal to allow for transmission over one cable, constituting a broadband signal.
- Distribution system—Very common and useful method of distributing multiple video signals throughout a facility; the RF video signal topology within the RF distribution system is controlled by splitters, taps, and line amplifiers.
- Splitters—Divide signal symmetrically, sending the entire composite signal down multiple cable paths.
- Taps—Divide the signal asymmetrically, sending part of the signal to a display.
- Line amplifiers—Boost the signal to compensate for cable attenuation.

RF parameters that the AV system designer must consider include:

- Frequency range—When designing an RF system, the maximum number of channels that can be carried by the system must be determined. Channels are expressed in frequency ranges of up to 450 MHz or 900 MHz.
- Signal strength—Signal strength must be managed to ensure that sufficient levels are provided to each destination. Standards organizations provide requirements that govern signal strength at each port and the allowable drop to the next port.
- Cabling losses—Cable attenuation of the signal can be significant and must be accurately calculated when designing the RF distribution system. These losses affect signal strength and vary with frequency. Equalization is used to restore the system to flat frequency response.
- Component insertion loss—Each component in the system, including splitters and other distribution devices, introduces an insertion loss attenuation of the signal for which the design must also compensate.
- Bidirectional subchannels—Sometimes subchannels are used for returning a signal (e.g., a camera feed) back to the headend. Subchannels also can be used for control signals, such as with a media retrieval system, and for cable modem communication. The system must incorporate bidirectional components to enable bidirectional communication.

Community Antenna Television (CATV) Architecture, continued

Headend

The headend of a CATV system is where incoming signals are received. These incoming sources can include satellite, microwave, computer, and off-the-air signals.

The headend equipment is typically housed in a dedicated building. National networks and movie channels are received by the headend through satellite antennas. Local network and community broadcast station signals are received by standard off-the-air TV receive-only (TVRO) antennas, through microwave links from the local stations, or point-to-point (PTP) optical fiber cable. Additionally, special services, such as pay per view (PPV) events and movies, can be placed on the cable system. Special events such as boxing matches are received from a satellite, but PPV movies may either be received from a satellite or played internally and placed on the system.

The carrier frequencies of the off-the-air, satellite, and microwave signals are converted and/or processed and combined in the headend. These carrier frequencies correspond to standard broadcast channels for viewing on cable-ready TV sets. The PPV and premium movie channels are scrambled or masked so that they cannot be viewed. The cable company, using one of several technologies, allows viewing of these channels by the subscriber. The first and oldest technology is a converter box, sometimes called a converter/descrambler, supplied by the cable company.

As the name implies, the converter works to convert a selected basic programming signal or to unscramble and convert a selected premium program signal into a single broadcast channel frequency (typically channel 3 or 4) that can be viewed on the TV.

The conversion is necessary because many CATV channel assignments are different than those supplied from off-the-air broadcast sources. For example, a channel designated as channel 11 in the CATV system may be locally broadcast for off-the-air reception as channel 24. When a converter (set top box [STB]) is used, all channel selection is done through the converter, while the TV set remains tuned to channel 3 or 4. Cable subscribers with older, noncable-ready, TV sets also must use a converter box to view basic CATV programming.

Modulators and Demodulators

An RF system takes composite or S-video signals along with their corresponding audio signals and converts them into modulated signals on a carrier channel. This is achieved by a device called a modulator. Modulators convert standard audio/video inputs to a frequency suitable for local CATV distribution.

A modulator is required for each simultaneous channel that will be broadcast over the network. For example, if two DVDs, one VCR, and five electronic slide presentations are occurring simultaneously, a system with at least eight signal modulators is required. A modulator also may provide the ability to incorporate an additional language into the signal. This is known as second audio programming (SAP). It allows remote selection of the required language through the monitor equipment.

Community Antenna Television (CATV) Architecture, continued

Demodulator and modulator pairs are sometimes used to convert off-the-air received VHF or UHF channels to a different output channel in the broadcast or CATV band. This is done by connecting the outputs of an agile demodulator unit to the input of a modulator unit.

Processing of the selected off-the-air received channel signal in the demodulator removes (demodulates) the carrier leaving the baseband (unmodulated) audio and video signals for output. The type of circuitry used to demodulate the signal depends on the method used to initially modulate the applied input signal. Typically, it is done by downconverting the channel input signal to an intermediate frequency (IF) signal and then detecting the IF signal in separate audio and video detector circuits to remove the carrier frequency. The resultant baseband audio and video signal outputs from the demodulator are then applied to the modulator, where they are modulated onto a new carrier to produce an output signal at the required broadcast or CATV channel frequency.

The modulator unit described here is commonly used separately in several other processing activities where baseband signals must be converted to a single broadcast or CATV channel. They are used to process the baseband audio and video signal outputs applied from satellite receivers, stereo encoders, VCRs, and similar equipment. Controls on the modulator provide adjustment for the audio and video modulation, audio/video ratio, and the output level. The audio and video modulation controls adjust the sound and picture brightness levels. The audio/video ratio control, sometimes called the aural level control, adjusts the level of the audio carrier relative to the video carrier.

A combiner, through multiplexing, then puts a number of modulated signals together. These signals combined together onto one cable constitute a broadband signal. The broadband signal is transmitted to its destination over coaxial cable. This process occurs at the headend where all of the transmission equipment is located. At the destination, a demodulator (or tuner) strips the baseband signals from the carrier, providing the composite audio and video again.

For example, multimedia message service (MMS) may incorporate content from the local cable or TV franchise or from an antenna. For this content to be rebroadcast over the local video network, it must first be converted to a baseband signal and then remodulated onto the video network. A demodulator converts a broadband source input (i.e., channel 12) from some other source, to baseband output. AV equipment, such as a VCR with a tuner, may be used as a demodulator. Dedicated hardware may be installed as an alternative.

Distribution System and Subscriber Drops

Cable TV signals processed in the headend are applied to the distribution system consisting of a combination of trunk, feeder, and drop cables. These can be run overhead, underground, or both. Trunk cables supply the signals from the headend to large portions of the CATV system network, such as an entire neighborhood. There, the trunk connects to multiple feeder cables that further distribute the signal along the paths of the individual streets, and then to drops that feed the individual homes that have subscribed to the cable service.

Community Antenna Television (CATV) Architecture, continued

Typically, the distribution systems use coaxial cable. However, the use of optical fiber cable for trunk distribution lines is becoming more popular. This is because optical fiber cables have lower loss, can carry more signals, and have the capability of carrying other communication signals on the same fiber in addition to the CATV signals.

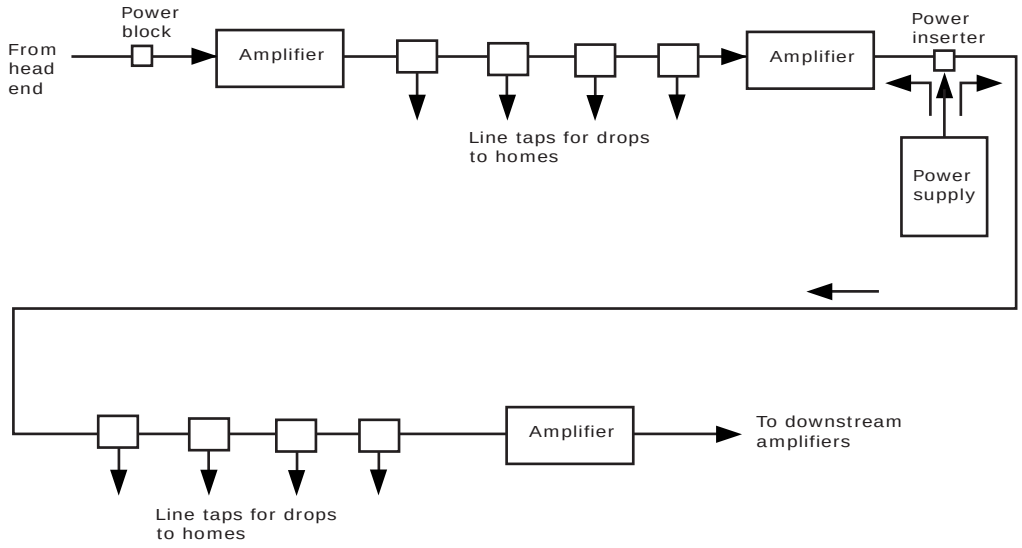
Ideally, a signal injected into the system network at the headend and transmitted through the entire distribution cable network would emerge at the subscriber's home with no loss of signal strength or quality. However, this is never the case because no practical system can be perfect.

Optical fiber cable provides the least loss and attenuation, but all signals carried through coaxial or optical fiber cable suffer from various signal losses and attenuations as they pass through the system.

Therefore, it is necessary to compensate for these inherent factors in such a manner that the signal tapped off the network at any point can supply a high-quality TV signal.

Signal loss in CATV distribution systems is compensated by the use of line amplifiers (see Figure 17.36).

Figure 17.36
Simplified distribution system



Community Antenna Television (CATV) Architecture, continued

Amplifiers are usually placed at intervals of several thousand meters or feet in a distribution system covering a typical neighborhood. The amplifiers are generally powered by 60 Vac or 90 Vac that is injected into the coaxial cable by a power supply. Filter chokes prevent the TV signal from being connected (short-circuited) to the power supply. In practice, only a segment of the system is energized by a single power supply.

Power block devices are used to prevent cross connection between power supplies. The power inserter allows the power supply to feed the cable distribution system. Suspended line drops to homes or commercial buildings are typically made using CATV rated or radio grade (RG) 6 coaxial cable (now called Series 6 cable) with either an integral steel messenger or a copper-coated steel center conductor that provides cable support.

Master Antenna Television (MATV) and Satellite Master Antenna Television (SMATV) Architecture

Private MATV and SMATV systems can range from basic residential installations to large, professional installations similar to CATV installations.

The professional systems are primarily used in commercial or institutional installations, including schools, hospitals, prisons, and hotels/motels. Some exist in a multibuilding campus such as a university, major medical center, or apartment complex.

The architecture for an MATV system is the same as for the SMATV system, with the exception that the headend of the MATV system does not receive the satellite antenna input. A feed from a CATV system may be included. Locally generated programming signals may be applied in the headend for processing. Devices such as video cameras, VCRs, DVDs, laserdisc players, and character generators can generate these programming signals.

MATV/SMATV systems consist of two main sections, the headend and the distribution system, consisting of trunks, feeders, and building room taps. In these systems, the headend and distribution components are typically housed within the same building. The TV signals processed in the headend are distributed to the building room taps through the trunk and feeders, in the same way as previously described for a CATV system.

Amplifiers are installed where required in the system to boost the signal strength to ensure a high-quality TV signal. The amplifiers and other equipment used in the distribution system of MATV/SMATV systems perform the same functions as the similar equipment used in a CATV distribution system.

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Broadband System Basics

The designer should gain a basic understanding of the following concepts when working with broadband CATV systems:

- Frequency spectrum
- TV channels
- Metric system prefixes
- Scientific notation
- Units of measurement
- Symbols

Frequency Spectrum

In the United States, designated portions of the RF spectrum ranging from 5 MHz to 1 GHz are allocated by the Federal Communications Commission (FCC) for TV channel assignments used for over-the-air broadcast TV and CATV. Each assigned channel has a bandwidth of 6 MHz. The FCC also has allocated specific frequencies in the frequency range from 0.95 GHz to 23 GHz for use by other communications systems and platforms.

Television (TV) Channels

In the United States, each 6 MHz wide TV channel is formatted in accordance with the NTSC standard. The color burst and sound carriers are 3.58 MHz and 4.5 MHz, respectively, above the video carrier. The sound carrier has a frequency modulation (FM) of 50 kHz (±25 kHz) signal. The video bandwidth is 4.2 MHz.

High Definition Television (HDTV) Channels

The TV broadcast industry and consumers in the United States are in the early stages of a transition from NTSC-formatted analog TV signals to digital HDTV signals. Digital HDTV provides for a TV presentation with higher resolution and clarity, wider screen pictures, and better sound when compared to present day analog NTSC systems.

HDTV broadcast signals are made up of coded digital instructions that are decoded by an HDTV receiver or an HDTV converter. To be a true HDTV signal, the signal format must meet the Advanced Television Systems Committee (ATSC) standards for HDTV. Since the transition to HDTV affects broadcasters, cable companies, and consumers, some important points about the transition to HDTV are that:

- Broadcasters have to purchase many new equipment items, such as cameras, remote broadcast units, control rooms, cables, and sound equipment.
- Cable operators must convert their headend equipment and all of their TV set converter boxes.
- Consumers must buy either a digital HDTV set or a special D/A converter to convert received HDTV digital signals into analog signals for viewing on an analog TV set.

Broadband System Basics, continued

The converted HDTV programming on an old analog TV set loses the resolution, format, and other benefits obtained by using a TV set specifically designed to display HDTV signals.

Today, many broadcast stations are already transmitting a limited number of HDTV programming channels. The transition from analog TV to digital HDTV is expected to take several years to complete. During this transition period, most broadcasters will continue to provide standard NTSC analog transmissions along with steadily increasing digital HDTV transmissions. Eventually, the analog transmissions will be phased out completely. In this regard, the federal government is encouraging broadcasters and consumers to adopt HDTV as quickly as possible, so that the analog transmissions can be completely phased out.

Satellite Technology

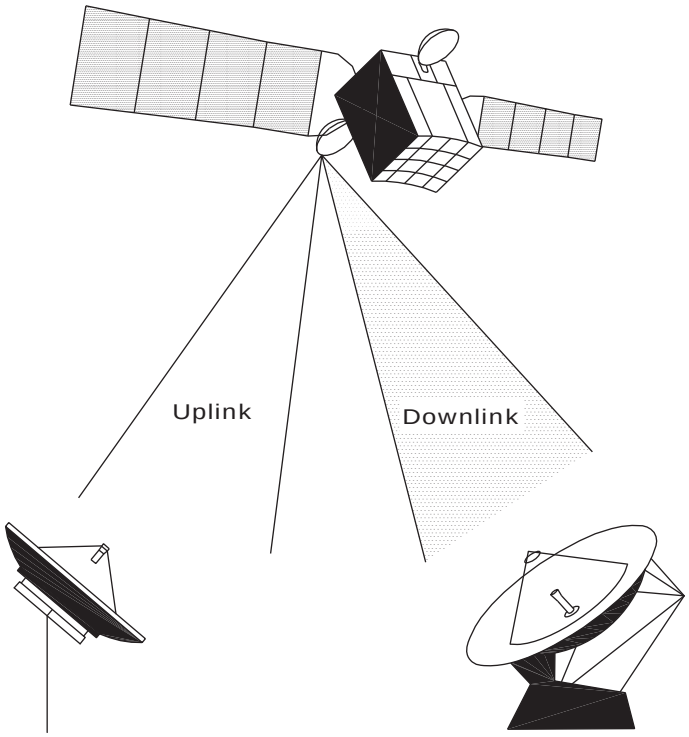
CATV and SMATV systems receive and process signals from satellites. Satellites were first used in the 1970s for the transmission of TV broadcasting to and from networks , to cable systems, and then directly to individual subscribers. Today, satellites are indispensable for the transmission and distribution of video programs and for industrial applications including security and surveillance.

In a basic satellite system (see Figure 17.37), Earth stations uplink (transmit) a video signal to a satellite by a narrow radiated beam. The satellite receives this signal, amplifies it, shifts the frequency to a downlink frequency using a transponder, and retransmits the downlink signal to the Earth at the same time.

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Satellite Technology, continued

Figure 17.37
Basic satellite system



Downlink Signal Parameters

A downlink signal covers an area on the earth known as the satellite's footprint. Three general types of uplink/downlink configurations determine the footprint of the downlink. They are:

- PTP—This configuration is used primarily for commercial communication carrier systems.
- Point-to-multipoint—This configuration is the one primarily used for satellite network broadcast TV or radio purposes. Various commercial network signals are transmitted from specific spots to a satellite. The signals are then rebroadcast to broad areas on the Earth for reception by commercial TV over-the-air broadcasters, commercial CATV systems, private MATV systems, home direct broadcast service (DBS), or other TVRO satellite antennas and receivers.
- Multipoint-to-point—A configuration used for a very small-aperture terminal (VSAT) where mobile or fixed station POS terminals or monitoring equipment are linked to an office through small to medium satellite antennas.

Such systems are typically used by gas stations, stockbrokers, commodity traders, and other businesses.

Headend Signal Processing

The headend consists of receiving and processing equipment required to electronically prepare selected off-the-air, satellite, and locally generated signals for application to the distribution system.

Headend systems sometimes use modular-type equipment to conserve space. In such systems, one or more rack chassis are populated with a variety of modular components.

Processing of the signals in the headend involves:

- Amplification of the off-the-air, satellite, or local signals.
- Rejection of co-channel and other spurious signals.
- Frequency conversions.
- Combining and splitting of signals.
- Generation of local signals.
- Signal gain control and balance.
- Control of in-channel audio carrier levels relative to the video carrier levels.
- Scrambling of premium program signals.
- Descrambling of satellite program signals.

The specific types of equipment used in the headend are determined by the source and frequency of the input signals and the output requirements. The equipment configuration can range from simple to complex.

With the exception of cases in which no satellite input or related equipment is involved, the headend of a professional MATV system is similar. The signal processing activities within the headend typically include:

- VHF off-the-air signal processing.
- UHF off-the-air signal processing.
- Satellite signal processing.
- Locally originated channel signal processing.

Headend Signal Processing, continued

Very High Frequency (VHF) / Ultra High Frequency (UHF) Off-the-Air Signal Processing

With the exception of the frequencies involved, processing of off-the-air VHF and UHF signals is performed in the same way. VHF frequency (54 to 88 MHz and 176 to 216 MHz), and UHF frequency (470 to 806 MHz) off-the-air broadcast channels, are received by high gain VHF and UHF antennas, respectively. These antennas can be either single channel or broadband antenna types. Low-level signals received by each of the antennas are applied through coaxial cable to the input of a low-noise preamplifier. Its function is to amplify and improve the signal-to-noise ratio (SNR) of the received signals to the level required for input to the processor. The preamplifiers are normally mounted on the related antenna mast, as close as possible to the antenna. Amplified VHF or UHF signals at the outputs of the preamplifiers are applied through coaxial cables to the associated processor units. Power for each of the preamplifiers is provided by a standalone DC power supply usually located in the headend building.

The power supply output is simultaneously applied through a power inserter onto the same coaxial cable that carries the VHF or UHF signal from the preamplifier to the processor. This arrangement eliminates the need for running a separate power feed cable from the power supply to the preamplifier.

The processors that receive the off-the-air VHF or UHF signals from the preamplifiers perform several functions. These functions include signal amplification, rejection of unwanted adjacent channel signals received by the antenna, precise signal level control, audio carrier level control, and generation of output signals at the required broadcast or CATV channel frequencies.

There are many different types of processors. The type used depends on the system requirements. Processors can range from the simplest type, called strip amplifiers, to the most sophisticated types, called frequency-agile processors.

Strip amplifiers are single channel amplifiers designed to receive a single VHF or UHF channel input and provide a single-channel output with no change in frequency. Frequency-agile processors have the capability to select any input VHF or UHF channel and provide an output at any other broadcast or CATV channel frequency. Other processors have channel selection capabilities ranging between the two. Each processor has output gain adjustments and input automatic gain control (AGC) circuitry that control the level of its output signal.

Headend Signal Processing, continued

The balanced signal outputs from all of the VHF or UHF processors are applied to combiners, where they are combined with each other and with the signals being generated by the satellite and local origination equipment. This produces the broadband output signal for application to the distribution system. If the headend output is applied to a distribution system with a coaxial trunk cable, the broadband signal output from the final combiner is applied to a post amplifier, sometimes called a launch amplifier. There, it is further amplified to a level sufficient to drive the trunk cable. If the headend output signal is applied to a distribution system with an optical fiber cable, the output from the final combiner is applied to an optical fiber transmitter to drive the optical fiber cable.

Locally Originated Channel Signal Processing

Processing of signals from local origination equipment, such as TV cameras, VCRs, laserdiscs, character/graphic generators, and similar devices, is often done to provide additional channels of prerecorded programming. Baseband audio and video signals generated by each of these devices are applied to related modulators. They accept the baseband audio and video signals and amplitude modulate them onto a carrier with a frequency for one channel within the CATV frequency range. The output signals from the modulators are equalized and multiplexed with those from the VHF/UHF and satellite signal-processing equipment, through combiners, for application through the launch amplifier to the distribution system.

Baseband versus Broadband

Baseband video and broadband video are terms often used to describe RF video systems. A baseband video signal is transmitted in its original form and not changed by modulation. Composite and S-video are examples of baseband video. It is the raw signal directly from the source and usually found as only one signal per wire.

Broadband (RF) video is multiple channels of baseband video. The baseband signal is combined with the accompanying audio signal onto a carrier frequency. The carrier frequency is modulated. The modulated video signal is degraded about 50 percent from the composite baseband signal.

An RF system may typically be broken down into two major sections: the headend and the distribution system.

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Baseband versus Broadband, continued

Distribution System Design

Distribution system design is a combination of cable layout and signal strength management. Typically, an RF distribution system is designed before the headend to ensure an adequate signal will be delivered to the receiver and to determine the type and size of the amplifier that will be necessary at the headend to generate that signal.

The coaxial cable that carries the signal away from the headend toward the receivers is called the trunk line. An RF system is much like a tree, with a main trunk cable off which branches, called taps, are taken.

Combiners, Splitters, and Taps

Combiners are used to take the balanced outputs from multiple processors and modulators and combine them into a single output signal for application to a post amplifier and the distribution system. Combiners commonly have 8, 12, or 16 inputs, called ports. Some can have frequency selective band filtering on the combiner inputs.

Two types of combiners are passive and active. Passive combiners only combine the signals, while active combiners combine and amplify the signals. Active combiners are designed to have unity gain (i.e., a gain of 1). This means that the amplification gain within the unit is only enough to overcome the loss of the combiner. Passive combiners are commonly used as splitters and splitters as combiners.

A splitter is a passive device that takes a signal and splits it into two or more lower-level output signals. Splitters are commonly made in 2-, 3-, 4-, and 8-way models. With the exception of a 3-way splitter, the output signal levels from splitters are all equal. With the three-way splitter, only two of the output signals are equal; the third is at a lower level.

To spread the signal to a wider area, line splitters are used. A splitter divides the signal symmetrically, and is available in 2-, 3-, 4-, 6-, and 8-way splits. Splitters divide the input signal equally, providing the same amount of signal at each output of the splitter.

Baseband versus Broadband, continued

Splitters are bidirectional devices. They are used in two ways. Information can be sent through the coupler and split into two paths. A hybrid splitter/combiner receives two signals and combines them onto one output.

Important combiner and splitter parameters include their insertion loss and port-to-port isolation. Insertion loss or through loss is a measure of the attenuation encountered by a signal as it passes through the combiner or splitter. The lower the insertion loss, the better.

Insertion loss is expressed in dB. Isolation, also expressed in dB, is a measure of the signal attenuation encountered by a signal from one port to another. The better the splitter, the higher the isolation. High isolation between ports reduces the amount of signal feedback from one port to the other.

Taps are used to siphon a portion of the signal from the trunk line. Taps are installed periodically through the facility at the location of tuners. All of the energy on the main trunk line passes through the tap, sending a small portion of the signal to the tuner and passing the major portion of the signal further down the line.

Cable and Connections

RF systems are wired with coaxial cable. Series 11 (RG-11) is typically used as the trunk cable because of its lower loss specification maintaining signal strength for the longest part of the run. Tap lines may be Series 6 (RG-6) or Series 59 (RG-59) depending on length.

Using RG-6 saves about 0.3 dB in loss per 30.5 m (100 ft) over RG-59. Physical termination of coaxial cables and F connectors can be made with a hex-type crimp. The cable's solid center conductor acts as the F connector's center pin.

A good solid crimp avoids an impedance mismatch. The threaded type of F connector should be used for best connectivity. The F connector is inserted over the appropriate input or output and a solid connection is established with a wrench. With the looping video, the signal is terminated only at the end of the distribution chain. A similar electrical termination is performed in RF video distribution. The end of each distribution cable, all of the unused ports on splitters, and open taps and splits must be terminated with a 75 ohm terminator (resistor). This stops the signals from traveling back up the line and causing ghosts and color smear. A resistor must be added to all of the unused ports on a splitter.

Signal Measurement

RF signals are measured in decibels millivolt (dBmV) and characterized by the following measurements:

0 dBmV = 1 mV of signal level

+60 dBmV = 1000 mV (1 V) of signal level

Baseband versus Broadband, continued

In the United States, the FCC states that the minimum signal level at the receiver should be 0 dBmV. A typical receiver should receive between +5 dBmV and +10 dBmV. A +10 dBmV RF signal is a little greater than 3 mV, which represents a small signal level requiring sensitive receivers.

RF signals can be measured using an RF spectrum analyzer, system analyzer, or automated test instrument designed for this purpose. The target signal level for the tuner is between +5 and +10 dBmV.

In an RF video distribution system, splitters are used to send the signal in more than one path. Every time a splitter is used, a measurable amount of signal is lost as a result.

Another element causing slight signal loss is a tap. Taps mark the locations in the signal path where part of the signal is split off and sent to a tuner. Splitters and the taps are rated to specific dB values. The dB ratings on these components represent the loss that occurs between its input and the connection of a tuner. In a typical system, the highest dB tap values will be closest to the headend and the numbers will decrease the further away the signal travels.

Signal Loss Causes

Five types of signal loss in a distribution system are:

- Cable loss—Signal loss through the cable is the first area of concern. The amount of this loss is dependent on the cable type used and the frequencies of the signals carried. The higher the frequency of the signal, the greater the loss.
- Temperature loss—Temperature also affects the cable signal loss. Typically, signal loss is measured at 20 ºC (68 ºF) ± 5.5 ºC (10 ºF).
- Splitter loss—Once a signal is split, signal loss is generated. When a splitter is inserted in the line, splitter loss or pass through loss is generated. If a two-way splitter is used, 3.5 dB through loss is generated on each branch or port; if a four-way splitter is used, 7 dB through loss is generated on each branch.
- Insertion loss—Each time a signal is tapped, signal loss is generated and taps exhibit two losses. The first is called insertion loss or feed-through loss. Insertion loss is the loss of signal as the trunk or distribution line travels through the tap. These losses vary by device.
- Isolation loss—Also called tap-off loss, this is an intentional attenuation of the trunk line signal to a level suitable for input to a TV or other RF receiving device. The resulting signal level should be in the 5 to 10 dBmV range.

Baseband versus Broadband, continued

Directional Couplers

Similar to splitters are directional couplers, devices used to connect two parts of a system together with a signal path in only one direction and providing isolation of the two systems. A directional coupler is used when the headend sends a signal in one direction, while a signal intended for only the headend travels on the same cable.

A directional coupler removes a specific portion of the main trunk line signal for output at one or more ports, typically to supply feeder or drop cables. Directional coupler parameters include insertion (through) loss, tap value, and isolation between the tap and through or output-and-through ports.

Like a directional coupler, a tap is used to split off a portion of the signal, usually for application to a subscriber's drop cable, while allowing most of the power to pass through to its output. Some taps are made with multiple tap ports with different isolation values. This is done to accommodate different drop distances along a trunk or feeder cable. As the distance from the headend or from a trunk line amplifier increases, the signal is attenuated more, resulting in the need to tap off a larger percentage of the signal. This is necessary to provide the subscriber with a signal level equal to that received by subscribers closer to the headend or line amplifier. Tap parameters include insertion loss, tap value, isolation between taps, and isolation between the tap port(s) and the output port.

Amplifiers

Common systems typically include an amplifier in the headend and other amplifiers in the distribution where required to boost the signal. This design is commonly used in CATV systems and in larger private MATV/SMATV systems.

Most amplifiers have built-in gain and slope controls used to adjust the maximum gain and slope of the output signal. Slope control circuits in the amplifier insert attenuation in the signal path to control the gain of the output signal so that the gain increases continuously, starting with the lowest channel frequencies and moving toward the highest channel frequencies. This is done to compensate for unequal signal losses of the amplifier's output signal as it passes through the distribution system coaxial cables. While passing through coaxial cables, higher channel signals encounter greater losses than do the lower channel signals. As the channel frequencies increase, so does the signal loss. This condition is called signal tilt (also known as cable tilt, corrected by the slope control).

All amplifiers contain circuitry to minimize signal distortions that can be generated within the amplifiers themselves. Unless suppressed in the amplifier to acceptable decibel levels, typically in the -50 to -70 dB range, these distortions (e.g., composite second order [CSO], composite triple beat [CTB], cross modulation [XMOD], and hum) can result in an undesirable TV picture.

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Baseband versus Broadband, continued

Antennas

Broadband and single channel TV antennas are the two main types of off-the-air TV receiving antennas. The typical residential receiving TV antenna is the broadband type. This antenna is optimized to receive low-band VHF (channels 2 through 6), FM, high-band VHF (channels 7 through 13), and UHF signals.

Antennas of this type usually consist of two antennas mounted on the same bracket—the VHF frequency band of 55 to 88 MHz and 176 to 216 MHz on one set of elements and the UHF frequency band of 470 to 890 MHz on the other, making up the all-band antenna. This type of antenna is more or less directional, depending on the number of antenna elements used. If stations are located more than 274 m (900 ft) apart, an electric rotation system is required to turn the antenna toward the station.

Commercial receiving antennas used for off-the-air broadcast TV signal reception in CATV, SMATV, or MATV installations are heavy-duty versions of residential-type single channel or broadband antennas. These antennas are made of thicker and heavier materials and are mounted on square beams that can withstand up to 201 kilometers per hour (km/h [125 miles per hour (mi/h)]) winds and substantial ice loads.

The orientation of commercial antennas remains fixed once they are initially positioned for best signal reception. Various mounting frames also are available to accommodate different tower and mast mounting configurations. Professional single channel VHF antennas are designed to optimally receive one selected low-band VHF, low-band VHF and FM, or high-band VHF signal. UHF antennas are typically made to optimally receive selected groups of UHF channel frequencies. For example, a particular UHF antenna may be designed to receive channels 14 through 19 or channels 20 through 26. Broadband VHF or UHF antennas are designed to receive all the VHF or UHF channel frequencies, respectively.

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Chapter 18
Venues

Just as systems build on components, venues typically comprise multiple systems. The audiovisual (AV) designer may be required to design for a variety of venues. Each one has its own unique considerations and challenges. This chapter seeks to highlight some of those considerations by looking at each venue type separately.

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Overview

When designing an audiovisual (AV) system to function within a specific venue, the designer must consider a wide range of factors that will affect the selection of AV components and the installation requirements.

AV designers are typically tasked with designing an AV system that meets the presentation requirements for a specific room. The purpose of a specific room affects the designer's approach to the AV system design. For example, boardrooms have different requirements from classrooms, which are different from conference rooms.

This chapter is intended to provide the designer with a basic understanding of typical AV systems found within a particular venue. In addition to this system overview, some typical issues or problem areas are addressed. These venue descriptions are not a step-by-step guide to specifying a complete AV system; however, they should provide a solid foundation with which to pursue further information.

Designing Primary and Secondary School Audiovisual (AV) Systems

Introduction

Schools have long been challenged to provide an efficient learning environment for children. With hundreds and, sometimes, thousands of children in a single location, the issue of communications is very important for efficiency both in learning and in safety.

Schools have turned to electronic systems to provide a means to communicate with the staff and students. These systems include centrally controlled clocks, scheduled bells, voice intercom/paging, television (TV), telephone, and computer data networks. The issue of safety also is addressed with electronic systems for fire detection and signaling, video surveillance, security and intrusion detection, and emergency call systems.

Although school designs and philosophies have changed over the years, the use of clocks, bells, and sound systems are still crucial methods of communicating with the classroom during school hours. The design of the systems has changed drastically over the last 15 years to integrate the functions of these, once standalone, systems and many useful features have been added.

Intercom/Paging System

Primary and secondary schools have used intercom/paging systems to communicate internally for more than half a century. The concept of the system was to provide the school's administration a way to communicate through voice with the classrooms. This was accomplished using a loudspeaker in the classroom and a master station in the main office.

The teacher could stand anywhere in the classroom and communicate with the office through the loudspeaker, minimizing any interruptions to their teachings. The classroom loudspeaker served a dual purpose, becoming the classroom microphone when the master station was in the listen mode. The other main purpose for installing these systems was to deliver all-call paging announcements throughout the facility.

Most systems are now microprocessor controlled, with software-programmable features such as zone assignments, off-site programming/diagnostic capabilities, and emergency signaling capabilities.

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Intercom / Paging System, continued

Zones divide the facility into areas (e.g., all common areas, hallway B, and playground). The zone capacity depends on the facility use. Some systems have 32 or more independent zones each for paging, music distribution, or time tones. The more zones, the more flexibility the facility has in case of change. Not only are these zones used for delivering voice announcements to specific areas, they are also used for sending time tones for class changes to different areas.

Class change tones, through the intercom/paging system, have supplanted mechanical bells as the preferred method to signal period changes in today's schools. An integral master clock, with multiple schedules, controls the timing and distribution of the tones as desired by school administrators. Outboard master clocks may be added to existing systems, acting as an audio source to the intercom.

Security Systems

Security plays an ever-increasing role in school design because of the chronic need to secure the building from intruders and to alert staff and students of imminent danger.

Entrances may be equipped with intercom stations and security cameras, providing the staff with both the audio and the visual communications to these locations. Visitors initiate a call to the office using the intercom system and a camera provides a visual image simultaneously. Once the visitor is identified, the door release functionality built into the intercom system allows access.

Studies show that school violence is most likely to occur where students are congregating under little or no supervision. High risk times are before and after school, during lunch time, and during class change. Strategically placed video cameras allow these areas to be visually monitored and audio can be captured using intercom stations. This allows the staff to monitor and then act upon a potential incident.

With the increasing need to provide a high level of security for both staff and students, the intercom/paging system has evolved into a significant element in addressing violence and vandalism. Key susceptible locations are school entrances, hallways, and locker areas, cafeteria and common areas, as well as classrooms.

The areas prone to potential problems can be equipped with emergency call points. In the event of an incident, the call point provides an instant method of signaling the office. When interconnected with the video surveillance system, the incident can be monitored and recorded automatically.

Security Systems, continued

Security issues are causing schools to practice lock-down drills in which the intercom/paging system is vital. If an intruder is identified inside the building, a system that signals and alerts staff of the condition can be used. This signaling can be done discreetly, using tones through the speakers or with emergency signaling displays (ESD) that give alphanumeric information about the situation.

Ensuring that the intercom/paging system is capable of this type of signaling is crucial. In the event of a serious condition in a school (e.g., a hostage situation), the police can use the intercom system by calling into the system from an off-site telephone monitoring the events in a classroom. They can even have then ability to establish two-way communications with the besieged location.

Master Clocks

Clock systems are very common in primary and secondary school environments. Schools should ensure that all clocks are the same time and also match the time tones for class changes. This is why ensuring that the clock system and intercom/paging system are synchronized is critical.

Intercom/paging/clock systems allowing synchronization with the nationally recognized time-keeping sources (e.g., global positioning system [GPS], atomic clock, and internet time sources) will guarantee that the time is always accurate.

A variety of clock styles is available. Analog clocks have been the most commonly installed over the years. Digital clocks are a good fit as well, and are normally easier to maintain than analog because they have less moving parts. Some intercom/paging manufacturers use ESD, which also double as digital clocks. In this way, the ESD can be used as the digital clock in the absence of emergency. Clock systems normally last 10 years or longer. The designer should make the best effort to envision how the environment may change over that time.

Systems that are local area network (LAN)/wide area network (WAN) compatible for programming, and even communications, are preferred because most school districts have strong LAN/WAN infrastructure. Systems that can offer voice over Internet protocol (VoIP) intercom stations and phone integration could prove advantageous for future use.

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Media Retrieval Systems/Video on Demand

Media retrieval systems/video on demand are a type of centralized systems rapidly replacing the cart-mounted TV and videocassette recorder (VCR)/digital versatile disc (DVD) units.

Instead of having to locate the cart and then obtaining the presentation media from the media center, the teacher can use the classroom telephone, TV remote control, or computer to access preloaded presentation material directly from the media center and have this material sent directly to a classroom's permanently mounted TV or projector.

These centralized systems operate over either category 5e or coaxial cable.

Commands can be sent by the teacher to the centralized system to perform all of the functions of a VCR/DVD (e.g., rewind, fast forward, play, stop, and pause). The media center staff can preload the presentation material for the teacher in a specific VCR/DVD. The request for material is usually made by e-mail over the school's network.

As the systems become more complex, less human intervention is needed in the media center and presentation material can be automatically retrieved and sent to the requesting classroom.

These systems also may prevent copyright infringement issues. A centralized system only allows the use of material that is authorized by the media center.

The first step in the design and integration of these systems into the school's infrastructure is a needs analysis. This can be done on an individual school or a school district-wide basis. Budgetary concerns play an important part in the choice of a particular system or topology.

Auxiliary Sound Systems

Larger spaces within schools often have their own, standalone, sound systems. Secondary schools often have separate systems for the auditorium, gymnasium, cafeteria, and media center or library. Primary schools may combine these functions into a single space.

Secondary school auditoriums have become quite sophisticated due to the complex productions staged. These systems have the same requirements as a performing arts center, though typically at a slightly smaller scale. Refer to the section titled Designing Performing Arts Audiovisual (AV) Systems in this chapter for more detail on the typical systems found within this type of venue.

Designing College/University Audiovisual (AV) Systems

Introduction

For approximately 10 years, colleges and universities around the world have been committed to creating state-of-the-art learning environments enabled with modern AV technologies. To complement computer networks and the Internet, facilities are built and retrofitted with presentation and interactive equipment for classroom and individual use.

New types of facilities, such as multimedia centers and laboratories, multimedia auditoria, computer labs, and production studios are created to complement the classroom activities. This integration of the converging educational technologies of video, multimedia, and electronic communications is challenging the traditional libraries and classrooms of the past, and posing new goals for administrators and faculty alike.

College and university administrators seek out and appreciate technology designers who provide a holistic approach to facility programming, taking the concepts described in this chapter into consideration.

Audiovisual (AV) Technology in Education

An educational system is an integral component of any society and it is embodied in the society's schools, colleges, and universities. The daily requirements of school operation are similar to those of any business administration, supporting the specific tasks of the classrooms and education professionals. The role of the classroom, however, is unique to schools and so are its requirements for productivity.

Teachers have quickly embraced the full array of communications technologies, and AV systems are no exception. Classrooms have always required support equipment to present lessons, communicate, document, and administer tests. Now a wide variety of AV capabilities also are becoming commonplace as their usefulness is discovered.

Considering the traditions, established practices, prohibitive costs, and classroom etiquette, however, many of the newer media technologies taken for granted in the corporate and entertainment environments are only now being implemented in the classrooms. Significant interest in funding these technologies has created a dramatic increase in their implementation that is, in many cases, faster than they can be embraced and adopted by instructors.

The shift towards modern AV equipment in schools has been fueled by several distinct, yet related, technology trends. The first was towards the use of video displays, as opposed to film projection. Affordable video projectors were not available for this purpose until the business world created sufficient demand for them. Likewise, the use of chalkboards and slide projectors has shifted towards the electronic media of personal computers (PCs) and document cameras.

Audiovisual (AV) Technology in Education, continued

Then, businesses required an easy-to-use presentation tool, and presentation programs, particularly Microsoft® PowerPoint®, filled this demand. Finally, the possibility of integrating all of these diverse components was not possible until the broader market created sufficient demand for affordable AV control systems.

These core technologies provide the basis for every electronic classroom in existence today. Design creativity comes into play when these core technologies are configured and interconnected with ancillary systems such as data networks.

Uses of Audiovisual (AV) Technology in Colleges and Universities

AV and information technology (IT) have become so prevalent in today's schools that they are used in a wide variety of spaces and purposes. The scope of the designer is to incorporate the requirements of all of these educational purposes.

With the large amount of technology required, the costs of the systems must be carefully analyzed and budgeted for. Addressing the different technology aspects in each classroom and planning a facility from an interconnected point of view may realize cost savings and operational efficiencies. This control on spending is important to administrators, taxpayers, students, and beneficiaries.

Furthermore, new synergies in media usage may be realized, allowing educators to reach new levels in effective teaching. AV designers should recognize the following purposes of their systems and how each of these becomes part of a greater system:

- Teaching
- Collaboration
- Production
- Communication
- Archiving
- Testing and examination
- Envisioning

Teaching

Classrooms are equipped with AV equipment capable of presenting produced media to students in a live environment. Classrooms are designed to maximize the effectiveness of electronic media using videographic projection or other display technologies. Instructors are able to preview and teach the multimedia-enabled presentations they created. Students are able to experience the latest teaching techniques including interactivity and conferencing.

Uses of Audiovisual (AV) Technology in Colleges and Universities, continued

Accommodations are made for the disabled, with improved access, auditory assistance, and other services. Audio systems complement the videographics systems, with speech reinforcement integrated into larger spaces such as auditoriums. Sophisticated classroom systems may include additional features such as student response keypads, annotation over the displayed images, multiple displays, and networked group interaction systems.

Collaboration

Today's interrelated media technologies require a variety of skills in the fields of video production, audio and music production, multimedia authoring, computer programming, graphics design, and other types of programming. Combining these technology capabilities with a professional staff, teachers, and students are enjoying an environment of creativity and inventiveness not possible in a traditional academic building.

Many of the educational models that encourage interdepartmental learning are enabled through media productions. The use of multimedia correlates well with interdisciplinary curriculum tracks. The use of collaborative conferencing on a Web- or distance learning-based scale capitalizes on the technology and allows new ways of teaching and learning not possible in a traditional classroom setting.

Production

Schools and campuses now include computer graphics and production labs, audio and video production and post-production studios, and preview spaces to provide the programming for instructional and entertainment video systems. These are at the heart of the media-enabled facilities, fueling the creation of materials for teaching, informing, and entertaining.

These complex materials enable students and teachers alike to become part of the development of courses delivered partly or wholly through multimedia. New professions are required to support this collaboration between individual instructors, their students, and across departmental boundaries. These professionals include instructional designers, graphics designers, audio and video producers, and AV systems support personnel.

Communication

Ultimately, programs created from the production and preparation areas are distributed over high-bandwidth computer networks and/or traditional cable TV networks. The interconnection of the laboratories, studios, classrooms, dormitories, and offices throughout campuses are as sophisticated as the work areas to allow easy access and transmission of the programs' components.

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Uses of Audiovisual (AV) Technology in Colleges and Universities, continued

Connectivity beyond the campus is equally important, allowing cooperation between schools, off-campus students and parents, and the wider community. Centralized control over these networks is common, with server farms and multimedia distribution systems connected together to facilitate and monitor cable channels, network traffic, and system performance. Administration of media issues such as copyright conformance, access, security, cost centers, and help desks also may be handled through the centralized media center.

Archiving

An important part of any production effort is the archiving of the material within environmentally controlled spaces. Videotapes, discs, computer data storage, and other media must be stored in an organized and easily accessed manner, both in physical and virtual space.

This role has traditionally fallen to the library, which continues to provide an integral service to the academic community. More recently, much of the archiving activity is relegated to servers accessible through the Internet, the gateway to these media centers.

Testing and Examination

Educational facilities often feature classrooms and halls equipped specifically for testing. This feature enriches the students' option to take tests locally and alleviates some of the faculty's scoring and evaluating burdens.

Testing may be administered in groups or individually, with different technologies supporting the requirements of each type of test administration. Enabling technologies include interactive systems that allow group or individual evaluation, with anonymous or individually logged results.

The same facilities may be used by instructors who have incorporated student interactivity into their courses, wherein frequent quizzing of the students ascertains the students' understanding and learning pace.

Envisioning

Conference rooms, offices, and common areas are designed to take advantage of the mingling of talents and interaction with the readily available media technologies. Acknowledgement of the needs of the community, including multicultural and age disparities, enriches the establishment.

Visionary thinking and collaboration is the future of education, and this may be supported by technology in a variety of ways. Multimedia components on a campus to support community messages include kiosks, information displays, Web sites, radio stations, and cable TV channels.

Audiovisual (AV) Systems in Universities

Although this chapter is concerned primarily with classrooms, many of the AV technologies on campuses have other types of uses. Each of these spaces poses their own set of design criteria. AV designers wishing to work in a college or university are usually involved in many of these spaces, including:

- Classrooms.
- Gymnasiums/physical education facilities/fitness centers.
- Auditoriums.
- Music laboratories.
- Libraries/media centers.
- Art rooms.
- Science laboratories.
- Student lounges.
- Administrative offices.
- Faculty offices.
- Computer laboratories.
- Cafeterias.
- Stadiums.
- Faculty lounges/conference rooms/faculty clubs.
- Other spaces.

Classroom Systems

The complexity of AV systems in classrooms varies widely. At a minimum, the essential elements are:

- Display systems, including display devices (e.g., a projector and a screen).
- Sound systems.
- Source equipment (e.g., PC, DVD players, document cameras).
- Switching and mixing equipment.
- Control systems.

Each of these subsystems must be custom-designed to fit the room environment and to establish a desired quality level. There are standard best practices for designing the display and sound systems, based on a variety of room and usage criteria. Designers should create systems that are easy to operate, which usually involves the use of an AV control system.

Distance Learning Systems

A specialized type of classroom, known as a distance learning classroom, is enabled with videoconference technology. These systems build on the AV system by adding several additional elements:

- Videoconference coder/decoder (codec)
- Student camera and instructor camera
- Microphones for the instructor, and possibly for the classroom
- Additional video displays
- Additional audio mixing and video switching capabilities
- Additional control system capabilities

As with any videoconferencing system, the single biggest investment is the videoconference codec and its connections to a LAN, digital telephone, or WAN. This must be coordinated with other such rooms within the university. In many cases, these codecs are part of a larger network that facilitates distance learning throughout a county, state, or university system.

Architectural Considerations

Beyond the operational requirements of these systems lies a myriad of architectural challenges. Similar to any construction project, these challenges differ between renovation situations and new building designs. The requirement for immediate or pending implementation of AV systems and associated technologies is now driving the design of the classrooms, associated spaces, and schools. This trend is similar to what is happening in courthouses, houses of worship, and other public spaces.

Distance learning, Internet access, AV, computer presentations, and other technologies are no longer an experiment—they have become a fundamental part of the classroom's business.

The fact that the classroom is fully functional only when it is equipped with AV equipment must be communicated to architects and interior designers on the team, who must understand that this technology has ramifications on many basic areas of their designs. For example, classroom dimensions, lighting systems, furniture layouts, technology support areas (i.e., equipment rooms [ERs] and other rooms), ceiling heights, and other aspects are different than in the past.

Provisions within the classrooms also must be made for mounting AV components such as loudspeakers, projectors, and cameras. These components have a visual impact on the room's appearance. Hiding components is always an option, but costs are involved in creating customized niches and details. Extensive coordination is required to create a classroom that is not only functional but also aesthetically pleasing with hidden technology.

Audiovisual (AV) / Information Technology (IT) Convergence

As the technologies become accepted and incorporated into schools, the costs, technology changes, and scalability issues present new challenges. To meet these challenges, the facilities should be future-proofed with the technology architectures capable of migrating to future communications platforms.

The concept that AV technologies are converging with IT has recently been brought to light. Investment in network architecture is a means by which administrators can work around the problem of incorporating AV technology into their schools today while avoiding new investments in the future.

The concept of a converged AV/IT architecture is very prominent in the university environment for a variety of reasons. Functionally, AV and IT can coexist to a great degree except where AV systems must be connected to communications or data networks. However, this does not take advantage of hybrid approaches to systems design as a transition strategy to bridging the old and the new technology paradigms.

Colleges and universities have historically been pioneers in the area of convergence, although the earliest adopters modified their cable TV networks to accept data traffic. Now the reverse is true: the structured cabling systems that have become the de facto standard throughout campuses are being used for multimedia distribution.

AV/IT convergence has advantages and disadvantages from different points of view (e.g., systems purposes, system interconnectedness, signal flow, IT cabling, system synergy, and architectural infrastructure). These interrelated topics are typically addressed one at a time by administrations and AV or IT professionals.

Many systems and equipment installed and widely used in virtually every educational and training institution are at stake. A planned migration path from traditional AV architectures toward a fully converged AV/IT architecture is prudent for existing colleges and universities.

Metacontrol—Leveraging Synergy of Networked Audiovisual (AV) Systems

Universities and other educational institutions of all types have been deploying increasingly complex AV systems for more than 25 years. AV control systems have evolved throughout this period, as the necessity to tie together disparate types of equipment has increased.

With the development of increasingly sophisticated equipment, the need to cohesively manage these systems within the overall enterprise has arrived. The AV/IT convergence is used to tie together AV systems, computer network hardware and software, and control system software.

Once the interconnections are made, metacontrol software may be used to manage inventory, monitor and plan system maintenance, track system usage, aid in budgeting and billing, and provide many other advantages of a fully networked AV enterprise. Metacontrol is an artificial intelligence (AI) term meaning the control of control systems. The evolution of AV control systems and the gradual convergence with IT has created the necessary conditions for metacontrol to exist.

Many of the AV applications important to AV personnel, facilities managers, and IT managers are affected and may be enhanced by this new technology. This is important both to institutions with limited resources and to those with a large amount of resources.

Small institutions may rely on metacontrol to manage their shared classrooms, bandwidth, and equipment. Larger institutions may use metacontrol for managing their considerable inventory with limited staff, perhaps across numerous buildings or campuses. Institutions with large amounts of data compiled in classes and meetings, such as from testing, voting, student response, or collaboration, may use metacontrol to manage this information and organize it for the use of the participants in real-time or in an archive. In short, metacontrol holds benefits to any institution, especially those that are growing on a limited budget.

Designing Places of Worship Audiovisual (AV) Systems

Introduction

AV systems professionals working in houses of worship encounter a myriad of relationships, new terminologies, technical challenges, and unique environments. This section focuses on some of the most important factors that the AV designer or project manager must consider before stepping into the first project meeting. A house of worship refers to a wide variety of buildings used by various religious organizations and denominations, including churches, cathedrals, mosques, and temples. A staggering variety of architectural types and sizes of houses of worship exist but many similarities can be found when considering the uses of AV systems in these spaces.

Architectural Integrity and Aesthetics

A house of worship project typically begins by determining whether the system will be installed in a new building or is a renovation of an existing building. This difference has the greatest impact on the process. Many of the architectural design elements in a house of worship are not open to modification for AV purposes. Hidden technology is required in these spaces more than in most others. This is because the architecture is designed to be a contemplative environment without distractions.

Frequently, the best practices of AV design are at odds with the architecture. For example, it is ideal to locate a videographics projection screen in the center of the audience's field of view. In a house of worship, this location usually contains a religious symbol. This creates a challenge for the designer, who often creates two separate displays, one at either side. This is a very popular design element for house of worship systems.

Aside from modifying major religious architectural elements, hiding AV components is a major challenge for AV installers. Historic materials in the architecture, including rare or extinct wood species, stone, marble, casework, plaster castings, and others are usually not open for modification. This is particularly true if the building is on an historic register or is classified as a landmark.

Drilling into or rigging onto elements such as marble columns and arches, mounting surface-mount cable pathways, locating loudspeakers, monitors, and auditory assistance transmitters is necessary but contradictory to the traditions of the space. These components must be discussed with the house of worship personnel. A responsible professional will attempt to mitigate the extent of these modifications.

Acoustics

Many issues regarding acoustics are present in houses of worship. For example, a cathedral's acoustics is considered good for pipe organs and chanting. However, for speech intelligibility it is considered bad due to the enormous reverberant field.

Designers also may face compromise situations when attempting to maintain the localization of the presenter. Locating a centralized loudspeaker to give the impression of a single voice may not be possible in many houses of worship.

Sound Systems

The religious denomination should be considered in determining whether the system will be used primarily for the reinforcement of the spoken voice or whether it will also have to reproduce live and recorded music and choirs. Many modern houses of worship have a variety of activities taking place during a service, including sermons, dramas, program material playback, and live performance music of varying volume and energy levels. A sound system must be capable of and optimized for each of these disparate requirements.

AV designers should consider using modern technologies that are capable of adapting to this variety. Components such as automatic microphone mixers, audio digital signal processors, and steerable line arrays may be incorporated into designs to aid in overcoming architectural challenges.

Typically, houses of worship are large, highly reverberant spaces with hard surfaces, such that designing a sound system for voice intelligibility (usually the primary goal) is not always straightforward.

Loudspeakers

The ideal system involves one or more centrally located loudspeakers, but this is not always possible. One alternative design approach is to use smaller distributed loudspeakers mounted closer to the congregants' ears. This approach requires less gain at any one location, and results in less overall acoustic energy within the space. The loudspeakers are typically grouped and wired in zones, providing for individual zone adjustment of gain, equalization, and delay.

Once a needs analysis has been completed and all parties are in agreement, the next design challenge will be one of architectural acceptance for the placement of the loudspeakers. In a new construction project, this may not pose a large challenge, especially if the system designer is involved at an early stage during the process and the loudspeakers are tastefully integrated with the interior design. In a retrofit or upgrade of an existing facility, however, the challenges can be considerable.

Sound Systems, continued

Another loudspeaker system design approach is to use digital signal processing (DSP) based steerable line array loudspeakers. The advantage of these is their unique ability to focus and direct the audio towards the congregation's seated and standing ear height and away from hard reflective surfaces. These systems can be very effective in cathedral-style houses of worship. These types of loudspeakers tend to be tall and narrow and architecturally blend in well when mounted to columns or walls. They also may be self-powered, eliminating the need to install speaker cable but requiring both a line level audio feed from the central equipment rack and alternating current (ac) power.

Both of the system design approaches described will satisfy the need for intelligible voice reinforcement but will not necessarily provide for the reproduction of recorded or live music.

Microphones

Careful consideration has to be given to the choice of microphones.

Gooseneck Microphones

A popular microphone type for this venue is the gooseneck lectern-style microphone. A directional or cardioid pickup pattern is typical for fixed microphones located on furniture and casework elements.

Lavalier Microphones

Another microphone type, the wireless lavalier microphone system, is very popular and allows a presenter freedom of movement during the service. This, however, can present a problem if the presenter walks within the congregation while speaking. The microphone within the audience space poses an acoustic opportunity for an open microphone capsule to become part of a feedback loop in front of a loudspeaker.

Choir-style Microphones

The third style of microphone popular in many houses of worship is the choir-style microphone. These are typically suspended from the ceiling above and in front of the assembled choir and are ideal for this use.

Sound Systems, continued

Feedback Eliminators

In an effort to maximize gain before feedback, sometimes a difficult proposition in a highly reverberant space, a designer may use a feedback eliminator. Some of the more sophisticated digital signal processing systems have feedback suppressor modules built in but, in a smaller audio system, where a sophisticated larger-scale digital signal processing system is not used, one of the free standing feedback eliminators may suffice.

These devices are not cure-alls but help identify and suppress problem frequencies to enable increased gain prior to feedback in a system. Several different types of feedback eliminators are available. Experienced designers typically use them only for ensuring feedback is canceled when an unexpected incident is caused by an operator error.

Sound Mixing Equipment

Intelligible speech reinforcement and live or recorded music reinforcement differ in a variety of ways. One is the psychoacoustic aspect of “localization,” or “directionality” of the source. Another is the difference in equalization of the signals. Often the best approach to design is to incorporate two discrete systems, one for each source type. In many situations, however, this approach may not be possible, so compromises will have to be made.

The use of modern digital processing systems now enables designing a combined speech and music system that may allow for easily reconfigurable system settings to accommodate both. Yet, without question, this is a compromised approach. Specifically, it may be necessary to change from monaural reproduction for speech to stereo reproduction for program sources. A compromise may be to mix all stereo sources to monaural, which may be a good decision considering the size of the space and the impossibility of maintaining a stereo sound field at all seat locations.

Another parameter is equalization—louder passages from contemporary music require a C equalization weighting compared to the A weighting of the lower level spoken word.

Once it is established how the loudspeakers will be designed into the space both acoustically and architecturally, the front end of the system may be designed. The first consideration is whether an AV technician would be present during the services to run and monitor the audio system.

Sound Systems, continued

If the system is used with a technician, a mixing desk location should be chosen to accommodate the technician. This location is ideally within the congregation, so the technician can hear the service live. Many times, this is not the case and all of the front-end audio sources and processing and amplification equipment reside in an equipment room.

If the system is used without a technician, using an automatic microphone mixer to handle the number of open microphone channels and their associated gain relationship is recommended. This can be accomplished using a traditional style auto microphone mixer or using a DSP-based product that includes an auto microphone mixer. The latter choice is preferable because it will provide greater flexibility in system configuration and will be more accommodating for other AV sources (e.g., compact discs [CDs], DVDs, and computers).

In systems where both voice reinforcement and the reproduction of live music for a musical group (e.g., a praise band) are required, a larger format multichannel mixing console is recommended. This larger format console typically has more auxiliary outputs (e.g., for effects and stage monitoring) as well as sub-groups or voltage-controlled amplifiers (VCAs) for creating sub-mixes of instruments, vocals, and other sources.

Monitor Consoles

In very large format worship services, an entirely separate monitor console may be used in addition to the main, front-of-house, console. This monitor console commonly has many auxiliary outputs for the sole purpose of feeding individual standard or in-ear monitors throughout the stage.

The monitor console is typically located on or just off the stage and is fed the same signals as the main console by use of a microphone splitter. A major consideration with the use of a separate monitor console is the requirement for an additional operator.

Sometimes a presenter requires a small audio monitor at the stand to monitor the public address system (PAS). This is a simple feature to provide but it can introduce additional feedback problems due to the proximity of the presenter's microphone to the monitor loudspeaker. In this situation, a powered monitor speaker works well, providing the presenter with a local gain adjustment.

A technique used to help eliminate the possible feedback loop is to delay the audio signal feeding this monitor speaker by a few milliseconds (ms). This small amount of delay is imperceptible to the human ear but is enough to break the potential feedback loop.

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Sound Systems, continued

Auditory Assistance Systems

Auditory assistance systems, also known as hearing-impaired or assisted listening systems, are often required in venues large enough to need a sound reinforcement system. These systems can be:

- Infrared (IR) based.
- Radio frequency (RF) based.

Both have advantages and disadvantages that need to be considered.

IR-based systems provide better security because the transmitter and receiver require line of sight (LoS), and the signal does not pass through walls. The disadvantage is that they require LoS to function and they are susceptible to sunlight, which also contains IR.

RF-based systems do not depend on LoS and are less secure because RF travels beyond the confines of the room and can suffer interference from external sources.

Houses of worship can present even the most seasoned audio system designer with difficult challenges. Acoustically, due to the reverberant nature of the finishes typically chosen, providing good speech intelligibility, which is a primary need, is not an easy task.

When both speech intelligibility and accurate music reproduction are required, the challenge becomes that much more difficult, but with careful planning, loudspeaker placement, and microphone pick up patterns, the obstacles can be overcome. This will allow for the implementation of a good quality, high performance, and stable system.

Video Systems

Video technology is increasingly used in houses of worship for a variety of purposes. The uses for projection displays include song lyrics, announcements, inspirational readings, and presentation graphics. On the live visual side, the use of image magnification (IMAG) is common for providing the view of performance through displays to the attendees in the back of a house of worship.

AV professionals face a variety of challenges in designing these systems, both on the source and on the display sides. The location of computers, video sources, and the associated cable routing are as important as the displays.

Capturing, producing, and monitoring the visuals mandate that a group of volunteer or professionals assume the responsibility for ensuring seamless presentations.

The three basic operational devices used to support visuals relate to:

- Switching.
- Camera operation.
- Recording transport controls.

Since a mixture of computer- and video-based sources (e.g., cameras) is typically used in house of worship settings, having a switcher capable of displaying multiple scan rates and resolutions is very useful. Modern presentation switchers are ideal for this purpose because they are designed to switch seamlessly from one image to the next, minimizing distraction to the audience.

These devices must be capable of scaling the resolution of each of the sources to match the native resolution of the main displays. Complementing this device are one or more camera controllers, usually of the joystick variety.

These components, along with corresponding preview monitors, allow an operator to control the pan-tilt-zoom (PTZ), and focus of each camera. Finally, if the service is to be recorded, a remote transport controller allows disc, tape, or hard-disc recorders to be operated.

Lighting

Although not strictly an AV function, the lighting of a house of worship typically falls under the purview of the AV personnel, as it is usually run in conjunction with live and programmed events. A large house of worship may require a lighting control board. This allows zones and fixtures to be addressed individually or in groups for effects or for normal scene selections. In addition, manual lighting functions (e.g., spotlights) may be used.

Operations

Control locations for AV systems in houses of worship have changed through the years, with the increasing necessity to place the operation under manual control.

The decision to design a system with automation or manual operation must be discussed with the client because the operation area may be significant and is ideally located amidst the congregation. This poses both an aesthetic and seating arrangement change to the congregation area.

Many furniture concepts have been developed to minimize the impact of this issue, including roll-top desks or permanently designed spaces in new house of worship construction. If both audio and video are operated, substantial space is required because the audio mixing console, lighting control console, presentation switcher, camera controllers, and transport controllers take up considerable table space. Other types of devices, including audio and video monitors, technical monitors, and recording and playback devices, also may be involved in this setup.

In large houses of worship, stage crew operations may be conducted, with a producer following the service and ensuring that the lighting, sound, and visuals are orchestrated. Other technical devices aid in this effort, including wireless intercoms and production booths.

At a minimum, the technical operations of smaller houses of worship should be simplified with an AV control system. This system ties together the components and subsystems and presents a simple direct interface to the user. This customized interface may be as simple as a wall plate or as sophisticated as a touch panel. The design of the control system should be carefully discussed with the client.

Subsystems

Besides the main part of a house of worship (e.g., sanctuary), many ancillary spaces also must be considered for AV implementation. These spaces include carillons, nurseries, fellowship halls, crying rooms, and other rooms that require AV equipment.

Some larger houses of worship include extensive recording and production facilities as well, to the extent that they can be considered as performing arts centers in addition to worship centers. AV designers have many challenges in determining the cabling pathways throughout the entire building to support these other spaces. Signal strength, power and grounding issues, and interference from lighting and heating, ventilating, and air-conditioning (HVAC) equipment must be considered in all of these cases.

Designing Corporate/Boardroom/Training Room Audiovisual (AV) Systems

Introduction

AV systems for today's corporate boardroom typically consist of:

- Presentation display system.
- Audio system for program and voice reinforcement.
- AV control system.
- Video conferencing system.
- Audio conferencing system.
- Electronic white boards and interactive displays.
- Lighting and lighting control.

When embarking on a corporate boardroom system design, meeting with the client or end user to obtain an understanding of the exact nature of the space and the end user's expectations is crucial. The system designer should listen carefully to the client's requirements and make system feature suggestions if they are not specifically requested. Typical questions to ask during this meeting are:

- How frequently will the boardroom be used?
- How many board members are there?
- Does auxiliary staff participate in the meetings? If so, how many?
- What types of presentations are required?
- What type of material is presented?
- Is there a need to incorporate audio and video conferencing?

This fact-finding meeting also may include the project architect in lieu or in the presence of the client.

The discussion of technology should include topics like AV connectivity at the table, motorized projection screens, motorized shades and blinds, the proximity of the room to noise-inducing building mechanical systems (e.g., air handlers and plumbing).

The discussion of room infrastructure should include topics like floor boxes, conduit requirements, ac power requirements, and the location for the AV equipment rack. This discussion should determine if the equipment rack would be located within the boardroom (e.g., housed within a piece of custom furniture) or located away from the boardroom (e.g., in a room).

Lighting is another critical design criterion. A boardroom should have several zones of architectural lighting, providing general room lighting, task lighting at the boardroom table and, if video conferencing is requested, color corrected indirect video conference lighting fixtures.

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Presentation Display Systems

Choosing the appropriate display system for a boardroom depends on the following criteria:

- Room size
- Room usage
- Project budget

Front projection is typical but is a poor choice if video conferencing is planned as part of the system design. Rear projection is often a good solution for both presentation and video conferencing but requires a rear projection room and often a costly projector mirror stand in addition to the screen. An additional advantage of rear projection is that the projector's cooling fans do not cause as much noise as front projection does.

Flat panel displays are very popular and work well for display and video conferencing. Their limitation, however, is the size, which currently does not approach the sizes attainable though projection systems. LCD panels produce less heat than plasma and do not suffer with image burn like plasmas.

Audio System for Program and Voice Reinforcement

In a boardroom that does not require sound reinforcement or use audio and video conferencing, only program audio is necessary. This typically entails loudspeakers flanking the projection screen (or plasma or LCD) to provide audio support for the material being displayed. If, however, the room is large enough to require voice reinforcement or audio and video conferencing are required, then a distributed voice reinforcement system will be required in addition to the program audio system. This system would typically require ceiling loudspeakers evenly spaced throughout the room. Often in this situation a custom mix-minus system will be used where a microphone, when live, will automatically turn off the speaker or speakers closest to it to allow for greater gain before feedback.

Audiovisual (AV) System Control Systems

Most of today's modern boardrooms have an AV control system. The control system typically consists of a control processor which can communicate to all of the necessary AV components and take control of them. The user interface could be a wired or wireless touch panel, in wall button panels or table top button panels. The intent of these systems is to replace all of the hand held remote controls that are provided for each of the AV components. In addition to taking control of the AV components, these systems can control the boardroom's lighting system, drapes, blinds and HVAC systems.

Audio Conferencing Systems

If audio conferencing is planned as a feature of a boardroom's AV systems, the mechanical systems' ambient noise level is more important and the mechanical engineer should be asked to design the mechanical systems to the noise criteria (NC) 25 standard. This will prevent minimal extraneous ambient noise from interfering with the audio conferencing system's functionality.

Video Conferencing Systems

If video conferencing is planned as a feature of a boardroom's AV systems, the room lighting, color temperature, surface colors, table and furniture colors need to be considered. In addition, the mechanical system's ambient noise levels are more important. The mechanical engineer should be asked to design the mechanical systems to the NC 25 standard. This will ensure minimal extraneous ambient noise detracts from the video conferencing system's functionality.

Another important issue to discuss is connectivity with other computer networks. The most popular options are Internet and multiple integrated services digital network (ISDN) lines.

Electronic White Boards and Interactive Displays

Electronic white boards and interactive displays are popular in today's boardrooms. They can be standalone wall-mounted units or overlays for flat panel displays. The purpose of an interactive display is to enable the user to annotate over a projected presentation using a special pen or stylus and be able to save the projected image and annotation to a computer file for later use or distribution.

Lighting and Lighting Control

Lighting and lighting control are two critical elements in the design of a boardroom.

Providing multiple zones of varying types of light is important. A combination of incandescent lights and fluorescent fixtures is common, with wall wash accent lighting and cove lighting also frequently used.

A dimming system providing multiple zones with the ability to recall multiple scenes is the norm. The systems can be tied into the AV control system for seamless integration and simplistic, intuitive, operation.

The key to a successful boardroom design is choosing the appropriate technology based on the defined client needs and integrating it into the room in a simple, intuitive, system.

Designing Command and Control Audiovisual (AV) Systems

Introduction

This section is intended to provide the reader with guidelines for the development of operation or command centers. Typically, these types of facilities are developed to support many types of functions including, but not limited to:

- Management of voice and data network communications.
- Military operations.
- Government operations.
- Law enforcement operations.
- Transportation operations.
- Data management.
- Product management.
- Facility operations.
- Traffic management.
- Crisis management.

Typical acronyms used to describe an operation center (OC) include:

- Network operations center (NOC).
- Satellite operations center (SOC).
- Emergency operations center (EOC).
- Command and control center (CCC).

NOTE: For the purposes of this chapter, the acronym OC will be used to describe any type of operation or command center.

Introduction, continued

The workflow of most operation centers (OCs) is broken down into several core components, including information:

- Gathering (input).
- Storage and archiving.
- Processing and evaluation.

Sizes of OC display environments vary from one- or two-image displays to extremely large 200-image displays.

OSs are no longer just a room with several large image displays and operator consoles. Actually, one room is only a portion of the larger overall facility. The OC also may include an IT network data center, redundant electrical power facilities, HVAC facilities, collaborative meeting spaces, office spaces for operations staff and facilities management, maintenance shop for network and AV equipment maintenance, archival storage, restrooms, kitchen, pantry, dining room, staff training room, press briefing room, press offices, staff break/game room, staff locker room, security screening, and rooms for public orientation and tours.

In AV technology, most modern OCs consist of image display devices such as video projectors, front or rear projection screens, optical fold mirror assemblies, flat panel displays, and light-emitting diode (LED) devices, video image capture and distribution, video image processing, video cameras, microphones, audio signal processing, audio amplifiers, loudspeakers, system monitoring, message and content storage, content distribution, many types of cabling, HVAC services, electrical services, and many other elements.

Planning

The designer and the owner should recognize that the OC is no longer a separate system but an integral element of the facility's IT, security, HVAC, electrical services, daily operations, and marketing functions. With that in mind, the AV designer must work in partnership with the entire design team to ensure the integration of the OC with these other elements.

Long before the designer begins specifying the technologies for an OC system, a responsible designer will insist on a structured formal programming and budgeting process. Should issues arise later on, this early phase is essential to the success of the project. Early documentation of the established design criteria will serve as a valuable reference guide and the basis of design and also support the designer's position in later phases of the project.

The OC designer must know which parties will be responsible for the contracting, requisition, and construction of each element, including:

- Image displays.
- Projection screen and optical mirror fold assemblies.
- Loudspeakers.
- Cabling, pathways, and closets.
- Electrical and electronic components.
- Commissioning and testing.

In particular, projects that will be staffed by a unionized workforce may insist on specific loudspeaker and cabling design and installation criteria. These criteria will affect the selection of products, procedures for installation, and final system commissioning.

For larger, more notable, facilities, the architect may focus on creating an interior and exterior building design that may or may not support the integration of OC components and infrastructure. The OC designer should convince the architect of the value of an interior design that supports the integration of technology.

Space requirements should be declared early in the design process. A balance should be achieved between the value of the floor space and the maintainability of the electronics, in particular the image display technologies.

Cable distance and limitations should be considered when locating equipment rooms in proximity to the OC and the operator consoles.

Planning, continued

A failed implementation of AV technology is often caused by the owner's lack of resources for creating and managing the content on the installed technology. The OC designer should discuss this topic with the owner. The owner must be prepared to support the daily maintenance and operation of the OC, just like the IT and mechanical, electrical, and plumbing (MEP) elements. The owner must provide a properly trained and experienced staff.

The cost of long-term sustainability of the image display and electronics technology should be considered when designing. The owner must be informed of the options and cost implications when determining display technologies (e.g., scheduled lamp and other component replacement).

Definition and distribution location of suitably sized technology rooms is vital. The room sizes and distribution should follow the accepted telecommunications industry guidelines. The positioning, sizing, and distribution of technology rooms must support the phasing of present and future construction and redundancy. Including excess space within a room for future expansion and renovations is vital.

Image Display Technologies

For the AV portion of any OC project, selection and design of image display technologies is the major element of the project, followed by the selection and layout of operator consoles. The designer must understand how the display technology will be used, the importance of operator view and interaction with the displayed content and staff workflow.

The range of display technologies appropriate for use in the nonstop operation matures each year. Current technologies include:

- Video projectors including cathode ray tube (CRT), digital light processing (DLP), LCD, and liquid crystal on silicon (LCOS) display engines. OC-rated video projectors typically include multiple redundant lamps and special short-throw lenses.
- Video cube array.
- Motorized and wall-mounted framed front projection screens.
- Glass or acrylic rear projection screens with options for control of ambient light.
- LCD flat panel.
- Gas plasma flat panel.
- Video LED.
- One-, tri-, or four-color LED.

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Image Display Technologies, continued

The OC designer should provide a display solution that not only meets the owner's current needs but also can be upgraded without major changes and addresses the long term cost of ownership. The designer should keep in mind that:

- Video cube technology, while having the benefit of easy install, locks the owner into a proprietary technology that cannot be upgraded or easily replaced on an image device-by-image device basis. Cost studies also show that a fixed-frame rear projection solution with off-the shelf nonstop video projectors is less expensive and supports future upgrades and changes to video projector display technologies with little or no impact to the permanent rear projection screens and optical mirror fold assemblies.
- Arrayed flat panel displays provide an easy solution in a space-limited environment and provide cost benefits for electrical load. The designer must provide the architect with the information regarding wall structural loads, wall blocking, and in-wall infrastructure for electrical and AV equipment. Unfortunately, this solution also can create long-term aesthetic problems as newer products likely will not be exact replacements for failed flat panel displays. The designer should consider that:
  - Gas plasma displays, while including software solutions to prevent image burn-in, have not proved over time. In addition, the organic gas has a limited lifecycle and thus not appropriate for 24/7 operations.
  - Over the gas plasma technology, LCD panels provide benefits of durability, lack of image burn-in, higher resolution and brightness and extremely long lamp life.
- All video projector lamps must be replaced over time. In addition, the color wheels and other components in DLP projectors also must be replaced about once per year. These are long-term costs that the owner must be prepared for.

The OC designer should meet with custom rear projection assembly and video projector display manufacturers to learn about and understand optical design factors including:

- Viewing distance.
- Type of content displayed.
- Image resolution, pixel size, and aspect ratio.
- Lamp brightness.
- Color temperature.
- Screen size.
- Screen types.
- Ambient room lighting.
- Ventilation.
- Lens selection.
- Optical folds.

Image Display Technologies, continued

The layout of OC consoles impacts the selection and design of display technologies. Often, the consoles are arrayed by the owner in teams or functions. The console layout may impact how the image displays are selected, positioned, and sized and what viewing conditions are provided. Furniture consoles vary in design, complexity, and features. Dozens of product manufacturers specialize in console furniture.

Acoustics

Including an acoustician in the design process is of vital importance. As the facility will be staffed for long periods of time, providing comfortable room acoustics is important, particularly for a call center. Major areas of concern are suppressing mechanical and other noises, suppressing reverberant sound, ensuring speech privacy, and controlling ambient noise levels.

OCs also typically introduce a significant level of noise from electronic equipment ventilation fans, power distribution, and ventilation devices. The designer should work with the acoustician to ensure this noise is contained within ERs and does not intrude into staff working areas.

Disability Access Guidelines

The designer should keep in mind that local disability access standards typically mandate aisle sizing, design of operator consoles, and access to display equipment.

Mechanical and Electrical Components

Most OCs also require redundant electrical power services. For sensitive AV equipment (e.g. control systems, digital processors, and video projectors), the designer cannot rely on the building's backup generators. During a power outage, at a minimum the AV electronics must remain active and functional to support soft shutdown of image display and other electronics. The designer should include sufficient sized uninterruptible power system (UPS) devices to maintain full functionality for a minimum of 10 minutes while the building power generator is cycling up or in case the generator fails to function.

Electrical power service conditioning (electrical power surges, electromagnetic interference [EMI]/radio frequency interference [RFI] filtering) on a circuit-by-circuit basis is highly recommended.

Power line conditioners are intended to prolong the life of the electronic components and prevent damage from power service anomalies. The designer cannot rely on the building's line conditioning to protect the vital and sensitive electronic components. To prevent damage problems induced after the load panel, conditioning of each individual electrical circuit is recommended.

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Mechanical and Electrical Components, continued

Often, even the best planned designs are not executed as designed in the field. Individual power line conditioners provide an added level of protection from incorrectly wired circuits, impact from motorized devices, improper circuit phasing, and ground loop potential problems.

Power line conditioners vary in type. Most common devices use solid-state electronic circuitry to provide line conditioning. Care must be taken as most also bleed the overvoltage to the same ground referenced by the AV and IT components. Higher level devices use series mode line conditioning circuitry with transformer isolation.

To prevent damaging high level current in-rush during automated power-up after lengthy power blackout, power circuit delay sequencing is recommended. Most AV industry equipment cabinet manufacturers also include power distribution and power circuit sequencing products.

To ensure electrical isolation between subsystems, use of optical fiber cable paths is recommended for transmission of data, audio, and video signals. Use of digital transceiver devices also is recommended to ensure signal quality retention over long distances.

Equipment HVAC control is vital. The designer should create lists that estimate typical operation power and heat loads on a room-by-room basis. For video projectors, required air-flow velocities should be included. This data should be given to the MEP designers with a note that the designed solution should provide continuous service, especially during power interruption, and that each room should be electronically monitored for temperature and humidity levels by the building automation system (BAS). The AV system also should automatically issue e-mail and pager alerts to the facility and MEP technicians.

Information Technology (IT) Infrastructure

Use of IT infrastructure and IT standards for infrastructure is recommended over proprietary AV networks. A typical IT network is maintained daily, includes redundant pathways, and typically includes sufficient bandwidth to handle the AV control and signal distribution.

The design should follow accepted information transport systems (ITS) industry standards for ER design, cable pathways design, and use of IT type cable and cable termination technologies.

Grounding

The AV system should follow current electronic industry, national, and local building code grounding standards.

NOTE: See Chapter 8, Grounding, for more information on this important subject.

System Electronics

Modern OCs typically include some form of software-programmable digital video signal processor (V-DSP). The V-DSP, when configured by the designer, provides a reliable, flexible software application solution for most OC functions when compared to the former solution of cascaded analog components. As a scalable video window environment, images can be tiled to use the entire array of displays as one congruent display, similar to a computer's operating environment of tiled applications on one or more computer monitors.

The entire AV system can automatically detect and notify of failed components and cabling. With this notification, a properly designed system can automatically route signals via redundant pathways (e.g., processors, amplifiers, cabling, and loudspeakers) to automatically repair the void in service. This same monitoring system also should notify the responsible staff of problems through e-mail and text messaging.

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Designing Hospital Audiovisual (AV) Systems

Introduction

AV systems are deployed in a wide range of applications within the healthcare environment. Each application presents unique design considerations for the AV designer.

AV systems can be found in virtually every area within a healthcare facility, including:

- Clinical AV systems—Systems that provide and route multiple video, data, and audio sources to multiple displays within operating rooms and trauma rooms.
- Presentation AV systems—Systems deployed in conference rooms, boardrooms, and patient education rooms.
- Medical education systems—Use of audio and video to facilitate the communication between medical students and instructors.
- Telemedicine systems—Use of telecommunications technology for medical diagnosis and consultation between facilities and departments.
- Interactive TV systems—Patient education, patient entertainment and, access to clinical software for staff through the master antenna television (MATV) distribution system.
- Paging systems—Supervised paging, code blue paging, and departmental paging.
- Intercom systems—Interdepartmental and specialized intercom applications.

Clinical Audiovisual (AV) Systems

A hospital operating room (OR) may require the integration and control of various audio and video sources as well as control of environmental elements such as lighting. The concept is to provide access to various types of information including patient vitals, diagnostic images, and feeds from cameras used in the procedure. The output can be routed on multiple monitors located in the OR, which can be viewed by various members of the surgical team.

A designer should begin by determining the quantity and types of sources that will be used. These sources can include patient monitoring systems, endoscopes, high resolution cameras, ultrasound systems, workstations, and picture archiving communications systems (PACS [e.g., radiological images]). The designer also should identify the connectivity requirements of each source (e.g., S-Video, video graphics array [VGA], digital visual interface [DVI]).

The designer must determine the number and locations of the output monitors and how the users want the sources switched to the output displays.

Clinical Audiovisual (AV) Systems, continued

Additional functionality such as video conferencing, procedure recording, and still image capturing is often required. Video conferencing also can be used to allow collaboration and increase the speed of diagnosis when used with the facility's lab and pathology department.

A touch panel is commonly used to switch the inputs and manipulate the OR's environmental controls. This touch panel is often located at the nurse's documentation station in the OR.

Source images that are scaled as the AV system processes and routes the image may not accurately represent the source image. The healthcare facility should be made aware if any image is altered from the original.

An AV designer should be familiar with all local codes that pertain to patient safety and the healthcare environment.

Interactive Television (TV) Systems

The patient's TV has become a powerful tool in the creation of a positive healing environment. The patient room TV can now deliver educational content, entertainment for patients, environmental control, and provide staff with access to clinical software systems.

Educational content can include disease awareness, post procedure care, newborn baby care, or drug information.

Patient entertainment also is used for pain management and as a distraction from unpleasant procedures.

The three major categories of healthcare TV are:

- Traditional MATV—This is the most basic form found in a hospital. The patient steps through the available channels on a TV mounted at the patient's footwall through channel up/down buttons on the nurse call pillow speaker. Standard remote controls are discouraged. Some of the available channels may include a facility bulletin board that provides information on daily activities. Closed-circuit television (CCTV) events such as a feed from the hospital's chapel may be required. Patient education and entertainment may be added to this setup by providing repeating programming on dedicated channels.
- Education and entertainment on demand—This option puts the patient in control of their environment. The model generally adds a set-top box to the patient room and a digital video server containing content in a telecommunications room (TR) or data center. The patient requests educational or entertainment content on demand through an advanced nurse call pillow speaker. In addition to access to education or entertainment content, the interactive system may have advanced functionality such as patient satisfaction surveys, dietary menus, and the ability to send requests for environmental changes such as temperature or lighting. Some systems allow the use of a remote keyboard to access Internet and e-mail functionalities.

Interactive Television (TV) Systems, continued

- Education and entertainment on demand with clinical access—This model changes the TV mounted to the patent's footwall to a swing-arm–mounted flat panel PC with an integrated keyboard. This provides all of the functionality listed above with the addition of enhanced ease of use for patient access to Internet and e-mail.

  The most significant enhancement is the ability to provide staff access to clinical information systems through the swing-arm device. Staff can chart patient vitals, view lab results, or access other medical systems. Due to the nature of this solution, additional considerations should be given to IT infrastructure and associated clinical software and interfaces.

Overhead Paging Systems with Ambient Noise Sensing

Paging systems provide the following vital functions in a hospital:

- Code paging—Crash team members are summoned through the paging system to respond to a patient unit.
- Departmental paging—Local zoned paging can be a benefit in busy areas such as emergency but is usually discouraged in most other areas of the facility. Overhead paging is not conducive to a healing environment and should be used only for emergency purposes.
- Building wide paging—As with departmental paging, building-wide paging should be used for emergency purposes only.

Ambient noise sensing can be effective to both raise the volume level in busy areas and to reduce the volume level in the quiet areas (e.g., nurseries).

Supervised paging systems may be required for healthcare facilities by local codes. These systems have redundancy, self-monitoring, and the ability to self-heal.

Intercom Systems

Intercom systems are critical to effective communication and perform various functions in the healthcare environment, including:

- Parking lot security—Vandal-proof call boxes are strategically placed in a parking structure. The call boxes can be connected through telephones, RF wireless, or cellular.
- Door access—Vandal-proof call boxes are strategically mounted at building entrances. They are often integrated with the electronic door locks and security cameras.
- Nurse call—These systems provide for audio and video signaling of patient requests. They provide for multiple levels of calls, including routine calls, bathroom emergencies, and code blue (e.g., cardiac arrest). They are often integrated with pocket pagers and wireless telephones.
- Procedure room—These small two-station intercom systems provide communications from a control room to a procedure room.
- Departmental—Various departmental specific applications for intercom include:
  - Nurseries—Secure door access.
  - Operating rooms—Communication with sterile supply, pathology, and other OR-specific rooms.
  - Sleep labs—Sleep rooms to control room.
  - Isolation rooms—Isolation room to ante-room.

Special Considerations

Medical Grade Devices

Medical grade devices are engineered for use in the medical environment. They contain the necessary electrical isolation and grounding to be used in the proximity of a patient.

Designers should refer to local codes for additional information on:

- Patient care areas.
- General healthcare installation/construction criteria.
- Low voltage equipment and instruments in healthcare environments.

Diagnostic Resolution

Images used for diagnosis such as PACS radiological images require special grayscale monitors specifically designed for diagnostic purposes. A designer should be aware of the intended use of display monitors so that the appropriate monitor may be specified.

Telemedicine

Multiple AV applications fall within the telemedicine umbrella, including:

- Remote clinics/rural hospitals—Remote clinics or rural hospitals may use conferencing systems to consult with specialists at a main facility. This application could be as simple as a remote camera with an audio feed or as complex as having the video output of patient monitors, ultrasounds, and other diagnostic devices routed to the remote end.
- Operating rooms—Surgeons may use video conferencing to communicate with internal departments such as lab, pathology, or teaching purposes. Video images of the pathologist's microscope can be routed to the OR. At the high end of telemedicine, surgeons can use a robot to perform surgery from a remote location.
- Home healthcare—Telemedicine also can be used to monitor patients at home.

A designer must fully understand the intended application and required inputs and control capabilities before designing an AV solution used in a telemedicine application.

Special attention should be given to resolution and latency.

Special Considerations, continued

Wireless Issues

When designing an AV system for a healthcare application that has a wireless component, the designer must consider the effect:

- The wireless component has on other systems—Interference with patient monitoring systems, wireless telephones, infant protection systems, and other wirelessly enabled systems must be avoided. The best way to ensure compatibility is to work with the facility to ensure that the system complies with the facility's wireless infrastructure guidelines.
- The medical equipment has on the wireless AV component—Medical equipment such as magnetic resonance imaging (MRI), surgical tools, and x-ray systems may have a significant effect on the performance of wireless products. A designer should be aware of the specific environment where the solution will be installed so that potential sources of EMI can be identified and avoided.

Patient Privacy Implications

Privacy rules mandate the protection and privacy of all health information. They specifically define the authorized uses and disclosures of individually identifiable health information.

AV systems by definition use audio and video technology to facilitate communication. A designer must ascertain if a particular system could disclose individually identifiable patient information. If such disclosure is possible, then the designer and installer should:

- Locate visual devices (e.g., screen or display boards) out the view of the general public.
- Restrict access to information with username and password security.
- Provide training for users to ensure patient privacy is maintained while using the system.
- Use open voice or hands free devices with caution.
- Consider speech privacy systems.
- Consider encryption of any wireless system, including microphones.
- Consult with the hospital's patient representative to ensure compliance.

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Special Considerations, continued

Working in the Healthcare Environment

Designers should be aware of the unique working requirements in the healthcare environment. Possible issues include:

- Hours—Hospitals are open nonstop and access to areas such as emergency rooms and ORs greatly depend on the activity level in the rooms. Access to patient rooms may be limited to only a few rooms at a time.
- Infectious disease control—The designer should consult with the facility's infectious disease control department to understand the requirements for the facility.

Designing Hotels and Conference System Audiovisual (AV) Systems

Introduction

The hotel business has always played an important role in the world's social and economic areas. Many hotels serve as stops on the road, while many have become destinations, hosting a wide range of activities, including recreational, entertainment, and meetings.

The meeting events in hotels have given rise to the need for quality built-in AV systems. The rising expectations of meeting planners, presenters, and attendees have focused the attention of hotel owners and operators and having quality AV systems and services is now a point of competition among hotels in many markets.

The characteristics of the architectural envelope are a critical factor to the successful implementation of hotel AV systems. The spaces' architectural acoustics play a crucial role in determining if an AV system could provide quality sound to the audience. The interior finishes and colors determine how effective the lighting is and how well projected images are displayed in the room.

The location of the AV ER also is important. Ideally, the hotel's sound system is in a dedicated room located centrally off the service corridor behind the largest flexible function spaces. The AV equipment storage room should be lockable and located close to the sound system room.

NOTE: The approach described herein applies mainly to typical full-service hotels and not necessarily to luxury hotels or conference centers, which typically have greater or different requirements for built-in systems.

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Flexibility

Flexibility is a key characteristic of effective hotel function spaces and the hotel AV systems.

Most hotels are designed with flexible function spaces characterized by movable partitions, guest circulation, assembly spaces, and various entry doors and corridors. The flexible arrangement is designed to accommodate a wide range of events and to reconfigure the physical spaces rapidly and easily.

Flexible audio systems start with a robust infrastructure that includes input/output plates located around the periphery of the space and sometimes in floor pockets. The location of the plates should be planned to minimize the need of laying cables in front of any public or staff doorway.

The plates should include balanced line and microphone level inputs to the system, balanced audio tie lines, coaxial video tie lines, MATV, and copper unshielded twisted-pair (UTP) and optical fiber tie lines. All of the inputs and tie lines from the input/output connections should land on patchbays in the AV ER. These patchbays permit rapid reconfiguration and flexibility in setting up the rooms to accommodate a wide range of event types. RF, Internet, and telephone services also are provided on these patchbays to permit distribution to any of the tie lines on an as-needed basis.

There are two types of sound systems used in hotel function spaces:

- Built-in sound systems
- Portable sound systems

The primary purpose of built-in sound systems is to provide highly intelligible reinforcement to the spoken word. The best way to provide consistently intelligible voice reinforcement in a flexible function space is by a distributed array of ceiling loudspeakers. The selection and spacing of these loudspeakers is critically important. Their performance and effectiveness is dependent on the architectural acoustics of the function space itself.

Flexibility in visual displays is provided by portable visual display equipment. The AV operating department sets up projectors and front or rear projection screens on an as-needed basis. Providing built-in projection screens in a hotel's flexible function spaces is not cost-effective since built-in projection screens are rarely used.

Video-on-Demand Systems

Video-on-demand is primarily a feature of the guestroom entertainment system and also is referred to as pay-per-view (PPV). These systems are almost always provided by outside services and are typically not part of the designed AV systems.

Radio Frequency (RF) Distribution

The RF distribution system includes:

- Program sources.
- Headend.
- Guestroom distribution.
- Public area distribution system.

The program sources include local TV and radio broadcast programs, satellite-delivered free-to-guest basic and premium programming, in-house local origination programming for amenities and event information, and PPV programming services. Many hotels also have a link to the property management accounting system to permit guests to order room service, preview their bill, and check out.

The guestroom distribution system in today's practice includes both RF and Internet protocol (IP) systems. The RF systems are typically daisy-chained and run to a vertical distribution backbone, while the IP system is home-run from each guestroom to an intermediate distribution frame (IDF) room on each floor. This permits supporting both legacy-based equipment and digital TV readiness. The design requirements for these systems may differ between the various programming service vendors.

The public space distribution system also is both RF and IP based, but all are home run to the nearest IDF or AV ER. Eliminating specific guestroom programming from this distribution system is necessary for protecting programming copyrights.

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Wayfinding and Digital Signage

The electronic wayfinding and digital signage systems are becoming more popular in larger hotels and conference centers. These systems are sometimes referred to as visual information systems (VIS) or electronic reader boards (ERBs).

Digital signage is one means of providing the information that the guests need to find their way around the hotel. Digital signage systems include vertically or horizontally oriented large public area displays, typically LCD type.

Locations are selected along with the signage/wayfinding consultant at specific decision points in the guest circulation flow to maximize effectiveness. These displays list the current and near-future meetings showing the group or organization name, the name of the meeting, and the time and location of the meeting.

The displays refresh to display multiple screens of information and sometimes, for larger venues, may require multiple displays to permit guests to view their meeting information within an acceptable period of time.

Since the digital signage is an intrinsic part of the wayfinding design, it must be considered along with the sign package. Typically, the digital signage is provided next to a back-lighted graphic map of the hotel public areas along with a you-are-here mark so that the guests can negotiate their way from that location to their destination.

Some hotels may want to use the digital signage to promote in-house amenities such as golf clubs, restaurants, or spas. Another use is to provide access to these displays to meeting planners as another way to reach their attendees with messages. Some hotels anticipate enough use of these auxiliary amenities to justify providing additional dedicated displays for these promotional purposes.

Extensions of the digital signage are room door-side displays. These are small LED alphanumeric multiline displays or LCD displays located next to each guest entry door to meeting rooms and flexible function spaces. The signs indicate the meeting names and times.

Touch Screen Driven Displays

Touch screen driven displays are typically used for standalone local information or electronic concierge kiosks. Touch screen driven or any other types of interactive display are not practical for wayfinding since they serve only one guest at a time. These locations typically require power and an Internet connection to permit the service provider (SP) to keep the system up to date.

Meeting Management Systems

Meeting management systems also are referred to as electronic ledger systems or property management systems (PMSs). These are typically customized versions or completely custom software packages provided by the hotel management company as part of their services.

Some stock and custom meeting management systems have an export function to send meeting information to the digital signage systems. Some stock and meeting management systems also include AV system and equipment management functions.

Each meeting management system provider has a guidebook that describes the specific system requirements for cabling, equipment location, interconnectivity, and power for their specific system.

Portable System Infrastructure

Infrastructure can be used to transport a wide variety of signal types including audio, video, computer graphics, control, and combinations of these signals.

Larger venues may include tie line plates in the floor and ceiling with copper and optical fiber network connections run to patchbays in the AV ER. These serve to provide signals to flown loudspeaker clusters, projectors, lighting instruments, theatrical effects, dimmers, and other components. The floor boxes may be equipped with large empty conduit chases between them to permit running cabling for event productions under the seating areas.

Portable system infrastructure may include lightweight hang points and rigging points. These are intrinsically related to the structure and must be located to provide appropriate lighting, sound, and projection geometry for the most likely staging locations.

Show power is part of the infrastructure also required to support portable AV and lighting systems. Adequate current capacity should be located to serve the most likely staging locations.

Broadcast Vehicle Connectivity

Outside connectivity may include tie cables to outside points. This is typically done with multiple audio and video connections between interior locations and exterior weatherproof enclosure. Often, open pathways also are required for unique events.

Background Music

Background music may be provided by a subscription service to the hotel. Such service may provide the music through satellite transmission, Internet transmission, or proprietary hardware means such as CDs. The monthly subscription service fee includes certain artist fees for public performance and record label fees for distribution/duplication rights of the music.

Typically, each food and beverage venue has a dedicated background music receiver located either within the venue or at the central AV ER with a remote control for that receiver in the venue.

One channel is dedicated to providing background music for the main lobby and public circulation areas of the hotel. The background music system for these areas generally extends to include all front-of-house public areas (e.g., lobbies, hallways, restrooms, pre-function areas, and gift shops).

Designing Stadium Audiovisual (AV) Systems

Introduction

The technical AV systems that are a part of sports stadiums and arenas consist of over a dozen individual systems, many of which share signals, bandwidth, or cable pathways. These systems may be designed by several different firms, installed by different integrators at different times, and be used by the owners of the building or one of its tenants.

Thorough planning and coordination are vital. Though not complete, the following descriptions emphasize unique aspects of systems and infrastructure relating to large stadiums and arenas.

Infrastructure

A well-conceived and properly implemented support system for the myriad of systems found in stadiums and arenas is essential for successful implementation and maintenance.

Cable Pathways

The typical scenario for the major pathways is to encircle the lower level or service level of the building with cable tray and join this with a set of risers that provide a vertical pathway to each level.

Cabletrays

The service level cable tray sizes depend on the cable requirements for a given section of the tray but can become very large and are sometimes found in multiples, typically stacked. Given the range of cable classes used to support the systems, cable trays must be partitioned.

Feeder trays from major cable destinations are required, such as the broadcast trucks and video production room. Also, smaller trays or hooks may be required for temporary cabling. An aluminum ladder tray is the usual choice.

Cable trays also may be found in the press level and over large collections of equipment racks.

Care is required to coordinate the path of the tray with other trades because they share the space in the corridor ceiling spaces. Also, the designer should understand where these pathways go through plenum areas as that affects the required cable rating.

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Infrastructure, continued

Risers

Rooms are generally found in each of the four corners in an arena. In a stadium, extra risers may be required in the end zones and sidelines, depending on the building geometry and the effective cable lengths. These rooms house support equipment for several systems required for that level. They must be sized as low-voltage electronics rooms rather than traditional telephone/data rooms.

Conduit

Conduit is used as the pathway between cable destinations and equipment racks, risers, or cable tray as the situation warrants. Given the quantity of cabling, the quantity and size of conduit runs can be substantial.

Space Planning

Proper space planning is essential to create a cable plant that can be implemented. Riser rooms should be stacked and sized to include room for all equipment, backboards, panels, racks, and mandated clearances in front and around them.

Power

Besides simply providing an adequate number of circuits for each system, knowledge of whether the systems must be on a UPS, or is best served by a certain type of transformer is required.

Some technical systems should have their own transformers because they provide a level of isolation from noisier systems used for lighting or motors. For example, the sound system should have its own transformer to reduce the chances of conductor-borne noise leaking into the system. Data-grade transformers are preferred for video production rooms.

On many occasions, isolated ground receptacles are called out for sound system power. Because many systems that tie together run on different power transformers from different parts of the building, technical ground systems become an important issue. A technical ground system is first a safety system and must adhere to the local codes. Due to cost considerations, technical grounds in these facilities are often deleted in favor of a single ground directly to the transformer that supplies a particular low-voltage system

Acoustics

The acoustics of these buildings include ensuring that sensitive spaces meet mechanical noise criteria, that adequate room-to-room isolation is maintained, and that acceptable reverberation times are achieved.

For outdoor stadiums, the additional challenge of adhering to local environmental noise standards also may be considered.

Indoor Stadiums and Arenas

To achieve acceptable levels of speech intelligibility from the sound system, having acoustical treatment in strategic locations throughout the main seating bowl is imperative.

Generally, sound absorptive acoustical treatment is added to the space to get the reverberation time of the space down to a reasonable value and to reduce offending reflections.

Outdoor Stadiums

In many cases, the acoustical situation in an outdoor venue can only be recognized and treated rather than prevented. Large reflective surfaces can have a detrimental effect on the quality of the reinforced sound, depending on the system layout and building geometry. While improvements can be made to offending surfaces, such as moving, reangling, treating, or simply removing, the best tactic to improve the system performance may be to modify the sound system design to reduce the effects of the offending surfaces.

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Technical Systems

The following systems make up the bulk of those in an arena or stadium:

- Sound systems
- In-house video production systems
- Coaching video systems
- Distributed TV
- Electronic signage
- Scoring systems
- Broadcast cabling
- Coach intercoms
- Wireless systems

Sound Systems

The sound system for the main stadium or arena seating bowl is a unique sound system challenge. The primary goal for the sound system is to provide good intelligibility. Good design practices that use high-power loudspeakers with good directivity control are preferred due to their inherent ability to keep sound energy directed onto the seating areas and off from reflective surfaces.

Careful system layout is necessary so that direct sound from the loudspeaker is much greater than the signal that arrives from adjacent loudspeakers, reflections, and room reverberation.

High-impact music is often a goal, especially in professional sports. For these systems, levels in excess of 105 to 110 A-weighted decibels (dBA) must be achieved. For collegiate and smaller municipal arenas, 102 dBA may be more reasonable due to budget constraints.

Several other small systems can be found throughout the building, including writing press, interview rooms, clubs, concourses, and entrances. Audio program for these areas may include main bowl, radio, TV audio, local input, microphone, and page microphone. The digital signal processing system used to support these systems, whether central or distributed processing, must allow use and control of these signals from a central location.

Technical Systems, continued

In-House Video Production Systems

This system is essentially a small, standalone video production system that provides original content for video displays in the main bowl and throughout the building. Pre-produced video, live camera, broadcast feeds, and replay video are among the sources for the display content. Typical equipment includes cameras, slow-motion recording and playback, nonlinear image file management, switching, and audio for video equipment.

The system may be extensive enough to produce all content for the displays along with support for press conferences, coaches' shows, and promotional material. Alternately, programs may be produced in offsite facilities.

Typically, an in-house video production facility for a sports facility takes up between 74 square meters (m^2 [800 square feet (ft^2)]) and 140 m^2 (1,500 ft^2) of space for technical and production areas only. Additional space may be required for on-site staff offices, office workstations, additional off-line editing, tape/media storage, and repair technician workbench. HVAC to these spaces should be a separate zone with nonstop control from within the space.

Coaching Video Systems

Coaching video systems employ a combination of high end, electronic news gathering (ENG)/ security grade cameras, digital storage and editing and playback distribution. Cabling types include optical fiber, category 5, and conventional video cabling. Typically, cable runs in the low-voltage pathways to the video coaching control/editing room with distribution to video systems, player, coaching, and team management areas.

Distributed Television (TV)

The current standard for a broadband distribution system is higher than 2.3 gigahertz (GHz) so that the system can accommodate digital TV, satellite antenna feeds, digital and analog cable TV systems, and video production room feeds. High definition (HD) programming can typically be included in this bandwidth.

The system is often laid out in a star-type topology, with the headend feeding the riser rooms through optical fiber and coaxial cable feeding each drop distributing from there. The number of drops in an arena or stadium can approach 1200.

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Technical Systems, continued

Electronic Signage

Signage may be broken down into four categories:

- Advertising
- Themeing
- Scoring
- Entertainment

The main seating bowl contains the most obvious and unique display—the main scoreboard—which has undergone steady evolution and currently consists of a dedicated video display. Typically, these displays are composed of surface-mounted LED devices in indoor venues while outdoor displays are dominated by discrete lamps for each color with a pixel due to the typically large pixel spacing of the outdoor displays.

The main, or centrally hung, scoreboard also includes a combination of game scoring, statistical, and advertising displays, which may be fixed digit, matrix, color, or monochrome. Also found are ribbon or 360 boards that use the same technologies.

Data distribution from the video production system is through fiber or coaxial cabling with almost all electronic signs and scoring displays being fed signals through optical fiber.

The smaller displays found in concourses, clubs, suites, and locker rooms are the technology of the day (e.g., plasma, LCD, or DLP technologies) and are as large as can be afforded or that space will allow. Signal is provided from the distributed TV system.

Scoring Systems

Scorers' tables are either courtside for basketball or in press-box areas for hockey, baseball, soccer, and football. These systems communicate with the scoreboard, clocks, and statistics boards.

Statistical software systems are league specific and are all network based, using multiple computer entry points. The statistical information data stream is often used by the video production system, which uses character generation software to display the information as part of a video image.

Technical Systems, continued

Broadcast Cabling

The broadcast cabling system is another star topology with cabling running from camera locations and broadcast booths to the TV truck parking areas. Tie-lines are provided between the TV truck cabling, in-house video production, and coaching video and audio systems. In addition, leagues featuring instant replay of game officials' calls also are tied to the TV truck system. A broadcast cabling system can contain over 48 kilometers (km [30 miles (mi)]) of cable and is the primary user of the building cable tray system.

A typical system consists of singlemode optical fiber, twisted-pair, triaxial, coaxial, data, and audio cabling. Users of the system include play-by-play TV, local news, ENG, and in-house video replay broadcasters.

Each camera position consists of a mix of optical fiber, triaxial, coaxial, audio, and data cabling depending on the location. Generally, these are located in an adjacent junction box. A room with equipment racks near the truck docks is typically used for cable termination.

Local TV trucks and production trucks also are provided parking with pedestals for cable tie-line terminations.

Coach Intercoms

Ultra-high frequency (UHF) wireless systems or wired systems are used for coach intercoms. The placement of antenna for these systems should be carefully considered.

Wireless Systems

Many wireless systems can be deployed in a typical sports building, including:

- Point of sale (POS).
- Audio microphones.
- Video cameras.
- Broadcast camera and microphones.
- Coach intercoms.
- Microcells maintained by a sponsoring cellular SP.
- Wireless fidelity (Wi-Fi).
- Conventional two-way radios.
- Commercial radio rebroadcast.

A sports building clearly is an RF-rich environment and the available bandwidth should be carefully considered prior to coordination.

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Designing Airport and Other Public Transportation Audiovisual (AV) Systems

Introduction

The typical PAS for a public transportation facility is responsible not only for broadcast of audible announcements but also visual announcements.

In the period following the events of September 11, 2001, all public transportation facilities, convention facilities, hotel conference facilities, public museums, and emergency announcement systems for public office buildings began sharing similar elements of a PAS.

Most PASs for these types of facilities must not only provide for the broadcast of general public information announcements, but also support emergency announcements, background music, facility operations information, scheduling information, advertising content, and distribution of TV network content.

Any modern PAS is a system comprised of microphones, audio signal processing, audio amplifiers, loudspeakers, system monitoring, message and content storage, content distribution, image displays, cabling, HVAC services, electrical services, and many other elements.

Planning

The designer and the owner should recognize that the PAS is no longer a separate system but an integral element of the facility's IT, security, HVAC, electrical, daily operation, and marketing functions. For this reason, the AV designer must work in partnership with the design team to ensure the integration of the PAS with these elements.

Long before the designer specifies the technologies of a PAS, a responsible designer begins the design project with a structured formal programming and budgeting process. This early phase of the project is essential to the success of the project. Should issues arise, the early documenting of the established design criteria serves as a valuable reference guide, serving as the basis of design and also supporting the designer's position in later phases of the project.

The PAS designer must know which parties will be responsible for the contracting, requisition, and construction of each element of the PAS (i.e., loudspeakers, cabling, pathways, rooms, electrical, electronics, commissioning, and testing). Projects staffed by a unionized workforce may insist on specific loudspeaker and cabling design and installation criteria. These criteria will affect the selection of products, procedures for installation, and final system commissioning.

Often the architect will focus on creating an interior and exterior building design that may or may not support the integration of PAS components and infrastructure. The PAS designer should convince the architect of the value of an interior design that supports technology integration.

Planning, continued

A failure of AV technology implementation is often caused by the owner's lack of resources to create and manage the content using the installed technology. The PAS designer should discuss this topic with the owner. The owner must be prepared to support the daily maintenance and operation of the PAS, just like IT and MEP elements. The owner must provide for a properly trained and experienced staff.

Definition and distribution location of suitably sized technology rooms is vital. Room sizes and distribution should follow BICSI best practices and ITS industry guidelines. Local authorities should always be consulted.

The positioning, sizing and distribution of technology rooms must support the phasing of present and future construction and redundancy. Including excess space within a room for future expansion and renovations is vital.

For airports, train stations, and other public transportation facilities, the designer must work closely with the governing agencies to ensure that their needs and requirements are included in the design. In the United States, the governing agencies can include any or all of the following: Federal Aviation Authority (FAA), Transportation Security Administration (TSA), Department of Transportation (DoT), Health Services Agency (HSA), Federal Bureau of Investigation (FBI), Bureau of Citizenship and Immigration, and local law enforcement and emergency preparedness agencies.

Management of the PAS contractors is often removed from the PAS designer's scope of work as an owner-driven cost-saving measure. The owner typically hands the designer's work to a design-build vendor, who is working either for the general contractor or directly for the owner. At stake is the PAS vendor's ability to keep up with the constant stream of changes. As the owner's needs change during the evolution of the project, changes, additions, and deletions of other elements of the project can arise.

The PAS designer must be ready to expect and react to change. The structure of the PAS network must include the ability to make zone changes to the PAS over time while maintaining uninterrupted daily operations. The PAS designer's contract must include sufficient scope for a high level of participation, including proactive coordination of PAS elements, construction administration, and PAS commissioning.

The PAS designer must provide the contract documents in drawing and written forms. A comprehensive written description of the functionality, integration and expected performance of the PAS is more valuable than the drawings. If a proper programming process was conducted in the beginning of the project, then the written specification will evolve directly from the program document.

The PAS designer must insist that the PAS vendor read and understand the entire scope of the designer's intent. Open lines of communication should be maintained between the PAS designer and the PAS integrator. The PAS is a large and highly complex network of components and software, which requires frequent collaborative discussions to resolve the fine details.

Acoustics

The value of including an acoustician in the design process is of vital importance. In the United States, the National Fire Protection Association (NFPA) 72, *National Fire Alarm Code*®, recommends that the implemented system should exceed the equivalent of a common intelligibility scale (CIS) score of 0.70. While this score is equivalent to a speech transmission index (STI) rating of at least 0.5, in a busy public use facility with lengthy announcements, a higher STI rating of 0.6 or 0.7 is recommended.

To achieve a higher STI rating, the use of acoustic wall, ceiling, and floor treatments and application of acoustically friendly wall construction is highly recommended. Typically, the owner of a facility may direct the architect to design a facility with durable materials (e.g., stone, metal). These durable materials are generally highly reflective and negatively impact the PAS designer's goal to achieve an acceptable STI rating.

A space can be designed using durable floor materials while also including acoustical treatments on the walls and ceilings. An experienced acoustician can provide both the architect and the PAS designer with valuable guidance on this topic.

For larger spaces, digital acoustic modeling of the space using computer software applications is recommended. The acoustician also can assist in this process. Several computer software applications that are supported by loudspeaker product manufacturers are available. These software applications are intended to provide the designer with valuable knowledge regarding expected STI ratings and to avoid acoustic anomalies that can negatively impact the performance of the PAS loudspeaker zone.

Once the basic room space model is created, including actual room acoustical environment conditions, the PAS designer can easily introduce various loudspeaker solutions to determine the appropriate loudspeaker products and positioning within the space.

Life Safety Guidelines

Often the local code authority insists on strict adherence to the current life safety guidelines. The PAS designer may struggle to locate PAS products that meet both the PAS criteria and life safety guidelines. The PAS designer should understand that, in the United States, the NFPA codes pertaining to emergency voice/alarm communications systems are recommendations, and not an absolute requirement, and that the local authority having jurisdiction (AHJ) also should be consulted.

On the one side, the design of the PAS must balance the owner's expectation of performance and features, and on the other side a strict adherence to life safety guidelines.

If properly designed and implemented, most PAS systems exceed the performance of the traditional building life safety systems.

The PAS designer must discuss this topic in detail with the local AHJ and get the code authority's approval in writing when wavering from strict adherence to the local codes.

Guidelines for Visually- and Hearing-Impaired Access

For hearing-impaired persons, best practice guidelines recommend providing simultaneous text messaging accompanying audible announcements. These guidelines also may detail text size, distance, and font types and colors.

For text messages, high-contrast amber/black foreground/background images are recommended for color-blind viewers. Displayed lengthy text messages should scroll to the approximately same cadence as the audible message.

For support of visually impaired persons and public safety, additional special zones of amplified audio coverage may be required for escalators, moving walkways, entrance doors, and security zones. These zones may require repeating messages to notify visually impaired persons. The zones should be subdivided in such a way that an entrance-exit combination can be reversed.

Mechanical and Electrical Components

The PAS solutions that support life safety must include redundant electrical power services. The PAS designer cannot rely on the building's backup generators. During a life safety emergency, the PAS must remain active and functional, even during the short time period that backup power sources (e.g., generators) are cycling up. Therefore, the PAS designer should include sufficiently sized UPS to maintain full functionality for a minimum of 10 minutes. This short time period is most critical during a building evacuation.

Electrical power service conditioning (e.g., electrical power surge protection and EMI/RFI filtering) on a circuit-by-circuit basis is highly recommended. Power line conditioners are intended to prolong the life of the electronic components and prevent damage from power service anomalies. The PAS designer cannot rely on the building's line conditioning to protect the vital and sensitive PAS components.

To prevent damage problems induced after the load panel, conditioning of each individual electrical circuit is recommended. Often, even the best planned designs are not executed as designed in the field. Individual power line conditioners provide an added level of protection from incorrectly wired circuits, impact from motorized devices, improper circuit phasing, and potential ground loop problems.

Power line conditioners vary by type. Most common devices use solid-state electronic circuitry. Most bleed the over-voltage to the same ground referenced by the AV and IT components. Higher level devices use series-mode line-conditioning circuitry with transformer isolation power conditioning.

To prevent damaging high-level current inrush during automated PAS power-up, power circuit delay sequencing is recommended, particularly for the audio power amplifiers. Most AV industry equipment cabinet manufacturers also include power distribution and power circuit sequencing products.

Mechanical and Electrical Components, continued

To ensure electrical isolation between subsystems, use of optical fiber cable paths is recommended for transmission of data, audio, and video signals. Use of digital transceiver devices also is recommended to ensure signal quality retention over long distances.

Equipment HVAC control is vital. The designer should create lists that estimate typical operation power and heat loads on a room-by-room basis. This data should be given to the MEP designers with a note that the designed solution should provide a continuous service, especially during power interruption, and that each room should be electronically monitored for temperature and humidity levels by the BAS. The building management system (BMS) also should automatically issue e-mail and pager alerts to the facility's PAS and MEP technicians.

Information Technology (IT) Infrastructure

Use of IT infrastructure and IT standards for infrastructure is recommended over proprietary PAS networks. A typical IT network is maintained daily, includes redundant pathways, and typically includes sufficient bandwidth to handle the PAS control and signal distribution.

It also is recommended that, in the United States, the PAS design follow BISCI best practices and TIA standards for room design, cable pathways design, and use of IT-type cable and cable termination technologies.

PAS audio between PAS paging stations, technology rooms, and active powered loudspeakers should use shielded twisted-pair (STP) or optical fiber cabling.

Grounding

The PAS should follow current BICSI best practices, TIA standards, and any local grounding standards.

Visual Paging and Digital Signage

Most new PAS applications require some integration with a digital signage solution. The solution may be standalone or integrated with flight information display system (FIDS), building information display system (BIDS), and rail information display system (RIDS).

When the system is integrated with other elements, the designer must understand who is responsible for the design, specification, and integration of these elements. In addition, if the PAS designer is responsible for FIDS, BIDS, and RIDS, the designer must understand the technical requirements for acquisition, processing, distribution, and display of the content.

The use of automated text message controllers integrated with the PAS is vital, particularly in large multi-zone PAS applications. The automated text message controller can provide message prioritization per zone level, and in particular, coupled with the audible message controller.

Visual Paging and Digital Signage, continued

The display of text messages may require support of multiple languages.

While pre-stored text messages can be easily recalled and displayed along with pre-stored audible announcements, the difficulty with visual text paging is providing text messages from spontaneous live audible announcements. At present, few PAS product manufacturers have addressed this issue.

A decentralized distribution of visual text messages and visual video image content is recommended. Rather than former traditional AV switched coaxial cable solutions, readily available AV/IT technologies using networked IP LAN/WAN protocols provide reliable redundancy, scalability, and remote management from multiple locations and applications. Many IP content digital signage management software and hardware products are available for content creation, content scheduling, PAS text priority, and content distribution.

Purposing the displays for facility information content, advertising content, and display of produced video content can offset the cost of text messaging displays.

Selection of display technology must address cost, font sizes, resolution, ambient light conditions, sustainability and installed form factor. Although the current trend is toward use of gas plasma and LCD flat panel technology, other display technologies like DLP, LCOS, and LED also are appropriate.

Loudspeakers

The selection of loudspeaker products should be based on a balance of acoustic performance, intelligibility, ambient noise conditions, sustainability, NFPA guidelines, form factor, integration with architecture, and cost. The list of available products and product types is extensive. Most modern PASs require dozens of different loudspeaker products.

The quantity and physical distribution of loudspeaker products depends on the selected product. Primary factors affecting distribution are ceiling height, architectural design elements, and zoning. The cadence of loudspeakers often does not match the cadence of other devices (e.g., light fixtures).

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Ambient Noise Sensors (ANS) and System Monitoring

Ambient noise sensors (ANSs) are active audio capture and processing devices (microphones with processors) networked to the central PAS monitoring and electronic supervision subsystems. One ANS should be distributed to each major zone of coverage.

An ANS provides the monitoring system with information regarding current ambient noise level conditions and monitoring of system component performance and reliability. Safety agencies typically require electronic supervision of PAS components, including automated notification of failures.

The PAS should include the ability to automatically adjust for current ambient noise conditions on a per-zone basis. The processor also must reference current audio program sources to avoid accidental volume ramping due to amplified announcements and background music sources.

The quality of intelligibility is linked to the acoustic environment. Therefore, a maximum volume level must be established to avoid the excess volume levels that could aversely affect the quality of intelligible message in a reverberant space.

The ANS monitoring system also is used to monitor and supervise the performance of the PAS components. Linked to the PAS processor, the ANS monitoring system can automatically detect and notify of failed components and cabling. The same monitoring system also should notify the responsible staff of problems through e-mail and text messaging.

As an element in support of life safety, the PAS must include redundant system components and signal pathways. With the ANS notification, a properly designed PAS can automatically route signals from processors, amplifiers, cabling, and loudspeakers through redundant pathways to automatically repair the void in service.

Microphones and Sources

The source of the audio content is the most often overlooked element of any PAS.

All microphones and recording media are not created equal. Even the highest quality PAS will be disappointing if the source is of poor quality. The designer should:

- Work with the owner to develop acceptable products for voice capture (e.g., microphones, paging stations) and content recording and retrieval.
- Understand the culture of the owner's workflow and daily operations.
- Understand that using a telephone as a paging source does not produce acceptable results.
- Understand that using inexpensive microphones and untrained voices for prerecorded announcements exhibits unacceptable results. The owner should budget to contract a professional studio and studio-grade voice talent. Use of calm, clear, and intelligible voices is preferred. The owner should provide the message script.

System Electronics

Modern PASs typically include some form of software-programmable digital audio signal processor (A-DSP). When configured by an audio designer, the A-DSP provides a reliable flexible software application solution for most PAS functions when compared to the former solution of cascaded analog components. Most modern fire alarm systems now include some form of A-DSP technology. Larger PASs for airports and museums also include digital audio and text message controllers and automated system monitoring.

Although the A-DSP can be the single central heart of a PAS, the PAS designer must consider how to address redundancy to meet life safety requirements. A decentralized A-DSP solution is recommended; however the selected A-DSP product must support a decentralized network of A-DSPs that can continue functioning if one or more A-DSP faults or fails.

Designing Retail Audiovisual (AV) Systems

Introduction

The retail venue, as with most venues, is a constantly evolving market needing to employ the latest AV technology. Today's retail customer has demands and expectations that require equipment similar to that of many high performance venue systems. While this technology is generally not the direct commodity in a retail location, it has become a vital part of the corporate brand image.

Whether the AV system is large or small, complex or simple, the purpose remains the same—to attract the customer.

As any visit to the local shopping mall shows, a broad range of retail concepts caters to different target customers. Therefore, every retail AV system is somewhat unique. The system requirements in a retail operation targeting 14- to 21-year-old male customers are vastly different from those for a store targeting new mothers. The former may require a system output in excess of 90 dB of sound pressure level (SPL), whereas the latter would typically be much lower.

Just as system output power requirements vary widely with each retail concept, so do all other components within the AV system.

When designing a retail AV system, a complete store profile should be put together. This includes, but is obviously not limited to, information such as:

- Target customer.
- SPL requirements.
- Style of music.
- Video source material.
- Store layout and architectural details.
- Aesthetic requirements.
- Tenant requirements/limitations (imposed by the landlord).

NOTE: This list varies by location.

With a completed store profile, the design process can be broken down into the three main areas of retail AV design:

- Background music
- Paging system
- Digital signage

Background Music

The old notion of background music is rapidly changing to what can be best described as foreground music. This changes not only the loudspeaker requirements but also the headend electronics from power amplifiers to the music source.

Music Source

The music source determines the choice of all the other equipment in the system. For example, a source with no low-frequency content does not need subwoofers. The designer must take into account the type of reproduced music and the source equipment.

Typically, retail locations have a paid subscription to a music source provider. This provider can tailor a dedicated music feed, provide access to general music channels, or provide music in a portable format (e.g., CD, hard disk). The music provider also typically supplies the hardware interface for the supplied music, much like a cable box for cable TV.

The hardware box communicates to the music source provider through satellite antenna, phone line, Ethernet network, or the portable format. In most cases the audio output of these devices are unbalanced stereo or mono.

In an effort to keep the customer engaged in a store visit, many systems incorporate interactive music selection. These systems consist of a touch panel with a list of music that can be selected and placed in the play list queue.

Another advantage to the paid music service is that all licensing fees are usually included in the subscription. The client should understand that the license fees are required to play copyright protected music publicly.

Loudspeakers

Many aspects of the retail location affect the loudspeaker design, each with their own importance. These aspects include:

- Bandwidth.
- Coverage areas.
- Aesthetics.
- SPL requirements.

Coverage

The main sales spaces are the primary areas requiring sound coverage. In many cases, the cash/wrap area requires diminished coverage to enable a clear sales communication. When dealing with mall locations there are often strict rules on sound propagation beyond the lease line. Other areas to consider for sound coverage are stock rooms, receiving areas, and office spaces. Outdoor speakers also can be installed to start the customer experience as early as possible.

Background Music, continued

In all cases, manufacturer specifications should be used to determine consistent coverage with the minimum number of loudspeakers. Overcoverage leads to many problems, such as phasing, especially as customers are continually moving through the space. For this reason, most retail systems are designed for mono. These coverage issues and added cost of electronics usually preclude any stereo or multichannel applications.

Aesthetics

Corporate branding is as important as the individual support systems that make up the retail location. Some clients like to see technology while others want everything to be out of sight. This will have a direct effect on the types and locations of selected loudspeakers.

Sound Pressure Level (SPL) Requirements

Using the specified SPL requirements, loudspeakers should be chosen based on the manufacturer's technical specifications. The SPL calculations should take into account the best listening locations (e.g., retail displays).

Headend Electronics

With an understanding of the music source and loudspeaker totals, the headend electronics can be determined. Items to consider in the selection of this equipment are:

- Number of sources.
- User control.
- Loudspeaker equalization.
- Required amplification.
- Auxiliary outputs.

Simple systems can consist of an all-in-one mixer-amplifier while some of the most complicated systems can include full DSP processing units, control systems, and racks of amplifiers. Simple systems can be located on a shelf, usually in the store office or stock area. More advanced systems consist of equipment racks, which can be wall-mounted or located in an ER. The designer should keep in mind that floor space is premium in most retail locations, which usually makes wall-mounted equipment more desirable.

Another key element to most retail locations is music-on-hold (MOH). This is usually an auxiliary output of the sound system that feeds into the store's phone system. This is typically a mono line level unbalanced feed.

Paging Systems

Paging systems can serve multiple purposes within a retail location. Store personnel primarily use them; however, it can be used to notify customers of pertinent information. In either case, speech intelligibility is imperative and must be taken into account when designing the loudspeaker system. For budgetary reasons, paging is usually incorporated into the music playback system.

Paging sources can generally be classified into three types:

- Phone generated
- Microphone generated
- Auto-generated

In-store phone systems usually have a page output that can be fed into the sound system headend electronics. Microphone-generated pages can either be auto-sensed or triggered by a push-to-talk button. Similar triggering can be employed for auto-generated pages that usually come from a hard disk for in-store advertisements.

Paging priority is typically not an issue in retail locations. However emergency/evacuation requirements can dictate certain system capabilities. In most retail locations, where local codes require so, a simple trigger to disable the sound system will suffice. This trigger is fed from the fire alarm panel.

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Digital Signage

Digital signage in a retail location is simply nothing more than a tailored video display system. Two types of displays in stores are:

- Advertisement displays.
- Entertainment displays.

For the designer the only real difference will be in the sources feeding the displays.

Typical sources for both types of displays are DVD, computer, and satellite (or cable) TV. In most cases, these sources directly feed a display; however, more complicated systems can make use of matrix switchers. RF distribution is rarely used today due to the increased size and accuracy of the displays.

Most retail locations are using LCD and plasma flat panel display technology. In rare cases, video walls are used. Projectors are seldom used.

Depending on the application within the store, screen sizes can vary widely. Basic display rules should apply. If it is a local display, smaller screens are acceptable. Larger screens are used for wide area display. Due to limited space availability, ceiling-mounted displays are usually preferred. The designer should observe all disability access requirements when mounting equipment.

As with all systems, but especially retail video, the designer should leave room for future expansion. This includes not only the physical numbers of displays but also input sources and format upgrades. Even more so than audio, retail video requirements are growing exponentially.

Designing Entertainment Audiovisual (AV) Systems

Introduction

Entertainment venues are some of the most demanding environments for professional AV systems. Large venues, like casino showrooms, can be purpose-built around a specific show, designed to accommodate touring road shows, or required to fulfill both functions.

Ticket prices for popular Las Vegas shows average around 100 U.S. dollars per person and premium seats can cost many hundreds of dollars. Audiences expect to be highly entertained by the performer and to be dazzled by the production quality.

Performers and show producers require consistency from show to show, placing great demands on the available technology, and the technical staff who operate and maintain it. While catastrophic failures of sound or video equipment may result in a canceled show, which is costly to the producer given that many showrooms are booked at or near capacity, cancellations also may damage relations with the venue's customers.

Design of high performance entertainment AV systems is a challenging endeavor.

Venue Programming

The entertainment venue may be designed around the specific requirements of a show, with the intent of a multiyear run.

The show content or genre could be a:

- Musical performance.
- Featured vocalist or group and a small musical combination.
- Featured vocalist or group and a full orchestra.

Production shows can contain one or more of the following:

- Dance
- Magic
- Comedy
- Music
- Animal acts
- Acrobatics
- Water shows

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Venue Programming, continued

Shows may use massive scenery and props, elaborate costumes, special effects, lighting, and staging. Sound systems can be designed to provide an immersive experience, where sound system localization goes far beyond standard formats for stereo or 7.1 surround (e.g., in systems equipped with dozens of surround channels capable of providing hemispherical imaging). Large format, multichannel projection, or flat panel displays, also may be used for image magnification of performers or to add on-demand video clips or effects.

Support of Touring Artists

Venues that book national acts are required by contract to provide systems and technical support to satisfy performance requirements conveyed in the technical rider.

The rider often calls out specific products by make, model, and quantity, as well as broad performance requirements such as:

- Average or maximum sound level requirements.
- System frequency response requirements.
- Quantity of mixing console input channels.
- Quantity of stage monitor mixes.
- Make, model, quantities, and location of microphones, stands, and direct boxes.

Accommodations required for touring systems typically include, but are not limited to:

- Dedicated electrical services for sound and lighting systems.
- Structural support capacity and access to locations for rigging of sound and lighting systems.
- Accommodation for temporary installation of the artist's sound and lighting consoles and ancillary equipment. This may require either removal of house equipment from sound/lighting booth, or displacement of audience seating.
- Accommodation for installation of microphone, line, or control cabling between front of house systems and stage.

Installation of touring systems on a temporary basis is labor intensive, so time and cost savings may be realized if the house system is acceptable to the artist. While no singular list of equipment will satisfy all riders, designing and implementing systems that satisfy most performers' requirements is possible. Details are often negotiable if the larger intent is fulfilled.

Ultimately, the system designer must determine the level of performance and convenience that the owner is willing to fund.

Entertainment Sound Systems

Entertainment falls within the domain of performing arts, so most or all of the system elements and methods, as described in the section on Designing Performing Arts Audiovisual (AV) Systems in this chapter, are directly applicable to the design of entertainment venues.

System, show, and sound designers are all aware that the ticket buying public has high expectations for the sonic quality of the performance. These expectations have been fueled by wide exposure to high quality consumer AV systems that include multichannel surround sound systems and systems that play compact discs and Dolby® or digital theater sound (DTS®) encoded multichannel digital video discs. Home theater systems have raised the benchmark for show producers and designers, who must deliver both impact and intimacy in large venues.

Loudspeaker Systems and Related Subsystems

Entertainment sound reinforcement systems often consist of high-powered, multichannel, multi-element, loudspeaker systems. These systems are typically required to deliver high sound levels (95 to 105 dB [decibel] with 10 to 15 dB of headroom) and extended to 40 hertz (Hz) low frequency (e.g., sub bass) response or below.

Loudspeaker systems may be deployed as mono, stereo, multichannel, or distributed arrays. They may employ one or more of the following elements:

- Direct radiator and horn-loaded loudspeaker systems
- Conventionally arrayed loudspeaker clusters, or line array loudspeaker technology
- Powered loudspeakers containing on-board amplifiers, filters, driver protection, and remote monitoring and control
- Multichannel digital signal processing to provide equalization, filtering, limiting, routing, and multichannel panning
- High-powered amplifiers, often containing on-board DSP and remote control and monitoring functionality.

Entertainment Sound Systems, continued

Show specific loudspeaker systems also may incorporate the following technologies:

- Loudspeakers installed in individual seats
- Water-centered shows that incorporate loudspeakers designed to provide audio to swimmers and divers
- Digital processors that enable the show designer to move apparent locations of sound around the venue on cue and in real time

Loudspeakers equipped with on-board amplification and processing offer the designer a highly optimized processor/amplifier/driver interface with the ability to eliminate or downsize the dedicated amplifier room.

System designers have a constantly increasing choice of loudspeakers available and sophisticated computer modeling, prediction, and auralization tools available to assist in determining coverage, intelligibility, and sound level capability.

Mixing Consoles

The choice of mixing console technology may be driven by a number of different considerations. The show designer may prioritize:

- Console size or footprint, keeping it small to conserve audience seating.
- Cue capability, so that the scene recall is smoothly automated and synchronized to events on stage.
- Sound quality.
- Output routing flexibility.
- Exceptional manufacturer support.
- Ease of rental.

Entertainment Sound Systems, continued

The touring sound engineer who mixes musical acts may have different priorities or place them in a different order:

- Sound quality
- Quick access to controls
- Familiarity (comfort factor)
- Exceptional manufacturer field support

The digital mixing console is widely used by both musical acts and production shows, due to its inherent flexibility, automation and recall capability, and the ability to put the control of high-input channel counts into relatively small spaces. Many levels of redundancy may be provided within digital consoles, including power supplies, control surfaces, mixing engines, and audio and control cabling.

Analog mixing consoles are still in wide use by musical acts and venues that may not be constrained by space, the need for automation, or extensive on-board processing or routing.

Digital consoles also may impact the infrastructure of the venue, given that microphone preamplifiers and analog-to-digital (A/D) converters may be separated from the console control surface and DSP and located on stage or in the band pit. Analog twisted-pair or shielded microphone cable, with its inherent susceptibility to RFI and EMI can be replaced by digital audio transmission on copper or optical fiber cable.

Digital audio also may be split and distributed to monitor, broadcast, or recording consoles, eliminating or minimizing the need for passive or active microphone splitting technology.

These capabilities can be incorporated either in the console design or through a third-party provider and also can be used with analog consoles by providing digital-to-analog (D/A) conversion where it is needed.

To summarize, front of house and monitor mixing console technology can be implemented as:

- Mute automation, available on many consoles.
- Digitally controlled analog technology.
- Sonic attributes of analog.
- Full recall capability.
- Fully digital consoles, available in multiple configurations.
- Integrated control surface and digital processing.
- Digital control surface connected to outboard mixing engines.
- Distributed inputs and outputs, allowing A/D, D/A, and digital standards converters to be located throughout the venue.

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Entertainment Sound Systems, continued

Mixing surfaces can be augmented or replaced by computer workstations or wireless computer technology to grant the mix engineer mobility.

Stage monitor mixing may be handled by a dedicated monitor console, and be supplemented by, or replaced with, smaller consoles distributed around the stage or pit to provide the musicians or artists the ability to handle the monitor-mixing tasks.

Playback Equipment

Highly scripted productions may use playback systems for sound effects or music playback. These systems are often implemented around computer-based digital audio workstations, sometimes incorporating complex digital processing and routing capabilities. These systems can be synchronized to mixing consoles, effects, or lighting systems through Society of Motion Picture and Television Engineers (SMPTE) or musical instrument digital interface (MIDI) control.

These systems provide the flexibility to edit playback lists, timing, and other performance variables.

Wireless Microphones

Most shows depend on wireless microphones to provide mobility to performers. Professional wireless systems for entertainment use are largely implemented through analog UHF transmission or other methods such as spread-spectrum and digital transmission systems now entering the market. Complex shows can require dozens of channels of wireless microphones as well as wireless in-ear monitor systems. This requires diligence on the part of the system designer with regard to frequency coordination, antenna distribution and placement, and real time monitoring of signal quality and battery condition. Complex wireless systems may require a dedicated technician to monitor systems and coordinate system handoff and replacement during the performance.

Infrastructure

As mentioned previously, digital technology has advantages over analog transmission, including:

- Immunity from interference.
- The ability to route quantities of discrete audio channels, over relatively inexpensive coaxial, twisted pair, category 5, or optical fiber cable.
- The high density distribution capabilities of digital audio, which can reduce both the quantity and size of electrical conduit.
- Fewer and simpler connections coupled with cable and conduit reductions, which may enable cost savings to facility infrastructure budget.
- The ability to remotely monitor and control signal processors, wireless microphone receivers, mixing consoles, amplifiers, and loudspeakers.
- The ability to use low cost, nonproprietary, computer network technology to handle routing and distribution.

While digital systems offer a great number of advantages over analog, the system designer has to continue offering analog capability for the foreseeable future.

Microphones, direct boxes, power amplifiers, and many other analog devices may be required to interface with installed systems, even if digital is in wide use in a given facility.

Entertainment venues in the planning stages should provide for analog and digital audio and control transport. Cable types should at least include:

- Single and multipair twisted, shielded, cable for:
  - Analog audio.
  - Digital audio.
  - Theatrical intercom.
- Low gauge twisted-pair speaker cable.
- Coaxial cable for:
  - Digital audio.
  - Analog video.
  - Digital video.
  - Control.
  - RF distribution.

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Infrastructure, continued

- Category 5 network cables for:
  - Ethernet.
  - Proprietary control systems.
  - Proprietary digital audio network(s).
- Unshielded twisted-pair cable optimized for analog video balanced unbalanced (baluns).
- Multimode and single mode optical fiber for:
  - Digital audio.
  - Digital video.
  - Computer networks.

Dedicated centralized patch facilities should be provided to enable interconnection of venue systems within the performance space to auxiliary spaces, as required.

Communications

Reliable communications systems are critical for show production. Theatrical intercom systems are typically distributed to all production and technical support areas such as amplifier rooms, lighting catwalks, dimmer rooms, and fly lofts.

Two- or three-wire party line systems are common throughout entertainment venues nationwide. They are capable of interfacing with two-way radios (walkie-talkie), full duplex wireless intercom, telephones, and specialized wireless intercom systems used by underwater divers.

Design goals include reliability and easy access to intercom receptacles or stations, as required. Large entertainment venues may be best served by multichannel systems that allow each discipline—sound, lighting, stage, video, and others—to operate independently if needed. Intercom matrices allow the designer to partition or combine the system as required.

Video Communications

Video cameras and monitors may be used to enable pit musicians to see stage action and vice versa. Video cameras also may be located to provide visual access to scenic elements to ensure that they are safely deployed. Video feeds may be provided to artist and chorus dressing rooms, the green room, and technical operations offices so that show progress can be monitored.

Remote control PTZ cameras may be controlled from a central location such as the stage manager console or from multiple locations. Cameras used in harsh environments require environmental housings for protection.

Video systems can be designed to be hard-patched using dedicated video distribution amplifiers and patch-bay systems or be routed through a matrix switcher. Switcher routing can be centralized or distributed. Alternately, the production monitor system can be modulated to RF and inserted onto a local CCTV system.

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Designing Performing Arts Audiovisual (AV) Systems

Introduction

Today's performing arts theaters can come in many architectural forms. Some are designed for a singular purpose, such as music, opera, or road shows. Others, designed to accommodate multiple uses, are called multipurpose halls.

The hugely diverse nature of modern performing arts centers makes a detailed description of all of the variations of electronic systems a task beyond the scope of this manual. Therefore, this discussion will be limited to the most common systems found in these facilities.

Acoustical Considerations

Successful performing arts hall designs require careful attention to certain fundamental acoustical requirements to achieve satisfactory listening conditions. Basic acoustical objectives for design of listening environments are both the control of all desirable sounds and beneficial reflections, as well as the control of undesirable noises, sounds from external sources, adjacent spaces, and HVAC systems.

Acoustical requirements vary significantly depending on the type of performance supported. For example, theaters designed for acoustic musical performance tend to be more reverberant or live sounding, while those designed for speech or dramatic production are less reverberant or dry sounding. These requirements present special challenges for multipurpose venues designed to support many types of performances. Often these halls incorporate variable acoustics systems allowing the acoustical characteristics of the room to be adjusted to suit the requirements of a particular type of performance.

Sound Reinforcement

In concept, acoustically well-designed theaters of up to 500 seats may not require speech amplification. In practice, however, sound reinforcement systems are usually implemented in spaces of larger than 150 seats to accommodate inexperienced talkers and whenever pre-recorded program material is presented. The purpose of a sound reinforcement system is to provide all listeners with sufficient direct signal that is free from distortion and at a level that is greater than competing sounds such as reverberant energy and HVAC and audience noise.

Sound Reinforcement, continued

Central Loudspeaker Clusters

In modern theaters designed to support speech, music and dramatic performance, the main loudspeaker system often consists of three loudspeaker clusters: left, right and center, flown above the forestage area. The loudspeaker clusters can be used to provide both speech reinforcement and program audio playback. Each loudspeaker cluster typically consists of multiple full-range cabinets designed to provide high-level, complete coverage of the entire seating area from each cluster location.

These clusters can be fixed in place or movable, allowing them to be lowered to the stage level for service or storage.

Subwoofer Loudspeakers

Subwoofers are intended to supplement the main loudspeaker clusters. These loudspeakers cover only the very low end of the audio spectrum and are used to enhance bass response for music and special effects. These loudspeakers are typically either located above the exposed ceiling structure or hidden behind architectural details. Alternately, though not ideally, they may be flown with the central loudspeaker clusters.

Satellite Loudspeakers

To provide high-quality audio to all seating locations within large theaters or those containing balconies, supplementing the main loudspeakers with satellite loudspeakers covering the balcony and under-balcony seating areas at the rear of the hall may be necessary. These loudspeakers may be needed because of the distance between the main loudspeakers and the seating areas or when the depth of the balcony overhang occludes the direct sound of the main loudspeaker clusters from reaching the rear-most seats.

These loudspeakers typically consist of full-range units located in the ceiling above the seating areas. Without these loudspeakers, direct audio at these seats may be lower than the reverberant level, resulting in reduced intelligibility.

Stage Side-Fill Loudspeakers

In larger halls and the multipurpose venues with an acoustical music component, loudspeaker arrays located on both sides of the proscenium opening and several meters or feet above stage level should be considered in the design. These loudspeakers will provide additional coverage for the first portion of the orchestra level seating and also could be used to provide speech reinforcement (e.g., narration and announcements during acoustic music performances) when the main loudspeaker clusters are not available for use. Each loudspeaker array may consist of multiple full-range cabinets arranged in a vertical linear array. They could be concealed behind acoustically transparent grilles on the inside edges of the proscenium wall.

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Sound Reinforcement, continued

Front-Fill Loudspeakers

The first few rows of a theater are often difficult to cover from the main loudspeakers because of the extreme angles involved. Loudspeaker outlets should be provided at the stage edge to allow small demountable loudspeakers to be attached along the front edge of the stage or installed into small niches along the front of the stage and lift edge to provide augmentation coverage to the first few rows of seats.

Surround / House Effects Loudspeakers

In support of multichannel playback of experimental compositions, surround sound, and cued theatrical sound effects, loudspeaker outlets may be provided throughout the hall to allow for connection of loudspeakers along the sides and rear of the hall.

Loudspeakers niches could be incorporated into the side and rear walls at the orchestra and balcony levels to conceal these devices. In addition, loudspeakers could be occasionally hung from a lighting rail on the balcony faces to provide additional surround coverage of the central orchestra and balcony seating.

Hearing Assistance, Audio Description, and Simultaneous Interpreting

To comply with the disability access requirements for hearing assistance, facilities with sound reinforcement systems typically must also include an assisted listening transmission system. The most common of these systems consists of a frequency modulation (FM) or IR transmitter and a pool of receivers for the audience.

Amplification systems enable the transmission of the sound picked up through microphones directly to the receivers worn by the individuals. These receivers, used either alone or in conjunction with the person's hearing aids through induction loops or direct audio input, have their own volume controls that enable the most effective use of the residual hearing.

Many modern theaters now offer audio description services to their patrons. Audio description is the descriptive narration of key visual elements of live theater and other media that enhances the enjoyment of blind and low-vision consumers, using the same type of equipment as the hearing assistance system.

Audio description involves the insertion of audio explanations and descriptions of the settings, characters, and action occuring in such media, when such information about these visual elements is not offered in the regular hearing assistance audio program.

These systems also can be used for real-time simultaneous foreign language interpreting to large groups of patrons.

Sound Reinforcement, continued

Sound Mixing Positions and Equipment

The two primary sound mixing positions to be considered are a:

- Control room.
- Front-of-house position in the direct sound field.

Additional mixing positions may include stage monitors, broadcast, and recording.

The control room is the mixing location for most simple productions and is typically located at the rear of the hall. This room should have a large operable window to allow the operator to get a sense of what the audience is hearing. While the mixing position in the control room is generally acceptable for small productions and lectures, larger productions using multiple microphones require a mixing position located within the seating area.

The front-of-house mixing equipment should be designed to be portable so that it can be moved from the control room to this mixing position for use. To accommodate touring productions, temporary equipment also could be brought in to this location and connected to make use of the permanent sound system. An underground cable chase is often provided to allow temporary cabling to be run from this location to the stage.

Audio Source and Recording Equipment

Equipment should be provided at the mix location for program playback and archival audio recording in the hall. This typically includes a limited amount of processing equipment and recording media, including CD and hard disk recorders. Additionally, the theater may have numerous tie lines to the facility's recording studio to allow for more sophisticated recording.

Stage and Portable Equipment

Most theaters include a number of input panels on the stage in all four corners and the orchestra pit to allow connection of microphone inputs, monitor loudspeakers, side-fill monitors, and other equipment (e.g., intercom and video).

A typical complement of portable equipment includes monitor loudspeakers, the amplifiers to power loudspeakers and microphones, stands, cables, and other ancillary equipment.

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Production Communications System

The installation of an effective production communication system ensures that directors' and designers' instructions can be conveyed anywhere in the hall and to anyone in the hall at the precise time the communication has to occur. Equipment can be adjusted and operated to carry out the artistic intent of the director or set designer. The increased communication capabilities also increase the safety level of production preparations and performances.

Many electronic devices are made for theater production communication systems, including:

- AV monitors.
- Call staff and performer systems for easy communications with dressing rooms, back-stage areas, and other parts of the halls.
- Talkback system for theater production set-ups and tear-downs.
- Intercom systems.
- Cue lights.

Production intercom systems are designed to allow production personnel in separate parts of the theater to communicate. Both analog and digital systems are available in either private or in party-line channel. Wireless units also may be included to allow untethered use.

Production Monitoring Systems

Performance audio and video feeds should be distributed to several locations throughout the facility including:

- Audio control/house mix location.
- Amplifier room.
- Lobby.
- Follow spot room.
- Makeup room.
- Costume shop.
- Dressing rooms.
- Dimmer room.
- Green room.
- Technical director's office.
- House manager's office.
- Scene shop.
- Box office and concessions.

Audio

A backstage paging and production monitoring system should be included in most theater system designs. Paging signals are generated in stage, control, and management areas and are reproduced in backstage areas, dressing rooms, green rooms, and production areas. Local volume controls should be provided for all individual locations. The volume controls that allow paging signals to override any local setting may be selected. Main intercom stations also can be configured to initiate backstage pages.

To allow production and performance personnel to monitor the course of a production, microphones can be mounted onto the balcony edges, suspended from the catwalk, or over the stage for use with the performance monitoring system.

Loudspeakers should be provided in the lobby and other public areas for latecomer monitoring, background music, and audience recall chimes or announcements. Digital audio recorder/players provide a flexible platform to store and recall chimes and other repeatable announcements. The box office also should have the ability to page into the lobby.

Production Monitoring Systems, continued

Video

A color video camera may be located on a balcony face at the center of the hall. This camera is focused on the stage to provide a constant video monitor signal of the stage for use by the production staff and to provide a video signal to latecomers' video monitors located in the lobby and interior seating entrances.

Additionally, video tie lines also may be provided between several locations on stage, backstage, pit, audience area, and the control area. These lines could be used to provide additional camera or monitoring capabilities. Video monitors or connection panels should be mounted near the main entrances to the audience chamber to allow latecomers the ability to monitor the performance while awaiting access to their seats. These monitors also would provide a platform for showing video advertisements during intermission.

Control Systems

A remote control system may be incorporated into the system design to allow centralized control over the presentation equipment, to allow a presenter to control the equipment from the stage, or staff to exercise control from the control location. The control system may interface with the lighting system for recall of presets for house lights.

To provide a high degree of flexibility, the control interface of the remote control systems is often a touch screen panel programmed to allow intuitive control of the system components. The touch screen can be portable for use from either the house mix location or on the stage.

Designing Museum Audiovisual (AV) Systems

Introduction

The profile of typical media usage by a museum or visitors' center has evolved significantly over the last decade. Visitors are much more media-savvy than before. They likely use PCs regularly and have moderate- to high-quality audio and video systems in their homes. Furthermore, museums have found that media have a unique way of telling the story and bringing artifacts and messages to life that cannot be replicated by static text and graphic panels.

Most new large-scale exhibitions use a central media control room. This room typically houses a number of vertical equipment racks that hold audio, video, and PC source players, processing electronics, audio amplifiers, show control system, and related electronics. All programs are originated and monitored from this room. When it occurs, an equipment problem most likely is localized in this room and can be dealt with efficiently and out of public view.

This leaves only the video displays, video projectors, loudspeakers, and visitor points of initiation (e.g., push buttons, motion detectors, and touch screens) in the exhibit area. Given the benefits to the museum, exemplified by central point of control, monitoring, and maintenance, and the benefits to the exhibit design team, exemplified by a smaller amount of equipment in the exhibit area, the use of central media control rooms are expected to expand even more.

At major museums, a typical permanent exhibition is in place for 20 to 30 years. Given this time period, the media content and the respective delivery systems will likely be upgraded or replaced several times during the life of the exhibit. To support this requirement effectively, the cabling infrastructure should be designed to support new delivery technologies expected for a foreseeable future.

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Localized or Focused Sound

Large-scale museum exhibitions of 929 m^2 (10 000 ft^2) to 1860 m^2 (20 000 ft^2) are not uncommon and they often tend to be filled with a variety of media experiences and delivery systems.

An exhibition may include an orientation theater, several mini or small-group theaters, one-on-one media elements, and a summary or conclusion theater. This concentration of media within a single exhibition often introduces a challenge to the design team to minimize the potential for neighboring media elements to interfere with one another.

The success of being able to contain the audio message to the specific physical area it needs to support often rests with a combination of factors, including:

- The ability of the exhibit design team to physically isolate the media elements within the overall plan. This can often be accomplished by physically orientating the exhibit media playback components away from competing, adjacent, systems.
- Using the opinion of an acoustical consultant who can suggest the utilization and placement of as much absorptive material as possible to suppress sound spill into adjacent areas.
- Using loudspeaker types, quantities and placement to support the containment strategy. This may include several techniques, including:
  - Using a larger quantity of loudspeakers than normal but with lower-volume settings.
  - Placing the loudspeaker so it is aimed at an absorptive surface.
  - Using a loudspeaker that has a dispersion pattern that closely matches the intended coverage area.

A number of loudspeakers are made specifically for this purpose. They are usually identified by the type of technology they include as:

- Hemispherical-reflector based.
- Parabolics.
- Ultrasonics.
- Beam shaping or beam steering.
- Steered line arrays.

The hemispherical-reflector based products are probably the most common in museums, but ultrasonics and beam shaping multi-loudspeaker arrays are now being used frequently as they become more competitively priced.

Personalized Audio

Most personalized audio systems consist of a self-contained audio player and headphones for the individual user. In some cases, the audio playback device is a customized CD player, but most companies seem to be migrating to either solid-state audio players or personal digital assistant (PDA) units. The industry tends to be dominated by a few major companies who market their products to museums and visitor centers through a shared-revenue rental plan that minimizes the upfront costs for the institution.

Until recently, the systems including the individual players were self-contained and had no significant electronic relationship to the balance of the museum. On some of the newer systems, two features that may alter this scenario in the future have been introduced:

- Some of the players now employ remote triggering devices. These triggers are often IR transmitters located at the entrance of each gallery or major theme exhibition area. The triggering device automatically starts the appropriate program on the player when the visitor enters the gallery or exhibit area. The visitor is free to manually initiate other programs of interest.
- Wi-Fi networks are increasingly used in museums. Many audio players and PDAs have limited memory capacity and cannot support the potential program content available in a large museum. Wi-Fi is used by some devices to tap additional content on an as-needed basis, depending on the requests made by the visitor. Several large museums are testing this technology both with the devices they rent and with devices owned by the visitor (tablet PCs and PDAs).

Control Systems

Virtually every major media installation in a museum or visitors' center is operated by a master show control system. These systems have evolved considerably over the past several years and now provide a significant degree of system monitoring and diagnostic functionality as well as basic scheduling.

Typically, the bulk of the master show control system is housed in the central media control room. This location allows the system to be in close proximity to the source players, processing electronics, amplifiers, lighting dimmers, and other devices operated under this control.

Typically, show control systems turn all of the components on in the morning and turn all of the components off in the evening. This timing cycle has now been expanded to include a number of sub-routines and diagnostic functions. In most current systems, the programming scenario begins by turning each of the devices on and then polling the device to verify they are actually on.

This is particularly true of devices that only have toggle on-off switches and require independent verification of their status. Once all of the devices have been powered on and their status verified, the show control system commands all of the devices to initiate their default playback scenario.

Depending on the source player and the show designer's intent, the default playback cycle might be a continuous loop or it might be waiting for the visitor's initiation through a pushbutton, motion detector, touch screen, or other device. Once the program initiation occurs, the show control system directs the source deck to perform the appropriate task and then verifies that it has occurred.

From this basic scenario, the show control system can provide a number of monitoring functions. It can record the total number of show cycles. In the case of multiple-choice programs, it can record which program was chosen and how frequently.

Lastly, it can continue to poll all of the devices controlled and confirm that they are responding and executing the desired functionality.

Beyond this monitoring function, many show control systems provide a higher level of diagnostic support. In the process of monitoring each device, the system will compare the current operational status with the scripted program. Any discrepancies will cause the reporting of an alarm status to the technician. The report can be an audible or visual alarm, a pager alert, or an e-mail. Further, the system will keep a cumulative log of all components or program failures, so problematic trends can be identified or mean time between failure cycles can be projected.

Control Systems, continued

Most show control systems can communicate over a typical data network. This provides two major advantages. First, the museum staff can monitor the status of the system continuously from their desktops or some remote location. Second, the AV contractor, show control provider, or equipment manufacturer can query the system on an as-needed basis to provide technical support and assist with the remediation of any problems.

Localized Video

Localized or personal video programs are often used to support a one-on-one interaction between the visitor and the media experience. They often have some level of interactivity so a visitor can select programs to view or, through a number of menus, drill down to a detail level of information.

Typically, a personal video kiosk contains a small (i.e., 508 millimeter (mm [20 inches (in)]) diagonal or less) video display, some method of interaction (e.g., pushbuttons, track ball, or touch screen), and localized loudspeakers.

In some high-volume exhibition areas, a larger, echo monitor is placed above the kiosk. The echo display replicates the image from the small primary kiosk display. The purpose of the echo display is to provide some shared experience for the visitors who are unable or unwilling to use the primary kiosk display.

While the echo display viewers do not interact with the program directly, they do get a sense of what is happening and can share the media experience. This echo display configuration becomes extremely beneficial to large, high-traffic exhibitions. If a visitor uses the kiosk to view a program or obtain information for about two minutes, that allows a throughput of only 30 visitors per hour per kiosk. In certain museums, up to 1000 people per hour can flow through an exhibition space. The echo display is a useful tool in addressing this visitor volume in conjunction with the kiosk configuration.

While the final design, details, and trim of the kiosk may be unique to the individual museum or exhibit, the basic kiosk design itself is driven by a number of factors or guidelines. The most important factor is absolute adherence to local disability access guidelines. Specific criteria have been established for height and angle of the video screen, wheelchair access, pressure for the touch screen and pushbuttons, and other functions. Further, local disability access guidelines also apply to the program content (e.g., captioning, type size and style).

Finally, kiosk designs require specifications for ventilation and service access and maintainability over the life of the exhibition.

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High-End Experiential Design

Media elements in museums and visitor centers tend to fall into distinct categories as they support specific areas and components of an exhibition storyline. These elements are typically identified as an orientation theater, mini-theaters, personal or interactive programs and a conclusion theater. However, several museums will take these theater elements to a higher level.

Such scenarios may include numerous video displays, multiple audio channels, and an audio soundscape, coupled with theatrical lighting effects and, in some cases, live performers. This scenario may have multiple variations, but all of them share some common traits.

In most cases, a specific show designer will be part of the program team to provide the look and feel of the show and, often working with the exhibit designer, develop the content. The technical criteria required to support these shows differs in several ways from the balance of the media in the exhibition:

- Media components have a higher concentration in this area than anywhere else in the exhibition. This will have to be accommodated in the exhibit and infrastructure design.
- All of the media elements in the experience should be considered one show rather than separate elements. Ultimately, how these pieces work together as a single entity will determine the success or failure of the show.
- The final audio mix, the programming of the lighting, and the show control programming will usually be done in the actual venue in the final phase of the installation. This allows the production team to work with the show in its native environment and to fine-tune the effects, audio, and lighting to the actual characteristics of the space.

While the final product is very desirable, the planning process and production schedule for this type of show often differs significantly from the other media elements in the exhibition and needs to be planned for accordingly.

Designing Legal Audiovisual (AV) Environments

Introduction

Courthouse personnel have quickly embraced the full array of communications technologies and AV systems are no exception. Courtrooms have always required support equipment to present evidence and communicate, document, and administer justice. Now a wide variety of AV capabilities also are becoming commonplace as their usefulness is discovered.

Beyond the operational requirements of these systems lies a myriad of architectural challenges. As with any construction project, these challenges differ between renovation situations and new building designs. The requirement for immediate or pending implementation of AV systems and associated technologies is now driving the design of the courtrooms and courthouses. This trend is similar to what is happening in schools, HOWs, and other public spaces. Electronic evidence presentation, videoconferencing, audio and video recording, and other technologies have become a fundamental part of the courtroom operation.

System Purpose

At their simplest, courtroom AV systems are replacements for, and enhancements of, traditional means of evidence submission. For example, attorneys place evidence on a document camera and display devices, allowing the jurors, judge, court personnel, and spectators to view an image of the object or document. This can be a great time saving technique during proceedings, where previously evidence was duplicated and distributed to all parties or where evidence was passed through the jury box. By presenting a single image to everyone simultaneously, attention may be drawn to the important aspects of the evidence without the logistics of evidence handling.

AV systems are particularly useful and perhaps irreplaceable where electronic evidence must be presented in its native format. This includes videotapes from surveillance or crime scenes, wiretaps, computer documents, and background information in videotape or computer format.

Display of computer documents is a particularly demanding and evolving need. Immediate access to documents scanned and subsequently stored on servers, CDs, DVDs, or retrieved from the Internet or legal database services is highly useful. Products from the AV and computer industries are only now meeting the technical requirements for affordable, high-resolution, computer displays to accommodate these images, just as the demand for them is increasing.

Besides the use of prepared AV sources, live sources also are electronically enhanced. Taped and live video testimony from expert, juvenile, security-sensitive, and ambulatory witnesses is now possible. The widespread use of video arraignment systems has resulted in travel time and cost reduction and has minimized the requirements for security personnel during prisoner transportation.

System Purpose, continued

Various forms of videoconferencing have enhanced or replaced requirements for unruly prisoner handling, foreign language interpretation, document transfer between sites, and others. As an added benefit, videoconferencing systems have enabled courts to increase their efficiency in the areas of training, conferencing, and traveling.

New purposes for AV systems are attempted and discovered every day as more courtrooms are equipped with them. Likewise, the proliferation of these systems has created a demand for ancillary systems, such as AV components in other areas of the courthouses and AV transport/distribution systems. Support services such as document transferring, video editing, multipoint videoconferencing, video-enhanced court reporting/recording, equipment rentals, and many others are rapidly expanding.

Audio Systems

Virtually every contemporary courtroom is equipped with an audio system, with a wide range of quality and design complexities. These systems use common audio equipment but are configured in a unique manner customized for each courtroom. In many instances, the audio system is crucial to the business of the court and an inoperable system can result in a delay of trial or a mistrial.

The ability to control the microphones is accomplished with one or more automatic microphone mixers. These devices allow only one or two active channels to be open at a time and manage the overall gain of the system. However, an unswitched continuous signal is made available to the court recording system to ensure no testimony is lost.

Most of the mixers also include matrix routing capabilities, allowing mix-minus circuits to be constructed to aid with feedback control. The mixers also may feature input-based logic outputs available to control video camera preset selection and video switchers. Mixers with intelligence- or discrimination-type circuits are preferable to eliminate false gating of inputs.

Finally, individual echo cancellers on each microphone input greatly enhance the intelligibility of audio or videoconferences.

The audio system must be designed with high intelligibility for local speech reinforcement. It also must possess sufficient power handling suitable for the additional requirement of program audio sound reinforcement and its increased audio bandwidth. The system should include zoned routing in such a way that each of the appropriate individuals or groups are routed the authorized audio.

Audio Systems, continued

The AV designer should understand the following terms:

- Judge's bench
- Clerk's bench
- Sidebar
- Jury box
- Well with the lectern
- Court reporter station
- Gallery

Sufficient expandability through auxiliary inputs and outputs should be provided for the future. These provisions may include wiring pathways into and out of the system and providing spare equipment rack capacity.

Other audio subsystems include personal listening devices or assistive listening systems, which allow close listening where required. Multiple channel versions of these devices are often incorporated to allow simultaneous interpretation (SI) for multilingual proceedings. This also may be accomplished remotely using full-duplex audio codecs connected to remote interpreters.

Wireless microphones also may be used in courtrooms, but the risk of potential security breaches must be taken into account. Some newer models include encrypted audio for jury interviews known as *voir dire* (French: to speak the truth).

Finally, noise masking is incorporated in the audio zone over the jury box, gallery, and witness stand to ensure no sidebar conversations are overheard.

Video Evidence Presentation Systems

Besides the audio systems, modern AV systems feature video evidence presentation systems. A video evidence presentation system should support all signal types so the design allows displaying a consistent and quality image regardless of the source being viewed.

Computer signals are displayed in the native resolution of the source, and video is converted (i.e., quadrupled or scaled) to match the resolution of the computer or the system. The resolution of 1024 by 768 lines is deemed the minimum acceptable resolution for viewing computer-based documents. A system bandwidth of approximately 200 megahertz (MHz) end-to-end allows this resolution.

Source equipment typically includes a video document camera, a PC, a VHS cassette player, and a DVD player.

Video Evidence Presentation Systems, continued

Video switchers, scalers, scan converters, and distribution amplifiers make up the signal processing.

Display devices include CRT, LCD, plasma video monitors, and various types of projection systems.

Video signals are typically distributed over video and red, green, and blue horizontal sync vertical sync (RGBHV) cabling to multiple monitors located in front of the jury, in front of the witness and the judge, and in front of the attorney tables in the well. Occasionally, other monitors are available to the spectator gallery.

Audio follows the video and is connected to the speech reinforcement/electronic recording system through a spare ungated input. Attorneys may present documents by placing them on the platen of the document camera, which includes lighting from above for opaque documents and objects and below for transparent objects.

Videocassettes or DVDs may be played and controlled using a remote control system.

Courtroom AV systems have some special features that make them most sophisticated among the AV systems. One feature, known as video muting, allows the monitors to be made blank (or blue) by switching to an unused source on the switcher. This is accomplished by a kill-video button on the judge's control panel and ensures that the jurors do not see inappropriate images. Alternatively, a graphic (e.g., the seal of the court) routed from a digitized video playback device may be displayed.

Another feature is evidence annotation, which allows attorneys or witnesses to electronically draw on an image to highlight or emphasize certain areas in much the same manner as that used by sportscasters. This annotated image may be displayed throughout the courtroom and captured or printed in real time.

Yet another tool may be a bar code wand used to read the indices of catalogued evidence, rapidly directing the computer to display that image from its hard disc or CD. Using evidence presented from a CD requires preparation and transfer or scanning of that evidence from its native medium. This document conversion is outsourced or operated by the court.

Audiovisual (AV) Control Systems

To manage all of the AV equipment, an AV control system is typically integrated. This is necessary because the number of sources and functions of the AV system increases. This unified control system is operated by touch-panel displays at the judge and court deputy locations and often at the attorney lectern position.

Designers select equipment that can be reliably controlled electronically (e.g., video routers and displays). A dedicated control system's central processing unit (CPU) is programmed to transfer commands from the control panels to this equipment in a seamless manner. In addition to environmental controls (e.g., lighting, draperies, HVAC, clocks), these controls include all of the AV and videoconferencing equipment. Modern control systems include touch panels that double as video and RGBHV monitors and may include features such as annotation and audio.

Displays

The most critical, but intrusive, AV technology in the courtroom are the display devices. Because this technology is rapidly evolving, numerous varieties of installations are now in place.

The essential goal in designing the display integration is that everyone involved in the proceedings can see the images clearly enough to scrutinize the presented evidence. This is particularly true in courtrooms with juries. A secondary goal is to allow the spectator gallery to have a clear view.

The courtroom is a unique presentation environment very different from a classroom, conference room, or theatre. The main difference is that the participants are not facing in the same direction as in these other spaces but are clustered around the well of the courtroom.

The simplest and least expensive display systems using rolling, freestanding monitors are generally not acceptable in courtrooms equipped with advanced AV systems. This is because sightlines between participants should not be disturbed. Instead, new-generation LCD monitors and plasma displays are strategically located within the millwork where possible. Jury boxes may have as few as two and as many displays as the number of jurors mounted to the rails, on pedestals, or on the arms of the chairs.

When possible, videographics projectors with high light output are mounted above the jury and projected on screens across the courtroom well. These screens must be large enough and of sufficient brightness for a juror to clearly read 10-point characters from projected documents.

Due to the proliferation of high definition television (HDTV) and wide-screen computer displays, accommodating 16:9 aspect ratios is desirable where possible. Smaller monitors, some with touch/annotation capability, may be located at the judge, court deputy, two attorney tables, lectern, and witness locations. These displays are increasingly included as part of the AV control system touch panels, allowing a higher degree of integration of the various subsystems.

Videoconferencing Systems

Although videoconference roll-about systems may be standalone and be useful without an integrated AV system, they also are intrusive in the courtroom environment and are not ideally configured for the court's business. Videoconferencing features can be built into the courtroom AV system and into the room itself in such a way that videoconferencing is seamlessly integrated. In fact, most of the expensive and difficult-to-install equipment is already integrated if an advanced system is in place, with the exception of several components.

Video cameras are the most difficult components to integrate aesthetically, because they must be mounted onto highly visible parts of the walls. As few as two and as many as 10 cameras may be used, with approximately three to five being a common project decision. Cameras may be built into wall cavities for aesthetic reasons and for noise reduction when PTZ/focus mechanisms are used. Cable routes from the cameras must be carefully coordinated, as millwork and other architectural details typically prohibit easy cable installation. Sightlines and camera angles must be carefully mapped.

Signal Distribution and Information Technology (IT) Connectivity

Numerous technologies connect the courtroom to other rooms and systems. Audio and video distribution to other areas such as holding cells, clerks' offices, and recording or shared equipment areas is common. Distribution to public spaces such as jury assembly rooms, lobbies, and other buildings is common for accommodating press feeds and overflow spectator seating.

Sources such as dedicated satellite video networks may be fed into the system. AV systems should be designed to be expandable and to have links to other parts of the building or government complex. As part of this design, issues of security, access, purpose, and operation must be carefully considered.

Networks and communications technologies address these distribution needs, including firewall-protected LANs and WANs, distribution over structured cabling, streamed signals, and shared equipment from data or operations centers.

Centralized control rooms allow numerous courtrooms within the building to be monitored and maintained. The sharing of resources such as videoconferencing multipoint control units (MCUs), data recording servers for electronic court reporting purposes, and routing systems to ancillary spaces in the building can be located in these operations centers.

Signal Distribution and Information Technology (IT) Connectivity, continued

Increasingly, proprietary, highly integrated courtroom software packages are incorporating AV requirements, courthouse administration, evidence databasing, court reporting, and docket management. These systems tend to be IT-centric, bringing with them the need for significantly different designs in the cabling and end-points of the AV systems. The benefits of these systems are mainly in the areas of rapid access to and review of evidence, and in the management of its annotation, storage, and linking to court reporting. Much of the audio and video is immediately digitized in these systems in such a way that it may be transported over standard networks.

Associated Equipment

AV systems are capable of controlling a variety of ancillary equipment in the courtroom. Lighting, HVAC controls, window shades, projection screens, security systems, paging systems, signaling systems, and others may be integrated in such a way that the touch screen user interfaces become even more useful.

Computer networks and telephone networks must be designed to accommodate the additional bandwidth necessary to handle traffic for videoconferencing, digital recording, real-time transcription, and other data usage. Modern AV control systems also may become part of the network, with the ability to perform diagnostics, and control from remote locations within or outside of the courthouse.

In short, AV systems are quickly becoming an integral part of the business of the court, and should be designed at the same time as the rest of the technologies within the building.

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Chapter 19
Project Processes

This chapter seeks to explain the common role the audiovisual (AV) designer plays throughout the course of a project and looks at common terminology and processes the designer must be aware of.

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Overview

Introduction

The goal of the audiovisual (AV) professional is to create AV environments that work well. This is more difficult today than ever before.

In the days of overheads and slides, AV professionals dealt almost exclusively with other AV professionals or end-users, who also were technicians. In a professional AV integration project today, professionals from other disciplines are involved, many of whom are unfamiliar with AV technology. In addition to AV consultants, integrators, manufacturers and technicians, an AV project also combines the skills of architects, engineers, general contractors, subcontractors, building facility managers, and a variety of specialty consultants.

AV is no longer an add-on to the building project. AV communications systems are increasingly becoming part of buildings. They are critical to the workflow and success of work environments. AV technology use varies from simple room signage to full mission-critical operation communications centers.

Building design and construction has become more complex and expensive. The course of a professional AV project as a low-voltage trade now often has an impact on construction projects equal to, or even larger than, any other single trade. That means the AV professional has (or should have) direct involvement in all aspects of building design and construction, including space planning, sightlines, lighting, acoustics, and electrical and mechanical systems. Simply put, the AV professional has to be able to relate to almost everyone who works on a construction project that involves an AV system.

The work of AV professionals during the course of an AV integration project has more impact than ever before on the other building industry designers and contractors. This dynamic requires teamwork. The creation of a technology-enhanced building requires a team made up of professionals from the AV industry and the other disciplines. A critical part of that team effort is learning about the different professions and the language they speak.

In many ways, contemporary AV integration is really more about project management and procedures than it is about audio and video or design and construction. It is about ways in which a project is handled and how each of the various professionals performs a critical role in the implementation of an AV system. Most, in fact, are there from start to finish and, despite their various job functions, are members of the same team.

The AV industry depends upon this teamwork, or collaborative project process, that results not only in satisfied clients (i.e., the owners and end-users), but also fosters the level of professional involvement that improves the industry as a whole.

AV projects follow a process to ensure their success. The process is methodical and can be applied to varying degrees to any AV project, be it a meeting room, classroom, performing arts center, or church. The process involves the proper assessment of what is needed, the management of human and financial project resources, and project scheduling, coordination, and communications. This chapter gives a comprehensive overview of that process.

Project Team

Collaborating Professionals

In a professional AV integration project today, AV and building industry professionals work as a team due to the complexities and the built-in aspect of the contemporary AV project. Professional encounters among the architectural, engineering, and AV trades have created a need to disseminate information to all who are involved.

Project participants are usually thought of in terms of teams that consist of a number of groups and individuals. Four teams that represent the range of common roles within the design and construction process are:

- Owner.
- Design.
- Installation.
- Management.

Owner Team

The owner team is the entity or entities involved as the buyer of the AV systems. The owner team may include several groups or individuals who participate in the project process, including:

- End-user.
- Facility manager.
- AV technology manager.
- Building committee.
- Buyer, purchasing agent, or contract representative.

Design Team

The design team designs the building and the systems and may include the following groups or individuals:

- Lighting consultant
- AV designer (an independent AV consultant in a consultant-led design or a designer working for an AV integrator in a design-build scenario)
- Data/telecommunications consultant (a BICSI™ Registered Communications Distribution Designer [RCDD®])
- Interior designer

Collaborating Professionals, continued

- Acoustical consultant
- Mechanical consultant
- Security consultant
- Electrical consultant
- Life safety consultant
- Plumbing consultant
- Other industry and trade-specific consultants
- Structural consultant

Installation Team

The installation team provides construction and installation services and may include the following groups or individuals:

- General contractor
- Lighting contractor
- Data/telecommunications contractor
- Security contractor
- Life safety contractor
- Other trade-specific contractors
- AV integrator
- Mechanical contractor
- Electrical contractor
- Plumbing contractor
- Structural contractor

Management Team

The management team provides management services on the project and is usually associated with or represents the owner in some way. The management team includes the following:

- Developer
- Construction manager
- Building management agency
- Move consultant

Whether the project team is small or large, many possible relationships, roles, and fiduciary involvements can exist. The team's hierarchy and the responsibilities of each of the team members should be identified and understood by the AV designer. For more information, the AV designer should refer to Construction Specifications Institute (CSI) *Project Resource Manual*.

Design and Construction Process

Introduction

Because professional AV design and integration occurs within the building design and construction process, this chapter highlights important elements including how professional AV fits into the process as well as best practices for the AV professional, the architectural and engineering design team, the building construction team, and the facility owner. It is a start-to-finish approach with recommended practices and suggestions for handling issues that arise during the project.

AV integration project phases in sequence are:

- Program phase.
- Design phase.
- Construction documents phase.
- Bidding phase.
- Construction phase.
- Commissioning phase.
- Warranty period.

Sometimes, the phases are compressed within a small project; however, large projects generally follow the full sequence if they involve an architectural firm in the process.

Program Phase

The process of creating an AV system begins with an AV professional's assessment of the needs and desires of the end-user through a needs analysis or program.

Within the building design and construction process, the term program is used to refer to the needs analysis phase. In this phase, the users' project goals and needs are translated into a textual report of building design criteria, occupancy, use, space program (i.e., types and sizes), space adjacencies, project schedule, and project budget.

Design Phase

The process of AV design may be conducted during the overall design phase of a new building or independently as an AV-driven process for the renovation of an existing facility. In either case, the necessary design documents are produced to communicate to the AV installation team the owner's needs and wants for the systems and infrastructure.

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Introduction, continued

The design phase translates the program information into drawings and specifications. It consists of the following subphases:

- Conceptual design phase—Following architectural programming, the architect sometimes creates a conceptual design, a one-line diagram that graphically portrays the program information for space shapes, adjacencies, and sizes.
- Schematic design (SD) phase—The conceptual design is developed to a more detailed level, beginning to show more detail (e.g., double lines for walls, door locations, and room orientations). In addition, the architect defines the overall massing of the building and a schematic narrative generally describes the major systems to be included in the building.
- Design development (DD) phase—The goal is to move beyond major coordination issues to the basic floor plans. During this phase, all major design decisions are made and finalized with the owner so the building floor plan is set, engineering systems selected, and detailing can commence. This is an intense period of design consulting and decision making for the design team and the owner. The end result is the final architectural and engineering design.

Within the architectural design process, the design development phase is a go/no-go decision point. Usually, enough design information has been gathered by the end of this phase to know with a fair degree of accuracy how much the facility construction will cost. For some projects, this is the stage at which the owner may decide that the project should be abandoned because of budget or other issues before proceeding into the construction documents phase.

Construction Documents Phase

The goal of this phase is to create the documents from which the facility will be built. Projects may range from a small room renovation to a skyscraper or multibuilding development. This phase defines the design in a manner in which it can be purchased; the result is drawings, specifications and contracts for the building's materials and construction.

Bidding Phase

The bidding phase occurs when a design-bid-build process is used. It is the period when the construction documents are distributed with additional contract language to potential bidders. This package is often referred to as the contract documents and becomes the bulk of the actual contract between the building owner and the contractors hired to renovate or construct the building.

Construction Phase

Once the contract is signed, the construction phase begins, during which the actual site work is conducted, the building is constructed or renovated and the engineering systems are installed.

Introduction, continued

The construction phase is focused on three key processes:

- Coordination
- Procurement
- Installation

Finally, the prepared designs are translated into physical form, and the systems are brought into functionality. This phase involves tasks that are associated with both the base building construction, which includes the AV infrastructure, and the AV systems electronics procurement and assembly.

Coordination, scheduling, and sequencing critical to the entire construction phase are reviewed in this chapter, along with typical project communications and how they relate to changes in the AV installation contract.

The construction phase includes the following steps that the integrator takes from the contract award to a complete installation ready for commissioning.

STEP	TASK
1	Meeting for the construction kick-off
2	Preparing for submittals
3	Procuring the AV equipment
4	Preparing the site
5	Pre-assembling and testing the AV system
6	Installing on site
7	Finalizing the documentation

Most of the AV integrator's work during this phase is related to the electronics rather than to the base building construction.

Commissioning Phase

When the construction work is at or near completion, a commissioning phase often takes place. In this phase, the building systems are put into operation, tested, and optimized.

The AV project is not over until the system commissioning phase is complete and training has been provided to the users.

Many aspects of the AV integration process focus on the AV infrastructure design, installation, and coordination. With this work completed and the systems installed, the commissioning process focuses on the system, its electronics, and its functionality within the environment that has been created.

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Introduction, continued

System commissioning plays a pivotal role in the entire AV project. The commissioning agent ensures that standards have been followed, verifies that contractual obligations have been met, and checks that the system is ready to perform properly in its intended use. All aspects of the system are tested, adjusted, and optimized. Workmanship is inspected, system performance is evaluated, and deficiencies are identified and corrected.

After the commissioning process is complete, training is the next step to complete the handoff to the end-users. The end-users, both technical and nontechnical, must receive instruction to ensure the ongoing success of the facility and AV system. Minimally, the end-users and those responsible for operating the facility need adequate training on day-to-day usage and ways to address a system that does not function as expected.

Beyond training, there are often other post-commissioning tasks associated with the AV systems contract, such as preventive maintenance, warranty support, and additional training for new users, as well as refresher training once the system has been used for a period of time.

Warranty Period

Once the building is complete and commissioned, the warranty period begins on the building and its engineering systems. This is typically a one-year period during which the contractor is required to correct any problems that are a result of the manufacture of the building.

Process Options

As the AV project process is addressed in more detail, important questions arise that affect the complexity and the quality of the entire AV design and integration process. They are:

- What are the AV-related concerns for the design and installation teams?
- When should the AV provider get involved?
- At what points during the process should the AV provider be included?
- Who is the AV designer working for?
- Who is the AV integrator working for?
- How do the AV systems and infrastructure fit into the overall project budget?

Many factors have to be considered when deciding on an appropriate process for making an AV project a reality. Scheduling, budget, policy or legal issues, and the owner's structure and expertise are issues that have a direct impact on the ultimate result.

Determining which process to use is the single most important decision in the AV design and integration. The right choice comes from reviewing the parameters, having the knowledge of the available options, and understanding what impact those options will have on the entire process.

Process Options, continued

The two most common processes are:

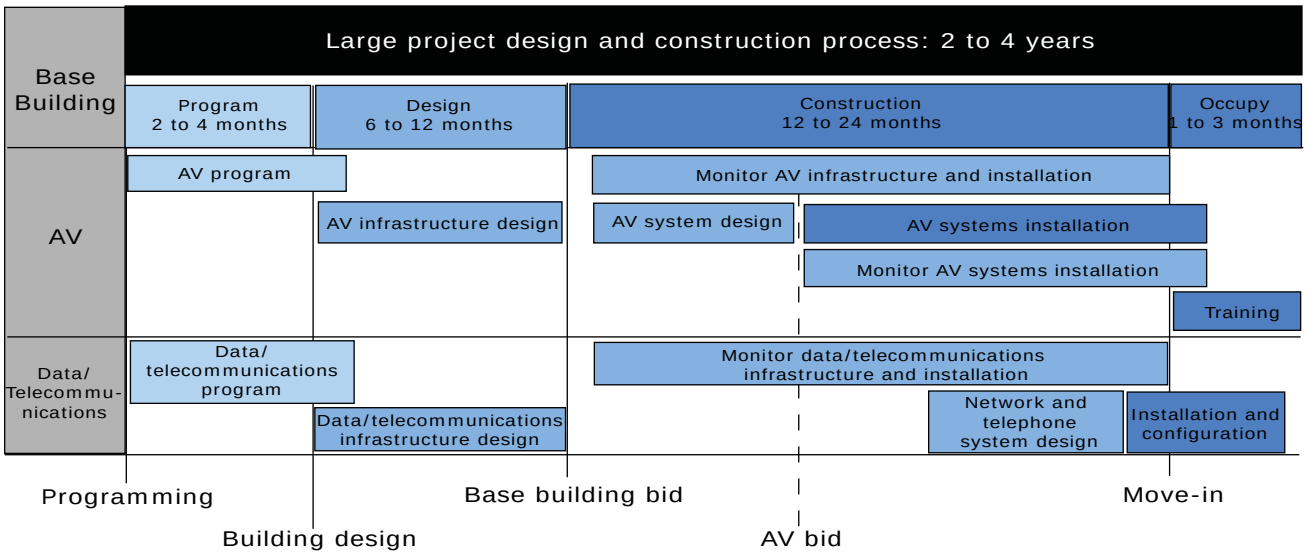
- Independent consultant led design-bid-build.
- Integrator led design-build.

There also are less commonly used hybrid processes:

- Consultant led design-build
- Owner-furnished equipment (OFE)/integrator-installed
- OFE/owner installed
- Consultant/integrator team design-build

The duration of the various project phases depends on the scope of the project. Figures 19.1 and 19.2 compare and contrast this difference.

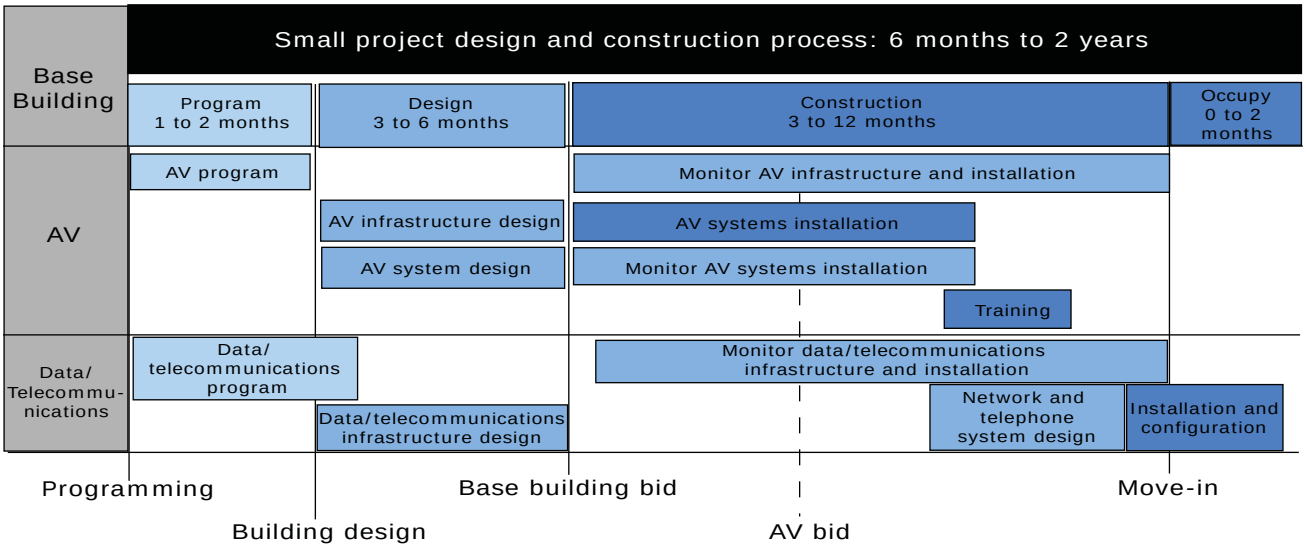
Figure 19.1
Large construction project—typical schedule



AV = Audiovisual

Process Options, continued

Figure 19.2
Smaller construction project—typical schedule



AV = Audiovisual

Project Documentation

Introduction

Projects are documented in three major parts:

- Contract documents
- Project specifications
- Project drawings

Contract documents describe and define the business issues associated with the project. They typically include scope of work (SoW), contractor performance requirements, proof of insurance, description of building issues, duration and deadlines for each project element, and exclusions to the contract. Although they are created by the building owner, the AV designer may have input regarding some of these documents (e.g., descriptions of the AV system elements and performance requirements).

Project drawings are the blueprints that depict the AV system and environment. They depict system components, layout and location of components, and other issues (e.g., conduit locations and reinforcement requirements).

Project documents created by the architect must be used to determine how the space is constructed and to create detailed documentation defining how the AV systems should be installed.

Project specifications are accurate and detailed descriptions of the system and system components. They describe the performance objectives of the space and the system. They may, for example, identify a specific model of projector and identify the target brightness and contrast to be achieved within the room.

Contract Documents

Liability Insurance / Bonding

AV system designers carry typical business insurance, including workers' compensation insurance, comprehensive general or commercial liability insurance, business automobile liability insurance, and employer's liability insurance. In addition, AV designers should be covered by professional liability insurance, addressing any errors or omissions in their designs.

AV installation contractors also carry typical business insurance and may be required to post performance bonds and payment bonds, assuring the owner that performance of the work will be covered as well as any payments due to subcontractors.

Contract Documents, continued

Letter of Transmittal

This form is used whenever documents, drawings, samples, or submittals are sent. It clearly indicates the addressee, sender, contact information, a list of what is sent (including date or revision number), and any action expected to be taken by the receiving party. This form is used whether the items are sent by mail, courier, overnight carrier, or fax.

Request for Interpretation (RFI)

As the project progresses, questions inevitably arise about the project. They generally revolve around three basic types of issues:

- Design issue
- Site issue
- Owner change or request

The structure normally set in place for this process is the request for interpretation (RFI).

This process is usually based on a paper or electronic form established for the project and that includes the RFI originator, the RFI receiver, and a space to enter the question and the response.

Some RFIs are simply resolved by a clarification from the recipient of the RFI without a change in anyone's contract. Others may need resolution through a change in the construction contract. In the latter case, other structured communications, such as a change order, may be generated.

Request for Change (RFC)

A request for change (RFC) is submitted (ultimately to be approved by the owner) if the integrator or consultant wants to change contractual obligations, equipment models or specifications, or system design. When an RFC is generated (or answered) by the integrator, pricing and impact throughout the project must be included.

Issues that can trigger an RFC are:

- Change in intended use of the system.
- Discontinued product.
- Architectural, mechanical, or millwork changes.
- Discovery of system or product incompatibilities or function.

The RFC can be submitted by any member of the project team, although on an AV project, the integrator or consultant most commonly creates the document. An approved RFC then becomes a change order.

Contract Documents, continued

Change Orders (CO)

Despite extensive due diligence during the design and bidding processes to ensure an appropriate system design, design and contract changes, requested with a change order (CO), may be needed as the project unfolds. Because of its ability to change the contract scope and pricing, this is arguably the most important form used during the construction phase. A few of the many reasons for AV system COs are:

- Changes or clarifications in anticipated use by end-user personnel.
- Architectural, millwork, finish, or other physical changes to the installation site.
- Design conflicts, omissions, or errors.
- Change in product availability or specifications.
- Availability of new products or technologies.
- Discovery of hidden site conditions.
- Budget adjustments.
- Schedule changes and delays by others.

Punch Lists

The punch list is a key element in the project process, because it becomes the final checklist for a complete installation and contract closeout. Depending on the contract language and relationships, the punch list may be created by the AV consultant, the owner's AV project manager or the AV integrator's project manager, or other internal personnel.

The preliminary punch list may be internal to the integrator under many design-build projects, but is usually required for distribution to various design and owner team members under most other methods. The final punch list generated after the final commissioning test and alignment is usually distributed to the designated project team stakeholders under any method.

During the preliminary checkout, a preliminary punch list that includes all of the discovered system deficiencies, along with the possible resolution of each deficiency and the party responsible for each item, should be developed. This punch list should be distributed to the responsible parties for completion and should include due dates for completion of each item

Contract Documents, continued

Each punch list is unique to the project for which it is generated, but some typical items that may appear on a punch list are:

- Poor AV connector terminations.
- Damaged wiring.
- Workmanship issues with equipment installation or aesthetic components of the work such as damaged wall finishes, undesirable cable management, and other problems that are visibly objectionable.
- Physical installation issues such as projector positioning, loudspeaker locations, and alignment and integration of devices into furniture.
- Delays in delivery of AV equipment.
- AV equipment failures.
- Slow delivery or no delivery of goods by non-AV service providers (e.g., millwork, electrical, and other contractors).
- Slow or no delivery of OFE or communications and network services.

While some items are the direct responsibility of the integrator, some are caused by delay in work by other parties. To resolve these issues, the AV integrator must play an active role in seeking timely solutions from the other parties. Proper planning, documentation, and communication are crucial.

Record Drawings and Manuals

A set of record drawings should be prepared after nominal site testing has been completed. This drawing set should include all changes (especially those occurring during shop fabrication/test and site installation/test) that were made to the shop drawings. In addition, the user manuals provided with the individual AV components arranged in alphabetical order by manufacturer should be compiled into a set of binders. These are made available for use by the technical staff for troubleshooting, repair and special equipment setups. The manuals should be augmented by a custom operation guide provided to the end-users for basic setup and operations in the rooms served by the AV systems.

Drawings

Everyone involved in a project should be able to read and interpret drawings to understand the vision and scope of the project. Project drawings are the road maps for an AV installation. They include the project locations, types of equipment, locations of each element, and installation specifications.

Two primary groups of drawings an AV project team will use are the:

- Architectural drawing package, describing how the space will be put together (irrespective of the AV).
- AV drawing package, containing:
  - Functional diagrams.
  - Connection details.
  - Plate and panel details.
  - Patch panel details.
  - Equipment diagrams.
  - Rack elevation diagrams.
  - Control panel layout.

Architectural Drawings

Architectural drawings are used by contractors to determine how to build all of the structure elements. Small jobs may have only one or two drawings; bigger jobs have entire sets divided into different groups based on the construction process. Architectural drawings provide a technical illustration of all construction details including:

- Site work.
- Foundation.
- Structure.
- Electrical.
- Mechanical.
- Finishes.
- Details.

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Drawings, continued

Audiovisual (AV) Facilities Drawings

AV plans describe how the AV system components are interconnected. These plans provide the equipment placement, interconnection schematics, and rack elevation drawings. The drawings used most often by an AV project team are:

- Floor plan.
- Reflected ceiling.
- Electrical.
- Elevation.
- Riser.

Audiovisual (AV) Systems Drawings

AV system diagrams depict:

- Audio flow.
- Video flow.
- Remote control system connection.
- Simplified line drawings.
- Riser diagrams.
- Rack elevation.

Drawings, continued

Equipment placement describes the layout of the AV equipment within the facility. These drawings depict the location of:

- Equipment racks.
- Podiums.
- Screens.
- Projectors.
- Lighting (if applicable).
- Specialty items.

Electrical plans created by AV designers typically depict components such as:

- Power panels.
- Equipment racks.
- AV interface boxes.
- Loudspeakers.
- Conduit size and connection.
- Backbox schedule.
- General notes.

Specifications

Harmonizing Design Specifications with Complement Drawings

Building systems cannot be designed or installed without the consideration of other system designs. Since typically a limited amount of space in a facility is allocated for infrastructure, the coordination of the AV design with other members of the architect, engineer, and consultant team is important. This includes not only the devices and their functional or physical locations but also power, cable pathways, cable, furniture, lighting, air conditioning, and other infrastructure. The standards of all applicable organizations must be strictly regarded. Incorporation in the project of such standards must be effectively communicated to the team members.

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Specifications, continued

Drawings do not provide enough information to proceed with installation. Since it is not practical to include sufficient notes on construction drawings, a separate set of written instructions is created to describe in complete detail all of the product quality and installation methods. Specifications provide further guidelines on how to proceed and put all of the elements together. Specifications include:

- Introductory information .
- Bidding requirements.
- Contract forms.
- Conditions of the contract.
- Project specifications.

All of the accompanying documentation (e.g., warranties, instruction and customers manuals) should be collected. Some companies gather all manuals for security and reference during the job and then create a customer binder with the information when the project is complete. Sometimes, technicians want their own copies of manuals for new or popular products. Many times these manuals can be found online and printed.

International Issues

Designing and installing AV systems internationally can present some changes to the process and the AV design. Designers may need to accommodate different laws, currency, design practices, availability of equipment and services, business practices, and general culture and customs of the country.

Codes and Standards Related to Audiovisual (AV) Industry

Code and standard internationalization efforts have brought the various building and electrical requirements closer than ever. AV system designers in countries other than the U.S. and Canada may find their local codes and standards refer interchangeably to the requirements set forth by the organizations described in this section.

IMPORTANT: The ensuing list of organizations and documents is not exhaustive. As is the case with all building and electrical requirements, the AV system designers and installers should always check with the local authorities for the predominant sources.

National Electrical Code® (NEC®)

The *National Electrical Code®* (*NEC®*), published by National Fire Protection Association (NFPA), defines recommended building codes that pertain to electrical systems, including elements of AV systems, and has been adopted by most North American areas to varying degrees.

The *NEC* provides guidelines for:

- Electrical power distribution installation.
- Conduit usage.
- Wiring composition for different spaces within a structure.

AV Installers should determine the codes that pertain to the specific area and follow the most restrictive code that covers it.

Canadian Electrical (CE) Code

The Canadian Standards Association (CSA) is a nonprofit membership-based association serving business, industry, government and consumers in Canada and the global marketplace. The CSA produces several documents and standards that affect AV in Canada. The Canadian Electrical (CE) Code is updated every four years.

The intent of *CE Code Part 1* is to establish safety standards for the installation and maintenance of electrical equipment, including telecommunications. As with the *NEC*, the *CE Code Part 1* is a voluntary code that may be adopted and enforced by provincial and territorial regulatory authorities. The *CE Code Part 1* is the Canadian equivalent of the *NEC* and the Institute of Electrical and Electronic Engineers, Inc® (IEEE®) *National Electrical Safety Code®* (*NESC®*) in the U.S.

Environmental Issues

Design considerations need to account for the environment in which the AV systems will be installed and operated. This may include, but is not limited to, issues such as temperature ranges, humidity ranges, and susceptibility to natural occurrences (e.g., hurricanes or earthquakes).

Americans with Disabilities Act (*ADA*)

The *Americans with Disabilities Act* (*ADA*) is a document establishing facility requirements for disability access. This document is mostly referenced only for accessible design considerations (e.g., spacing between equipment and room layouts), but it also contains regulations concerning alarms and signage. It also addresses mounting heights and device and communication requirements applicable to AV designs and installations.

Telecommunications Industry Association (TIA) Standards

Telecommunications Industry Association (TIA) is a nonprofit trade association serving the communications and information technology industry in the United States. TIA is involved in standards development, and its members manufacture or supply the products and services used in communications.

Construction Codes

Construction codes are governmental regulations that define the construction requirements for all aspects of building construction, including:

- Location.
- Size.
- Materials.
- Plumbing.
- Electrical.

Construction codes are defined for a particular state, city, or jurisdiction. The requirements defined by construction codes must be followed by all persons working on a construction project, including AV installers.

The *International Building Code* (*IBC*) is a construction code developed by the International Code Council® (ICC®). The IBC is often used by local officials when developing the building codes for a particular jurisdiction.

Society of Motion Picture and Television Engineers (SMPTE)

The Society of Motion Picture and Television Engineers (SMPTE) is a technical society for the motion imaging industry. SMPTE members are spread throughout 85 countries. SMPTE publishes American National Standards Institute (ANSI) approved standards, recommended practices, and engineering guidelines.

American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)

The American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), formed in 1959, is a global organization setting standards and guidelines and providing technical and educational information for heating, ventilating, and air conditioning (HVAC) and refrigeration.

Federal Communications Commission (FCC)

The rules and regulations of the Federal Communications Commission (FCC) are codified in Title 47 of the *Code of Federal Regulations* (*CFR*). Title 47, Part 76—*Cable Television Service* (47 CFR 76), addresses multichannel video and cable television (TV) service. The rules and regulations of Part 47 provide for the certification of cable TV systems and for their operation in conformity with standards for TV broadcast signals, program exclusivity, cablecasting, access channels, and related matters.

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International Power

AV designs and installations must take into consideration the electrical system of the country in which the equipment is manufactured and installed. Electric voltage standards and power plugs vary by country.

Three primary power variables that AV designers should be aware of for international installations are:

- Voltage.
- Frequency of power generation.
- Type of electrical plugs.

For example, in the U.S., typical power is 120 volts (V) at 60 hertz (Hz), using either a flat-blade attachment plug or a flat blade plug with a round grounding pin.

Many other countries, however, use higher voltage (220 to 230 V), a lower frequency (50 Hz), and different types of plugs. Converters may be used to step-down voltage from one amount to another, while transformers may be needed to step-up lower line voltages into higher voltage. Frequency cannot be converted (e.g., from 50 to 60 Hz), although some equipment may be able to handle the differences in the frequency. Different types of plugs can usually be handled with plug adapters.

InfoComm International®

InfoComm International is the premier trade association specifically addressing the AV communications industry. Its membership is from 56 countries and more than 3200 companies and individuals. InfoComm provides education and certification for AV communications professionals, including the Certified Technology Specialist (CTS) designation.

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Glossary

This Glossary provides concise and up-to-date terminology that reflects the audiovisual (AV) industry worldwide. It includes specific definitions from standards bodies, where appropriate, in an effort to harmonize terms within the industry.

Terms

Numbers

1k tone A sound wave at a frequency of 1 kilohertz (kHz).

3 mm (1/8 in) mini jack See 3 mm (1/8 in) mini plug.

3 mm (1/8 in) mini plug Available in mono and stereo, these male connectors are typically used for connections with microphones and headsets.

A

absorption The ability of a material to soak up the sound energy and not reflect it back into a room.

accent lighting A type of lighting intended for marker boards and wall surfaces used for displaying the presentation material.

access control list (ACL) The database that keeps track of and controls access to network services or physical entry to an area through assigned privileges for users and groups. Also called authorization profile.

access floor A system consisting of completely removable and interchangeable floor panels that are supported on adjustable pedestals or stringers (or both) to allow entry to the area beneath.

access point (AP) **1.** The point of entry into a secure area. **2.** A stand-alone hardware device or a computer wireless adaptor known as a wireless access point with software that acts as a wireless communication hub for users of wireless devices to connect with each other and to bridge those devices to the cabled portion of the network.

acoustics The study of sound wave motion and sound behavior both within an enclosure and outdoors. It also is the name given to the qualities of a room in respect to transmission of sound.

air handling unit (AHU) A heating, ventilating, and air conditioning unit that consists of fans, heating and cooling coils, filters, and other components through which the air is moved to be conditioned.

air terminal unit (ATU) See variable air volume (VAV) box.

alternating current (ac) Electric current that alternates periodically (usually sinusoidal) in magnitude and direction. Contrast with direct current (dc).

American wire gauge (AWG) A system used to specify wire size. The greater the wire diameter, the smaller the AWG value. Historically, the AWG number has represented the number of drawing processes applied to a given wire.

amplitude The maximum absolute value reached by a voltage or current waveform.

amplitude modulation (AM) Modulation in which the amplitude of a carrier wave is varied in accordance with some characteristic of the modulating signal.

analog clipping Exceeding an upper limit beyond which they can no longer accurately represent the amplitude (level) of an audio signal.

analog signal A signal that varies in amplitude (strength) directly with the loudness of the voice and varies in frequency directly with the tone of the voice. Contrast with digital signal.

analog-to-digital (A/D) signal conversion Conversion of analog signals to digital signals using sampling rates and bit depth. Contrast with digital-to-analog (D/A) signal conversion.

apparent power The product of the measured voltage and measured amperage.

Application layer The Open Systems Interconnection Reference Model layer responsible for providing mechanisms that enable software applications on different systems to use the services of a network to exchange information. Also called Layer 7.

architectural lighting A general term applicable to general commercial and institutional facilities and space types and includes the lighting systems for corridors, offices, conference rooms, and most public spaces.

articulation index (AI) The metric used to predict speech intelligibility. See also speech intelligibility.

asymmetric digital subscriber line (ADSL) A digital service designed to provide high data transfer rates over traditional telephone cable. Asymmetric refers to different speeds for uplink and downlink traffic. See also x digital subscriber line (xDSL).

audio-conferencing mixer A rack-mountable mixer set up to function automatically.

automated mixer A mixer automated by a computer, which stores presets, control settings, and various mixing moves.

automatic mixers A mixer that automatically turns microphones on and off when volume levels are above or below a specific threshold.

auto-negotiation (AUTONEG) A feature that determines link options and optimal settings for a given connection. When AUTONEG is enabled, a network interface card can determine the capabilities of the device at the far end of the link and select the best mode of operation.

B

backbone cabling Cable and connecting hardware that provide interconnections between telecommunications rooms, equipment rooms, and entrance facilities.

backbone pathway The portion of the pathway system that permits the placing of main and high-volume cables between the entrance location and all cross-connect points within a building and between buildings.

bandwidth **1.** A range of frequencies available for signaling expressed in hertz (Hz). **2.** The information handling capability of a medium, expressed in units of frequency (Hz).

bandwidth limiting Encoding a full-bandwidth video signal's color channels to fit a black-and-white signal space.

Bantam connector A type of connector used most often in modern professional patch bays. See also patch bay.

baseband video signal See composite video signal.

basic rate interface (BRI) An integrated services digital network interface standard that consists of two B-channels and one 16 kb/s D-channel.

basic service set (BSS) A single wireless local area network access point and its associated clients, loosely equivalent to a wireless collision domain.

Bayonet-Neill Concelman (BNC) connector See BNC connector.

bel A logarithmic ratio of analog signal strengths. It was named in honor of telephone pioneer Alexander Graham Bell.

bidirectional microphone A microphone sensitive to sounds from the sides 180 degrees apart, while rejecting the sound from all other directions. Also called figure-8 microphone.

bit depth The number of bits that describe a signal value.

bit rate Transmission of a binary signal measured in bits per second (b/s).

bit **1.** The basic unit of digital information, used to indicate the existence of one of two binary states or conditions (e.g., current flow or no current flow, on or off). **2.** A digital pulse representing a one (1) or a zero (0); contracted from the phrase "binary digit." **3.** A binary digit; the smallest element of information in binary systems. It is either a logical one (1) or zero (0), also called "an on or an off bit" of binary data.

blanking interval The time during which the electron beam is turned off.

Bluetooth® A low-power radio frequency personal area network technology that enables cordless data transfer between Bluetooth equipped devices at short range.

BNC connector A coaxial connector with twist-on bayonet locking coupling.

boundary microphone A microphone with a pickup element located so that the microphone picks up only the sounds reflected off a nearby surface. Also called surface mount microphones.

branch circuit The circuit conductors between the final overcurrent device protecting the circuit and the alternating current (ac) outlets. An individual branch circuit is a branch circuit that supplies a specific device or component (e.g., an equipment rack).

broadcast domain The span of a local area network as represented by the devices capable of receiving a Network layer datagram addressed to all.

button microphone See table microphone.

C

cable loss A type of signal loss dependent on the cable type used and the frequencies of the signals carried. The higher the frequency of the signal, the greater the cable loss.

cable tray A rigid structure for housing and protecting cables or conductors. Usually consists of one-piece solid or ventilated bottom or individual transverse members with two side rails.

candela A term used to describe the intensity of light leaving a lamp or luminaire in a given direction to measure the quantity of light from a source.

candlepower A unit of brightness.

capacitance (C) **1.** The ability of an electronic component to store electrical energy. **2.** Opposition to a change in voltage.

captive-screw connector A connector that may be 3.6 mm (0.14 in) or 5 mm (0.2 in) large and provides connections for balanced or unbalanced line-level stereo, audio and communications signals.

cardioid microphone A microphone with a heart-shaped pickup pattern, sensitive to sounds predominantly from the front of the microphone diaphragm.

carrier sense multiple access with collision detection (CSMA/CD) A media access control protocol utilized by wireless local area networks. Network devices “listen” to the network by sending a broadcast signal before real data is sent.

category A rating that defines the performance of cabling components and systems. Describes mechanical properties and transmission characteristics of balanced twisted-pair cabling and provides a numbered designation. Categories are defined in many regional standards.

category 3 Balanced twisted-pair copper cabling specifications characterized in a frequency range of 1 to 16 megahertz.

category 5e Balanced twisted-pair copper cabling specifications characterized in a frequency range from 1 to 100 megahertz. This category specified transmission parameters that were not characterized by category 5 (e.g., power sum near-end crosstalk, return loss, equal level far-end crosstalk, power sum equal level far-end crosstalk) and features more stringent near-end crosstalk than category 5.

category 6 Balanced twisted-pair copper cabling specifications characterized in a frequency range from 1 to 250 megahertz.

category 6, augmented Balanced twisted-pair copper cabling specifications characterized in a frequency range from 1 to 500 megahertz. The augmentation from category 6 covers frequency range, insertion loss specifications, and alien crosstalk mitigation.

category 7 Balanced shielded twisted-pair copper cabling specifications characterized in a frequency range from 1 to 600 megahertz.

category 7_A Balanced shielded twisted-pair copper cabling specifications characterized in a frequency range from 1 to 1000 megahertz.

cathode ray tube (CRT) A video display tube used in some types of monitors and receivers, radar displays, and video computer displays; a high-vacuum tube containing an electron gun to produce the images seen on the face of the tube.

ceiling/choir microphone A small profile microphone suspended from a ceiling.

cellular floor A floor distribution method in which cables pass through floor cells, constructed of steel or concrete to provide a ready-made raceway for distribution of power and telecommunications cables. (TIA)

Certified Technology Specialist (CTS) An InfoComm International® certification designation for an audio and video professional who has developed a high level of expertise. The CTS certification is recognized by the National Certification Commission.

character generator A device that has a console with a typewriter-style keyboard and a dedicated video monitor for the manipulation and display of television programming graphics.

chroma (C) signal In-phase signal and quadrature signal added together. See also in-phase signal and quadrature signal.

chroma decoder A decoder that separates the chroma signal into the color difference signals red minus luminance and blue minus luminance.

chromaticity Purity or intensity of color. Also called hue.

clinical system A system that provides and routes multiple video, data, and audio sources to multiple displays within operating rooms and trauma rooms.

coaxial cable A cable consisting of a central metallic inner conductor separated from an enclosing outer conductor by a dielectric material. This material may be solid, foam, a suitable gas, or dry air. The outer conductor comprises a metallic braid, a foil layer, combination of braid and foil.

color difference signals Red minus luminance and blue minus luminance signals.

color rendering index (CRI) A metric that measures the quality of white light and is a the effect of a light source on the perceived color of objects relative to the illumination by a reference light source.

color temperature A scientific measurement for the distribution of the colors radiating from a light source, expressed on the kelvin scale.

color-burst signal A signal that serves as the decoder for unlocking the color information for each video line.

comb filter A filter used in mid- to high-range display devices due to its ability to separate the luminance from the chrominance and eliminate the majority of the cross-color and cross-luminance artifacts.

comb filtering Unwanted frequency variations created by summing up two signals with misaligned phases stemming from the difference in the time of arrival at the microphones generates.

combiner A device that takes the balanced outputs from multiple processors and modulators and combines them into a single output signal for application to a post-amplifier and the distribution system.

complex waveform A combination of different frequencies and amplitudes that determine the sound quality.

composite video signal The chrominance signal and the luminance signal added together. Also called baseband video signal.

compression The action of molecules pressing closer together.

compressor A device that evens out loud variations in the dynamic range for a more consistent sound.

condenser microphone A microphone that converts sound into electricity using a capacitor and electrostatic principles.

conduit system Any combination of ducts, conduits, maintenance holes, handholes, and vaults joined to form an integrated whole. (TIA)

contact closure A type of control between two equipment components or systems that notify, activate, or communicate to one system when the state of the other system changes.

contrast ratio A ratio between the projected image and the ambient light condition at the image location.

control system A system that integrates various manufacturers' equipment and systems (e.g., lighting; sound; video; security; and heating, ventilating, and air-conditioning.

critical distance (D_c) A distance from the sound source at which the direct and reverberant fields have the same attenuation; the point where the direct and reverberant sound have the same sound pressure level.

current (I) Flow of electrons in a conductor measured in amperes.

D

Data Link layer The Open Systems Interconnection Reference Model layer responsible for providing reliable data transfer in the form of frames on a local area network. Also called Layer 2.

decibel (dB) A logarithmic unit for measuring the relative voltage, power (in watts) or strength (in voltage or current) of a signal. A dB is one tenth of a bel. See also bel.

decorative lighting A type of lighting that consists of luminaires required by a specific architectural or interior design style, period, and motif.

Deutsches Institut für Normung (DIN) connector See DIN connector.

diffusion A phenomenon whereby sound strikes a surface and scatters in all directions.

digital clipping Exceeding the sampling resolution.

digital direct drive image light amplification (D-ILA®) A JVC® technology characterized by high contrast, high brightness, and high resolution; the chip has matrix addressing switches placed behind the light-modulating liquid crystal layer.

digital light processing® (DLP®) A type of projection system based on the digital micromirror device. It uses over 500 000 microscopic mirrors on a chip focused through an optical system to display images on screen.

digital mixer software A type of software that allows extensive processing to be located on a small mixer without all of the knobs and faders typically required on an analog mixer.

digital multiplex (DMX) 512 The theatrical dimming system control protocol used mainly with theatrical stage lighting consoles and theatrical lighting instruments.

digital signal A signal that encodes information in the form of a sequence of discrete states. For example, a binary signal uses two states to encode the two states (0,1). Contrast with analog signal.

digital signal processing The improvement or deliberate modification of the intelligibility or fidelity of the digital signal before it is converted to analog signal.

digital television (DTV) A television signal transmitted digitally.

digital-to-analog (D/A) signal conversion A process of converting the digital strings of 1s and 0s into a signal that resembles an analog waveform. Contrast with analog-to-digital (A/D) signal conversion.

digital visual interface (DVI) A data transmission port that supports up to 5 Gigabits per second (Gb/s) speed. It is the only digital interface capable of accommodating uncompressed digital data such as high definition video. It also has the bandwidth to support higher audio fidelity.

digital visual interface (DVI) connector See DVI connector.

dimmer A device that regulates the amount of light emitted from the lighting instruments. Also called potentiometer.

DIN connector A connector commonly used for carrying S-video signals.

direct attached storage (DAS) The combination of a high-speed interface and shared disk drives, where the disk drives are connected directly to the servers—internally or externally.

direct current (dc) A constant-value electric current that flows in one direction in an electric circuit.

direct sound See near-field sound.

directional coupler A device with one input port and two or more output ports that splits a single signal to multiple outputs while providing a high attenuation for reverse signals.

directional microphone A microphone designed to pick up signals in the pickup zone of the microphone and to reject signals outside the pickup zone.

dispersion The breaking up of light into its individual components caused by the refraction of different wavelengths of light at various angles.

display resolution The measurement of horizontal and vertical pixel counts, which determines the amount of detail the display device is capable of reproducing.

distortion level The state of being a particular decibel value below the original source signal.

distributed amplifier system A system that places amplifiers away from the central distribution point.

distribution amplifier (DA) A device that sends a single signal to multiple locations while maintaining signal quality and integrity. VDAs are used for video and ADAs are used for audio signals.

dithering A process designed to introduce random noise into the signal to mask the effects of quantization distortion within the analog-to-digital converter.

D-subminiature connector A multi-pin connector used in data communications.

DVI connector A connector that provides for a direct digital connection of a source to a display.

dynamic microphone A microphone whose diaphragm vibrates when struck by sound waves. Also called moving-coil microphone.

E

early reflected sound A sound created by sound waves, which are reflected (bounced) off one or more surfaces between the source and the listener.

echo Distinct, late arriving reflections from a single wall surface.

electrical service The conductors and equipment used to deliver energy from the electricity supply system to the wiring system of the premises.

electrical service equipment entrance panel A panel that receives the incoming power and derives the equipment grounding conductor.

electromagnetic compatibility (EMC) The ability of the design and operation of equipment in a manner that makes them immune to certain amounts of electromagnetic interference (EMI), while keeping the interference generated by them within specific limits.

electromagnetic interference (EMI) Radiated or conducted electromagnetic energy that has an undesirable effect on electronic equipment or signal transmissions. (TIA)

electromagnetic radiation (EMR) Radiation made up of oscillating electric and magnetic fields and propagated with the speed of light. Includes gamma radiation, X rays, ultraviolet light, visible, and infrared radiation, radar, and radio waves.

electromagnetic spectrum The full range of electromagnetic emissions, which includes all light and radio waves.

engine generator A unit that uses a fuel-powered engine to drive a rotary generator.

equalizer (EQ) A sophisticated frequency control device that allows a range of frequencies of a given signal to be either boosted or reduced.

equipment room (ER) An environmentally controlled centralized space for telecommunications equipment that usually houses a main or intermediate cross-connect. (TIA)

ergonomics A group of factors or qualities in the design of a workplace or the equipment used by people at work that contribute to comfort, safety, efficiency, and ease of use.

evaporator See air handling unit.

extended service set (ESS) A collection of wireless access points that are tied together by a wired backbone in a single collision domain, or by virtual local area networks, to allow Data Link layer (Layer 2) roaming.

F

F connector A 75-ohm radio frequency connector typically used in cable television and on entertainment devices for coaxial cable.

fan coil An air-handling device where the amount of cooling (or heating) is controlled by the amount of chilled water passing through the unit's coils.

feedback An unwanted oscillation or tone that quickly grows in loudness.

feeder duct A raceway of rectangular cross-section placed within the floor to tie distribution duct(s) or cell(s) to the telecommunications room. (TIA)

feeders The circuit carrying the power between the electrical service equipment entrance panel and the distribution panel, then to the subpanels.

figure-8 microphone See bidirectional microphone.

file transfer protocol (FTP) A protocol used to reliably transfer files between devices over a network.

filter A device that allows specific frequencies to be removed from a signal.

fire alarm (FA) A system that provides a reasonable level of safety by reducing the probability of injury or loss of life from fire, smoke, and heat in buildings by providing detection, suppression, and notification functions.

firestop system A specific construction consisting of the material(s) (firestop penetration seals) that fill an opening in the wall or floor assembly, and around and between any items that penetrate the wall or floor (e.g., cables, cable trays, conduit, ducts, pipes), and any termination devices (e.g., electrical outlet boxes) along with their means of support.

flat network A network that consists of a single broadcast domain. See also broadcast domain.

focal lighting The vertical illumination of a presenter in a distance learning situation or participants in a videoconference application.

frame synchronizer A device that takes a digital snapshot of each incoming frame of video and releases it immediately as the next frame comes in.

frequency The number of cycles that a periodic signal completes in a given time; if the unit of time is one second, the frequency is stated in hertz (Hz). One Hz is equal to one cycle per second.

frequency-agile processor A processor capable of selecting any input very high frequency or ultrahigh frequency channel and providing an output at any other broadcast or community antenna television channel frequency.

frequency modulation (FM) Modulation in which the instantaneous frequency of a sine wave carrier is caused to depart from the center frequency by an amount proportional to the instantaneous value of the modulating signal. In FM, the center frequency is called the carrier frequency.

Fresnel zone The circular zone about the direct path between an electromagnetic wave transmitter and receiver in an unbounded transmission medium free of radiation sources.

front of house (FOH) mixer A mixer used for live sound mixing.

full-bandwidth signal A combination of the three red, green, and blue signals and sync or timing signals that makes up all of the information contained in the image converted by the camera's sensors.

full-normalled patch panel A patch panel that is normally connected unless a patch cord is plugged into one of the points. Contrast with non-normalled patch panel.

fundamental waveform A single sine wave.

G

gender changer an adapter that has a male-to-male or a female-to-female configuration and could be temporarily added to complete a cable connection.

Gigabit Ethernet (GbE) A local area network protocol with a data transfer rate of 1000 Mb/s (1 Gb/s).

glare The result of the scattering of unwanted light across the retina by a bright luminous source in the visual field.

gooseneck microphone A microphone with a thin, flexible, suspension arm that supports the microphone element.

graphic equalizer (EQ) A 1/3 octave EQ with 31 control points over 10 octaves capable of raising and lowering the gain of the center frequency labeled above the control.

grounded circuit conductor A conductor that is intentionally grounded at the utility power source or main service entrance and intended to provide electrical power at line-neutral voltages and carry the unbalanced load current between phases. Also called neutral conductor.

H

half-normalled patch panel A patch panel that allows the monitoring of the source signal or routing to an additional destination.

handheld microphone A microphone that allows the presenter movement while speaking.

handhole (HH) A structure similar to a small maintenance hole in which cable can be pulled, but not large enough for a person to fully enter to perform the work.

harmonic distortion The production of harmonic frequencies by an electronic system when a signal is applied at the input.

harmonics Higher frequency waves blended with fundamental waveforms.

Haas effect A psychoacoustic effect that leads the listener hearing two identical sounds from two sources believe that the closest sound source is the only sound source.

headworn microphone A hands-free microphone, typically designed to be worn as a headband or wrapped behind the ear.

heat load The amount of heat generated by a combination of the human bodies and equipment in a space in addition to the radiant, conductive, and convective heat generated by a building's exterior environment.

high definition multimedia interface (HDMI) A nonprofessional connection standard that includes audio, control, and digital asset rights management information intended as a point-to-point connection between video devices.

high definition television (HDTV) A television format superior to analog TV in picture detail and realism that can be transmitted in the same size channel (6 megahertz) as analog broadcasts.

horizontal scan rate The rate at which the electron beam in cathode ray tube display scans each line from left to right and back again.

horizontal (H) sync The signal that controls horizontal timing in a visual display.

hot spotting An event caused by the properties of the screen surface and manifesting as a brighter area on the screen.

hue See chromaticity.

hybrid cable An assembly of two or more cables, of the same or different types or categories, covered by one overall sheath. (TIA)

hyper and super cardioid microphones A type of microphone sensitive to sound coming from one direction and typically used for sound reinforcement for one or two persons.

hypertext transfer protocol (HTTP) A protocol used to access content that is stored on Web servers using various applications software (e.g., a browser).

I

illuminance The light level incident on a surface or plane from a source or sources expressed in lux (lx [lumens per square meter]).

impedance (Z) The total opposition (resistance and reactance [capacitance and inductance]) that a circuit, cable, or component offers to the flow of alternating current (ac) at a given frequency. It is measured in ohms.

impedance-matching transformer A type of transformer used at each loudspeaker to convert the 25 volt (V) or 70 V signal to a much lower voltage. Also called voltage step-down transformer.

incident light The original light.

index of refraction The ratio of the velocity of light in a vacuum to the velocity of light in a material.

inductance (L) A condition that opposes the flow of current while causing a voltage phase shift in +90 degrees.

infrared (IR) The electromagnetic spectrum having wavelengths between 750 nanometers (nm [7.5×10^{-7} meters (m)]) and 1 millimeter (mm [1×10^{-3} m]) or between 30 microinches (3×10^{-5} in) and 40 000 microinches (4×10^{-2} in).

infrared (IR) serial control A type of control that uses infrared light to transmit and receive serial data.

innerduct A nonmetallic raceway, usually circular, placed within a larger pathway. (TIA)

in-phase (I) signal The red minus luminance signal, compacted through filtering to 1.5 megahertz of bandwidth.

insertion loss The signal loss resulting from the insertion of a component, or link, or channel, between a transmitter and receiver. (TIA)

insulation displacement connector (IDC) block A connector available in many sizes, the most popular of which are 66 block and 110 block. These types of IDC terminations are used for some audio patch bay connections and other types of connections.

insulation displacement contact (IDC) A type of wire termination in which the insulation surrounding a conductor is displaced at the connection point without physically stripping the insulation from the conductor and consequently makes a gas-tight connection to the conductor.

integrated services digital network (ISDN) A fully digital communications facility designed to provide transparent end-to-end transmission of voice, data, audio, video, and still images across the public switched telephone network. Different versions exist for North America and Europe.

interactive television (TV) system A type of system that may include patient education, patient entertainment and, access to clinical software for staff through the master antenna television distribution system.

intermodulation The production, in a nonlinear element of a system, of frequencies corresponding to the sum and difference frequencies of the fundamentals and harmonics that are transmitted through the element.

intermodulation distortion A nonlinear distortion characterized by the appearance, in the output of a device, of frequencies that are linear combinations of the fundamental frequencies and all harmonics present in the input signals.

Internet printing protocol (IPP) A protocol that allows printers to be independently accessed and managed remotely over a network, which enables, for example, sending files directly to a printer over the Internet.

Internet protocol (IP) The Open Systems Interconnection Reference Model protocol most commonly used for internetworking. Required for communications over the Internet. Also called Layer 3.

Internet relay chat (IRC) A protocol that enables real-time text-based communications sessions between individuals on a network.

internetwork The connection of two or more networks.

inverse square law A physics law that states that the measured energy emitted from a point source decreases to a quarter of its level for each doubling of distance from the source.

isolation loss An intentional attenuation of the trunk line signal to a level suitable for input to a television or other radio frequency receiving device. The resulting signal level should be in the 5 to 10 decibel millivolt range. Also called tap-off loss.

isolation transformer A transformer with high galvanic insulation used to break ground loops at low frequency in communications systems operating over copper cables.

K

Kelvin scale A scale based on the color of light emitted when a substance is heated.

L

latent heat The heat produced by a change in the temperature of the air's water content.

Layer 1 See Physical layer.

Layer 2 See Data Link layer.

Layer 3 See Network layer.

Layer 4 See Transport layer.

Layer 5 See Session layer.

Layer 6 See Presentation layer.

Layer 7 See Application layer.

light reflectance value (LRV) A measurement often applied to paint and other room finishes indicating the percentage of light reflected from a particular surface independent of the color.

light-emitting diode (LED) A semiconductor diode that converts information from electrical to optical form.

lighting zone A group of lighting luminaires controlled together. Zones are established for each basic lighting function.

lightweight directory access protocol (LDAP) A protocol that provides a uniform, application-independent set of services for creating, storing, accessing, and updating directory-based information on a network.

line level The audio level in the range of –20 to +25 decibels referenced to 0.775 volt root mean square.

line of sight (LoS) The imaginary line that connects the observer's eye with the object the observer is looking at. See also Fresnel zone.

line-interactive uninterruptible power system (UPS) unit An off-line uninterruptible power system unit with line conditioning included.

liquid crystal display (LCD) A display device made up of a panel that utilizes two transparent sheets of polarizing material with a liquid between them. It does not produce light, rather each pixel is either on or off and a back light is used to produce the image.

local area network (LAN) The standard industry term for a network installation that serves a relatively small area (e.g., structured cabling installation serving a building).

logarithm The opposite of an exponent. The logarithm $\log_x y$ for a base x and a number y is the inverse function of x^y.

low-pass filter A filter that passes all of the information only up to a certain point.

lumen A rating of average brightness.

luminaire A complete lighting assembly including the housing, reflectors, and lamps.

luminaire efficiency The ratio of total lumens emitted by the lamps within a fixture to the total lumens that exit from the fixture.

luminance The luminous intensity from a surface in a particular direction.

luminance or luma (Y) signal A bandwidth-limited signal that combines the sync information with the signals for brightness.

luminance ratio (contrast) The mathematical ratio of the lightest area to the darkest area of a visual field of view.

luminous exitance The measure of light reflecting off a surface in all directions and measured in footcandles.

lux A contraction of the words luminance and flux. A single lux (lx) is equivalent to one lumen per square meter and 0.093 footcandles (fc).

M

main distribution panel A panel located at the service entrance that distributes the power to subpanels throughout a facility.

maintenance hole (MH) **1.** A vault located in the ground or earth as part of the underground duct system and used to facilitate placing, connectorization, and maintenance of cables as well as the placing of associated equipment, in which it is expected that a person will enter to perform the work. (TIA) Formerly called manhole. **2.** A hole through which an underground or enclosed structure may be accessed.

masking system A system that provides a constant and predictable level of background noise that makes nearby conversations less intelligible and unwanted intermittent noise less noticeable.

master technical power panel A panel that distributes the power (and the equipment ground) to all other locations within the facility.

matrix decoder A decoder that takes the color difference signals output by the chroma decoder and the luminance signal output by the delay circuit and matrixes them together to produce red, green, and blue signals.

matrix switcher A compilation of several switchers, the number of which is the actual number of outputs specified by the size of the matrix. Also called router switcher.

maximum channel insertion loss The difference between the minimum transmitter output power coupled into the optical fiber and the receiver sensitivity, less any power penalties established.

media access control (MAC) address A hexadecimal identifier, unique to each device on a local area network.

medical education systems Systems that use audio and video to facilitate the communication between medical students and instructors.

metacontrol An artificial intelligence term meaning the control of control systems.

metropolitan area network (MAN) A data communications network that covers an area larger than a campus area and smaller than a wide area network (WAN).

microphone level The audio level in the range of –60 to –20 decibels referenced to 0.775 volt root mean square.

mixing A process of combining different audio sources or tracks and their blending for the best sound quality and balance.

mixing console A large-format mixer with many input and output channels and extensive processing. It is intended to have an operator at all times.

modular connector A telephone-type connector that clicks into place to connect and commonly used for data and voice. It may be 4-, 6-, or 8-position.

modulation The process whereby a radio frequency or light wave's amplitude, frequency, or phase is changed to transmit information.

modulator A device that converts standard audio/video inputs to a frequency suitable for local community antenna television distribution.

monitor mixer A mixer used for very large events where extensive stage monitoring is required and cannot be handled by the main front-of-house mixer.

Motion Pictures Expert Group (MPEG) A collection of video compression tools.

motor generator A device that provides electrical isolation from the utility line by using the utility to drive a motor, which in turn drives a generator, producing an alternating current waveform at the desired voltage.

moving-coil microphone See dynamic microphone.

muffler See silencer.

multi-image processor See picture-in-picture (PIP) device.

multimode optical fiber cable A cable made of glass fibers with a common diameter in the 50 to 100 micrometer (μm) range for the light-carrying component, with the most common size being 62.5 μm.

multiplexing Combining two or more signals into a single wave (the multiplex wave) from which the signals can be individually recovered.

musical instrument digital interface (MIDI) A communications protocol that allows electronic musical instruments (e.g., digital keyboards) to communicate with one another.

N

National Television System Committee (NTSC) standard A color video standard used in the United States.

near-field sound A sound that travels from the source to the listener in a straight-line path without interference from room reflections. Also called direct sound.

needed acoustic gain (NAG) A metric that specifies how much to electronically increase the amplitude of an original acoustic wave that strikes a microphone for it to be equivalent to some closer location where no amplification would be required for adequate hearing.

network interface card (NIC) Circuitry in a device that provides the means to physically connect to a network.

Network layer The Open Systems Interconnection (OSI) Reference Model layer responsible for internetwork message transfer (e.g., between local area networks on an internetwork). Also called Layer 3.

network news transfer protocol (NNTP) A protocol used to read and reply to messages posted on news servers.

neutral conductor See grounded circuit conductor.

noise criteria (NC) A rating system that specifies or quantifies the background noise levels from ventilation equipment or other sources in an occupied space. Also called noise reference.

noise isolation class (NIC) The field-measured noise reduction provided by a construction assembly.

noise reduction coefficient (NRC) A single-number rating used by the building industry to quantify the sound absorption of a material in the speech frequency range.

noise reference (NR) See noise criteria.

non-normalled patch panel A patch panel that provides no connection until a patch is completed. Contrast with normalled patch panel.

nonplenum-rated cable Any cable not meeting flammability and smoke requirements for the purpose of fire, life, and safety as described by National Fire Protection Association 70, the *National Electrical Code*®.

normalling A term used to describe a patch panel wiring pattern in which a circuit path is established from one point of contact to another (usually above or below the first point of contact) without the use of a patch cord.

notch filter A filter that removes the sub-carrier information along with the luminance information at the sub-carrier frequency of 3.58 megahertz.

null modem adapter An adapter that helps determine the proper wiring scheme.

Nyquist frequency The highest frequency of the analog signal being recorded and equal to half of the sampling rate.

Nyquist theorem A theorem that states the sampling rate must be at least twice the highest frequency of the analog signal being sampled.

O

off-line uninterruptible power supply (UPS) unit A device that powers the load directly from the utility and only provides backup power when the utility power goes below the preset tolerances. Also called standby uninterruptible power supply unit.

Ohm's law The mathematical relationship among electric current, resistance, and voltage. The voltage in volts is equal to the current in amperes multiplied by the resistance in ohms.

omnidirectional microphone A microphone that picks up sound from all directions equally, with a slight preference for the sounds coming from the direction in which they are pointed.

online double-conversion uninterruptible power supply (UPS) A conventional uninterruptible power supply unit that completely rectifies the alternating current (ac) line from ac to direct current (dc) and uses this dc to both charge the battery and power a dc/ac inverter.

Open Systems Interconnection (OSI) Reference Model A seven-layer architecture developed by the International Organization for Standardization that has served as a foundation for the development of many standards for network systems communications. The seven layers are physical, data link, network, transport, session, presentation, and application.

optical fiber cable Cable made up of one or more strands of glass consisting of a central core and outer cladding (optical fibers), strength members, and an outer jacket.

overcurrent protection device (OCPD) Thermal or thermal-magnetic devices such as circuit breakers or fuses. An individual circuit might provide power to all of the lights in a room or several electrical convenience outlets, but the total power consumed on the circuit cannot exceed the current limiting device's rating.

P

panelboard A single panel (or group of panel units designed for assembly to form a single panel) that includes buses and automatic overcurrent devices (circuit breakers or fuses) with or without switches for the control of light, heat, or power circuits.

parametric equalizer (EQ) An equalizer with two or three knobs that allow users the control over various frequency aspects of the signal. One control allows selecting a specific frequency. Another control determines how much boost or reduction is applied to that frequency.

patch bay A junction panel of connector jacks (patch points) for making system connections. It consists of two rows of connector jacks wired with various signals from rear equipment panels.

patch panel A connecting hardware system that facilitates cable termination and cabling administration using patch cords. (TIA)

pathway **1.** A sequence of connections that provides the connectivity between devices on a network or between networks on an internetwork. **2.** The vertical and horizontal route of the telecommunications cable. **3.** A facility for the placement of telecommunications cable. (TIA)

percentage articulation loss of consonants (%ALcons) The percentage of articulation loss of consonants in speech.

peripheral device External equipment connected to and controlled by a station or a server (e.g., compact disk read-only memory drives, modems).

personal area network (PAN) A data communications system that covers an area generally associated with an individual workspace (e.g., office, cubical).

phase alternate line (PAL) standard A color video standard used in Australia, China, Western Europe, and some of South America and Africa.

phase conductor The portion of the power supply cable that carries the current.

phase The relationship in time between two waveforms of the same frequency.

phon Unit of perceived loudness.

phono connector A connector used for carrying video or unbalanced audio line-level signals in consumer products. It also is used for data and power connections.

photon A light particle.

Physical layer The Open Systems Interconnection Reference Model layer responsible for the transfer of bit streams over a specific medium. Also called Layer 1.

picture-in-picture (PIP) device A device that enhances and expands the capabilities of a presentation system. Also called multi-image processor.

plasma panel An array of cells, known as pixels, composed of three subpixels, corresponding to the colors red, green and blue. Gas in the plasma state is used to react with phosphors in each subpixel to produce colored light (red, green, or blue).

plenum-rated cable A cable that meets flammability and smoke requirements for the purpose of fire, life, and safety as described by National Fire Protection Association 70, the *National Electrical Code*®. Contrast with nonplenum-rated cable.

point-to-multipoint A wireless connection from one point to several other points.

point-to-point (PTP) A direct connection established between two specific locations, as between two buildings or devices.

poke-thru A penetration through the fire resistive floor structure to permit the installation of horizontal telecommunications cables. (TIA)

polar pattern The pattern in which a microphone senses the sound occurring in its vicinity.

potential acoustic gain (PAG) A formula that determines what the audio system will be able to produce in sound pressure level before the room begins to feedback.

potentiometer See dimmer.

power (P) **1.** Rate of transfer or absorption of energy per unit time in a system. **2.** Energy required to operate an electrical device (e.g., motor, amplifier, telephone transmitter).

power factor (PF) The ratio of real power to apparent power. See power and apparent power.

Presentation layer The Open Systems Interconnection (OSI) Reference Model layer responsible for various forms of message conversion, including compression and encryption. Also called Layer 6.

presentation system A system deployed in conference rooms, boardrooms, and patient education rooms.

primary rate interface (PRI) An integrated services digital network (P/ISDN) interface standard that, in the United States, consists of 23 64 kb/s B channels and one 64 kb/s D channel using a T-1 line. In Europe, P/ISDN consists of 30 64 kilobits per second (kb/s) B channels and one 64 kb/s D channel using an E-1 channel.

prioritization A function performed by a network interface card that makes it possible to assign different levels of priority to the applications running simultaneously on a station. Also called traffic prioritization.

private branch exchange (PBX) A private telecommunications switching system allowing private local voice (and other voice-related services) switching over a network. (TIA)

processing amplifier A device that allows adjustments for the luminance, chroma, and hue components of the video picture. A processing amplifier prompts raising or lowering video signal levels, black level, and color saturation or correcting color balance problems.

projection display solution An image display system with a discrete projection device and an image (screen) surface.

psychoacoustics The study of how the brain perceives sounds.

public switched telephone network (PSTN) A domestic telecommunications network usually accessed by telephones, key telephone systems, private branch exchange trunks, and data arrangements.

pull box A device for access to a closed raceway used to facilitate placing of wire or cables.

Q

quadrature (Q) signal The blue minus luminance signal compacted through filtering to 0.6 megahertz of bandwidth.

quality of service (QoS) **1.** A commitment to performance, based on predefined service parameters. **2.** A measure of the level of service provided on a network.

quantization The process of selecting whole numbers to represent the voltage level of each sample.

quantization noise The error between the actual signal value and the digitized value.

R

rackmount style mixer A mixer with fewer inputs (often 8 or less), which provides very limited signal adjustment. Each channel commonly has a gain knob, a master gain, and some limited equalization.

radio frequency (RF) The group of electromagnetic (EM) energy within the EM spectrum whose wavelengths are between the audio and the light range (usually between 535 kilohertz and 300 gigahertz).

radio frequency interference (RFI) The disruption of radio signal reception caused by any source which generates radio waves at the same frequency and along the same path as the desired wave. (*Newton Telecommunications Dictionary*)

radio frequency (RF) video Composite video with two audio channels, modulated at a carrier frequency. RF video must be demodulated prior to viewing. See also composite (baseband) video signal.

rarefaction The action of the molecules moving apart.

raster scanning The process in a cathode ray tube where an electron beam moves in a sequenced and ordered manner, charging phosphors.

reactance (X) Inductance and capacitance added together.

recording mixer A large or small-format mixer similar to the front-of-house mixers. These mixers additionally often incorporate such things as automation and more extensive metering. Compare to front-of-house mixer.

red, green, and blue (RGB) The primary colors of light.

reflection **1.** The changing of the direction of light caused by materials with a mirrored or glossy surface. **2.** The phenomenon by which a sound wave is re-radiated or bounced off a surface.

refraction The bending or changing of the direction of a light ray as it passes through material (e.g., water or glass).

Registered Communications Distribution Designer (RCDD®) A BICSI® designation for individuals who demonstrate expertise in the design, integration, and implementation of telecommunications (voice, data, video, audio, and other low-voltage control) transport systems and their related infrastructure components.

request for information (RFI) A written request for clarification or information about the contract documents, products, or services offered. It may be issued from a supplier of products or services or it may be issued by the customer.

request for interpretation (RFI) See request for information.

request for proposal (RFP) A detailed document of requested services and equipment of a buyer submitted to others for responses.

request for quotation (RFQ) A detailed document that solicits quotes for projects or equipment and provides vendors with all the information necessary to prepare a quote.

reservation A quality of service technology whereby an integrated services group reserves and assigns network resources to specific types of traffic, guaranteeing network availability for a data stream prior to its generation by the sending device.

resistance (R) The ability of a conductor to resist the flow of electricity through it.

resolution of a digital audio signal The range of numbers that can be assigned to each sample.

reverberation The effect of sound scattering and steadily decaying in a room.

reverberation time (RT60) A metric that quantifies reverberation; the time in seconds required for the sound within a room to attenuate 60 decibels after its source is abruptly halted.

room criteria (RC) A metric that quantifies the tonal characteristics of ventilation noise (e.g., rumble or hiss).

router switcher See matrix switcher.

RS-232 A type of serial communications named after the Telecommunications Industry Association standard TIA-232-F, *Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange*.

RS-422 A type of serial communications based on the Telecommunications Industry Association standard 422-B, *Electrical Characteristics of Balanced Voltage Digital Interface Circuits*.

RS-485 A type of serial communications based on the Telecommunications Industry Association standard 485-A, *Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems*.

S

sabin The metric unit for absorption.

safe working load (SWL) A metric that determines the equipment weight that must not be exceeded.

safety factor A multiplier applied to the maximum carried by the mounting equipment and hardware (also, design factor, load factor, or safety ratio).

sample The digital level of an analog signal at a particular point in time.

sampling rate The number of times a sample is taken per second.

scaler A device that configures and optimizes the capture and processing of signals and then outputs them at the most appropriate resolution and refresh rate for the source material and the display.

scan converter A device that converts the faster scan rate of the computer image to the slower scan rate compatible with television technology.

scattering The reflecting of the incoming light waves in multiple angles due to an uneven (textured) surface.

screen gain The ability of a screen to redirect projected light to make the image appear brighter within the viewer axis.

second audio programming (SAP) A modulator that provides the ability to incorporate an additional language into the signal.

sensible heat The heat produced by a rise in the air temperature.

Séquential Couleur avec Mémoire (Sequential Color with Memory [SECAM]) A color video standard used in France, Russia, the former Soviet Union, Asia, and Africa.

serial communications A form of data communications where information is sent sequentially, one piece at a time, down a cable.

serial digital interface (SDI) A digital video standard used in broadcast, production, and post-production systems.

server A network device that combines hardware and software to provide and manage shared services and resources on the network.

service conductor A supply conductor that extends from the utility-provided power source (e.g., transformers) to the service equipment of a building.

service drop An overhead service conductor from the last pole or other aerial support (including splices) that connects to the service-entrance conductors at a building or other structure.

service entrance The point at which power enters the building.

service lateral An underground service conductor between the street main and the first point of connection to the service entrance conductors in a terminal box, meter, or other enclosure.

session initiation protocol (SIP) An open protocol designed by the Internet Engineering Task Force for universal connectivity that places the requirement for intelligence into the endpoints. The network's task is to recognize the protocol and allow it to pass cleanly.

Session layer The Open Systems Interconnection (OSI) Reference Model layer responsible for providing services used to organize, synchronize, and manage a given message exchange between network devices. Also called Layer 5.

shielded twisted-pair (STP) cable Cable made up of multiple twisted copper pairs with an additional metallic shield covering each individual pair. The entire structure is covered with an overall shield or braid and an insulating sheath (cable jacket).

shotgun microphone A microphone that must be aimed at the sound source. It has a long, slotted, tube designed to reject unwanted sound and pick up a speaker or sound source from many meters (feet) away.

show controller A specialized computer memory system programmed to record all of the aspects of lighting operation and effects.

signal loss Attenuation of a signal, usually measured and expressed in decibels.

signal separation Providing physical distance among cables carrying various signal levels.

signal separator A device that separates luminance with sync and chrominance signals.

signal tilt The loss undergone by a higher channel signal while passing through a coaxial cable. The higher the channel frequency, the higher the signal loss.

signal-to-noise ratio (SNR) The ratio between the amount of signal power at the receiver.

simple mail transfer protocol (SMTP) A protocol that enables exchanging messages created using any SMTP-compliant e-mail software.

simple network management protocol (SNMP) A protocol that allows remote hierarchical views into the abyss of the network and its connected devices so that troubleshooting, error logging, maintenance, and configurations can be managed remotely.

singlemode optical fiber cable Optical fiber with a relatively small core diameter of 8 in, 9 micrometers (μm) and a cladding diameter of 125 μm; lightwave propagation is restricted to a single path, or mode.

skylight A diffuse daylight created by the considerable amount of sunlight scattered by the earth's atmosphere.

slip sleeve An oversized conduit that moves easily along an inner conduit and covers a gap or missing part of the smaller conduit. (TIA)

solid conductor cable A cable composed of a single gauge conductor wrapped in an insulating coating. Contrast with stranded conductor cable.

sound attenuator See silencer.

sound isolation The capacity of a structure to prevent an unwanted sound from transmitting from one space to another.

sound pressure level (SPL) The actual air pressure created by a sound as measured by a sound level meter.

sound transmission class (STC) The sound isolation performance rating measured in a controlled laboratory.

sound trap See silencer.

speaker level The audio level greater than +25 decibels referenced to 0.775 volt root mean square.

speech intelligibility The ability to hear and understand the spoken word clearly.

speech transmission index (STI) A measure of speech intelligibility.

split system A heating, ventilating, and air conditioning system where the condenser (outside unit) and evaporator (inside unit) are in separate locations joined by refrigerant piping.

splitter A passive device that takes a signal and splits it into two or more lower-level output signals.

splitter loss The signal loss generated by signal splitting, a splitter's insertion into the line. If a two-way splitter is used, 3.5 decibel through loss is generated on each branch or port; if a four-way splitter is used, 7 dB through loss is generated on each branch.

standard definition television (SDTV) A digital version of the programming on traditional television.

Standards of Excellence Ten standards of excellence developed for audiovisual (AV) solutions providers and AV clients: 1) Complete solutions; 2) Informed advice; 3) Best value; 4) Ongoing technical support; 5) Systems compatibility; 6) Scalability; 7) Clear scope of work; 8) Appropriate documentation; 9) Expert technical staff; and 10) Training support.

standby uninterruptible power supply (UPS) unit See off-line uninterruptible power supply unit.

static uninterruptible power supply (UPS) unit A solid-state device designed to protect critical loads from most types of power fluctuations.

station **1.** A device used by an individual to access network services. **2.** An input or output point in a telecommunications system (e.g., telephone, computer, fire alarm station).

stranded conductor cable A cable composed of a bundle of smaller gauge wires wrapped in a single insulating coating. Contrast with solid conductor cable.

strip amplifier A single-channel amplifier designed to receive a single very high frequency or ultrahigh frequency channel input and provide a single-channel output with no change in frequency.

structured cabling system (SCS) The complete collective configuration of telecommunications cabling and associated hardware at a given location.

subnetwork A single broadcast domain in a network that is made up of multiple broadcast domains.

surface mount microphone See boundary microphone.

surge arrester A protective device for limiting surge voltages by discharging or bypassing surge current.

sustainable (green) design A concept that recognizes the human civilization is an integral part of the natural world and that nature must be preserved to ensure the survival of the human species.

S-video signal Luminance with sync/chrominance signal.

Switcher A device that has the ability to choose between two or more sources and send the information from that source to a particular destination.

synchronization Coordination of the signal information with respect to time.

system headroom The difference between the level of a typical audio system operation and the maximum level attainable by a system.

T

table microphone A small microphone that is flush mounted onto tabletops, typically for conferencing situations. Also called button microphone.

tail time The amount of time an echo canceller can still recognize a signal as an echo from the remote speaker's speech and not interpret that signal as speech from a local speaker.

tap **1.** An electrical connection permitting signals to be transmitted onto or off a bus. **2.** The linking between the bus and the drop cable that connects the workstation to the bus in 10BASE-5 Ethernet. **3.** A device used on community antenna television cables for matching impedance or connecting service drops. See also bridged tap.

tap-off loss See isolation loss.

task lighting A type of lighting intended for the horizontal work surfaces at task locations (e.g., desks, tables, and counter tops).

T-carrier system A series of wideband digital data transmission formats originally developed by the Bell System and used in North America and Japan.

technical power system A power system dedicated for technical systems.

telemedicine system A system that uses telecommunications technology for medical diagnosis and consultation between facilities and departments.

telephone plug A connector used for audio signals (e.g., common musical instrument and equipment connector).

temperature loss The temperature that affects the cable signal loss, typically measured at 20 ºC (68 ºF) ± 5.5 ºC (10 ºF).

time-base corrector (TBC) A device that corrects inconsistencies of an analog playback videocassette recorder.

tip-ring-sleeve (TRS) connector A telephone plug connector used for balanced circuits and unbalanced stereo circuits.

tip-sleeve (TS) connector A telephone plug connector used for unbalanced circuits.

tone The overall sound of a particular note produced by an instrument or acoustic transducer. See also transduction.

traffic prioritization See prioritization.

traffic shaping A technique that directs data streams on the basis of their address, protocol, priority, or application content.

transduction Conversion of the vibration of the ear fluid to electrical signals by specialized cells within the inner ear area (cochlea).

transmission control protocol (TCP) An Open Systems Interconnection (OSI) Reference Model Layer 4 connection-oriented protocol. TCP supports reliable, end-to-end transmission of data by allowing for guaranteed delivery and sequencing of packets. Contrast with user datagram protocol.

Transport layer The Open Systems Interconnection (OSI) Reference Model layer responsible for providing a level of quality to the message transfer process. Also called Layer 4.

trigonometry A study of the mathematical properties of the right triangle.

U

ultrahigh frequency (UHF) Frequencies in the range of 300 to 3000 megahertz.

ultraviolet (UV) light The portion of the electromagnetic spectrum in which the longest wavelength is just below the visible spectrum, extending from approximately 10 nanometers (nm) to approximately 400 nm.

underfloor duct system A network of metal raceways embedded in concrete, which facilitates the distribution of horizontal cables (e.g., between telecommunications rooms

and work areas).

universal serial bus (USB) Bidirectional serial hardware interface protocol for attaching computer peripheral devices.

unshielded twisted-pair (UTP) cable Cable made up of one or more pairs of twisted copper conductors with no metallic shielding. The entire assembly is covered with an insulating sheath (cable jacket).

user datagram protocol (UDP) An Open Systems Interconnection Reference Model Layer 4 connectionless protocol that is part of the Transmission Control protocol/Internet protocol suite. UDP supports single packet data transmission with no guarantee of message delivery. Contrast with transmission control protocol.

V

variable air volume (VAV) box A small damper box that controls the amount of conditioned air introduced into the conditioned space to control the temperature.

variable voltage control A type of control used when adjustable voltages are required for quality control testing, electronic equipment burn-in, life-tests, and improved system performance.

veiling reflections The result of the direct reflection of the light incident upon a gloss surface into the eye of the observer, which makes the visualization of detail (e.g., written text) difficult.

vertical scan rate The rate at which the electron beam completes its cycles of vertical motion, from top to bottom, which is one field.

vertical (V) sync Vertical image position.

very high frequency (VHF) Frequencies from 30 megahertz (MHz) to 300 MHz.

virtual local area network (VLAN) A technique made possible by switching technologies that permits the logical grouping of any number of network devices into one or more subnetworks to improve traffic management and/or security.

visible color spectrum A small section of the electromagnetic spectrum visible to the human eye.

voltage drop A consequence of power consumption caused by the resistance of electrical conductors.

voltage regulator A device that adjusts the line voltage to the load, while maintaining the input voltage within the range of the regulator.

voltage step-down transformer See impedance-matching transformer.

voltage Electrical potential or potential difference expressed in volts.

W

wavelength The distance in between two corresponding points of two consecutive cycles.

wide area network (WAN) A data communications system that uses telecommunications circuits to link local area networks that are distributed over large geographic distances.

wired equivalent privacy (WEP) WEP data encryption is defined by the Institute of Electrical and Electronics Engineers, Inc.® 802.11 standard to prevent **(a)** access to the network by intruders using similar wireless LAN (WLAN) equipment and **(b)** capture of WLAN traffic through eavesdropping. Access is denied by anyone who does not have an assigned key.

wireless fidelity (Wi-Fi) Often used when referring to IEEE 802.11b/g equipment, a trade term promulgated by the Wi-Fi Alliance. Wi-Fi is used in place of IEEE 802.11b/g in the same way that Ethernet is used in place of IEEE 802.3.

wireless local area network (WLAN) Using radio frequency technology, such networks transmit and receive data over the air, minimizing the need for wired connections. Thus, WLANs combine data connectivity with user mobility. WLANs are essentially networks that allow the transmission of data and the ability to share resources (e.g., printers) without the need to physically connect each node, or computer.

wireless microphone A microphone that uses the patterns of cable microphones but eliminates the need for a microphone cable by transmitting the signal wirelessly over a radio frequency signal.

working load limit (WLL) See safe working load.

X

X digital subscriber line (xDSL) A family of digital technologies designed to provide high data transfer rates over existing (legacy) telecommunications circuits. See also asymmetric digital subscriber line.

X series, latch, rubber (XLR) connector A connector most commonly used for audio, video, and control. It may take on different forms ranging from a rectangular chassis mount jack to a right angle plug. Most common are the straight connectors intended to terminate on the end of a cable.

Z

zero reference 0 decibels.

Acronyms and Abbreviations

SYMBOLS

µm	micrometer
µs	microsecond

A

%ALcons	percentage articulation loss of consonants
A	ampere
A	anode
A/D	analog-to-digital
AAC	advanced audio codec
AAC-LD	low-delay advanced audio codec
ac	alternating current
AC	articulation class
ACL	access control list
ADA	*Americans with Disabilities Act*
ADSL	asymmetric digital subscriber line
A-DSP	digital audio signal processor
AEC	acoustic echo canceller
AF	average footcandles
AFF	above finished floor
AGC	automatic gain control
AHJ	authority having jurisdiction
AHU	air handling unit
AI	articulation index
AI	artificial intelligence
AM	amplitude modulation

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ANS	ambient noise sensor
ANSI	American National Standards Institute
AP	access point
ASCII	American standard code for information interchange
ASDL	asymmetric digital subscriber line
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ATA	analog telephone adapter
ATM	asynchronous transfer mode
ATM	automated teller machine
ATSC	Advanced Television Systems Committee
ATU	air terminal unit
AUTONEG	autonegotiation
AV	audiovisual
AWG	American wire gauge

B

b/s	bits per second
BAS	building automation system
BIDS	building information display system
BMS	building management system
BNC	Bayonet Neill-Concelman
BRI	basic rate interface
BSS	basic service set
Btu	British thermal unit
Btuh	British thermal unit per hour
B-Y	blue minus luminance

C

C	capacitance
C	cathode
C	chroma
CATV	community antenna television
CAVSP	Certified Audiovisual Solutions Provider
CCC	command and control center
CCK	complementary code keying
CCT	correlated color temperature
CCTV	closed circuit television
CD	collision detection
CD	compact disc
CENELEC	Comité Européen de Normalisation Electrotechnique (European Committee for Electrotechnical Standardization)
centrex	central exchange
CFR	*Code of Federal Regulations*
CIE	Commission Internationale d'Eclairage (International Commission on Illumination)
cm	centimeter
CMOS	complementary metal-oxide semiconductor
CO	change order
CO	central office
codec	coder/decoder
CPU	central processing unit
CRI	color rendering index
CRT	cathode ray tube
CSA	Canadian Standards Association
CSI	Construction Specifications Institute
CSMA/CA	carrier sense multiple access with collision avoidance

CSMA/CD carrier sense multiple access with collision detection

CSO composite second order

CSU channel service unit

CTB composite triple beat

CTS Certified Technology Specialist

D

D delta

D/A digital-to-analog

DA distribution amplifier

DAS direct attached storage

dB SPL decibel sound pressure level

dB decibel

dBA A-weighted decibels

dBm decibel referenced to milliwatts

dBmV decibel millivolt

DBS direct broadcast service

D_c critical distance

dc direct current

DD design development

DDS dynamic digital signage

DHCP dynamic host configuration protocol

D-ILA® Digital Direct Drive Image Light Amplification

DIN Deutsches Institut für Normung (German Institute for Standardization)

DLP digital light processing

DMD digital micromirror device

DMX digital multiplex

DNS domain name server

DoT Department of Transportation

DSL digital subscriber line

DSP digital signal processing

DSSS direct sequence spread spectrum

DSU data service unit

DTMF dual tone multi-frequency

DTS® digital theater sound

DTTB digital terrestrial television broadcasting

DTV digital television

DVB digital video broadcasting

DVD digital versatile disc

DVI digital visual interface

DVR digital video recorder

E

E electromotive force

EAD equivalent acoustic distance

EF entrance facility

EIA Electronic Industry Alliance

EM electromagnetic

EMC electromagnetic compatibility

EMI electromagnetic interference

EMP electromagnetic pulse

EMR electromagnetic radiation

EMT electrical metallic tubing

ENG electronic news gathering

ENT electrical nonmetallic tubing

EOC emergency operations center

EQ equalizer

ER	ellipsoidal reflector
ER	equipment room
ERB	electronic reader board
ERL	echo return loss
ERLE	echo return loss enhancement
ESD	emergency signaling displays
ESS	extended service set

F

FA	fire alarm
FAA	Federal Aviation Authority
FBI	Federal Bureau of Investigation
FC	fiber connector
fc	footcandle
FCC	Federal Communications Commission
FHSS	frequency hopping spread spectrum
FIDS	flight information display system
fl	footlambert
FM	frequency modulation
FMC	flexible metal conduit
FOH	front of house
FOV	field of view
fps	frames per second
FS	Federal Standard
FSM	feedback stability margin
ft	feet
ft/s	feet per second
ft^2	square feet
FTP	file transfer protocol

G

Gb/s	gigabits per second
GbE	Gigabit Ethernet
genlock	generator locking
GHz	gigahertz
GPS	global positioning system
GSM	Global System for Mobile Communications
GUI	graphic user interface
G-Y	green minus luminance

H

H	height
H	horizontal
h	hour
HAS	Health Services Agency
HD	high definition
HDMI	high definition multimedia interface
HD-SDI	high definition serial digital interface
HDTV	high definition television
HF	high frequency
HH	handhole
HID	high-intensity discharge
HPS	high pressure sodium
HTML	hypertext markup language
HTTP	hypertext transfer protocol
HVAC	heating, ventilating, and air conditioning
Hz	hertz

I

I	in-phase
I	intensity
IAQ	indoor air quality
IBC	*International Building Code*
IC	integrated circuit
ICC	International Code Council®
ID	inside diameter
IDC	insulation displacement connector
IDC	insulation displacement contact
IDF	intermediate distribution frame
IEC	International Electrotechnical Commission
IEEE®	Institute of Electrical and Electronics Engineers, Inc.®
IETF	Internet Engineering Task Force
IF	intermediate frequency
IM	instant message
IMAG	image magnification
IMC	intermediate metal conduit
InfoComm®	International Communications Industry Association (formerly ICIA)
InGaN	indium gallium nitride
IOS	internetwork operating system
IP	Internet protocol
IPP	Internet printing protocol
IPv4	Internet protocol version 4
IR	infrared
IRC	Internet relay chat
ISDB	Integrated services digital broadcasting

ISDN	integrated services digital network
ISM	industrial, scientific, and medical
ISO	International Organization for Standardization
ISP	Internet service provider
IT	information technology
ITS	information transport systems
ITU-T	International Telecommunication Union-Telecommunication Standardization Sector

J

J	joule
J/s	joules per second

K

K	kelvin
Kb	kilobit
Kb/s	kilobits per second
kg	kilogram
kHz	kilohertz
km/h	kilometer per hour
kV	kilovolts
kWh	kilowatt hours

L

L	inductance
LAN	local area network
lb	pound
LCD	liquid crystal display
LCoS	liquid crystal on silicon
LCS	live communications server

LDAP	lightweight directory access protocol
LEC	line echo canceller
LED	light-emitting diode
LoS	line of sight
LPD	lighting power density
LRV	light reflectance value
lx	lux (lumens per square meter)

M

m	meter
m/s	meters per second
m^2	square meters
mA	milliamperes
MAC	media access control
MAN	metropolitan area network
MATV	master antenna television
Mb/s	megabits per second
MCU	multipoint control unit
MEP	mechanical, electrical, and plumbing
MgO	Magnesium oxide
MH	maintenance hole (formerly called manhole)
MHz	megahertz
mi	mile
mi/h	mile per hour
MIDI	musical instrument digital interface
mm	millimeter
MMS	multimedia message service
MOH	music-on-hold

MPEG	Moving Picture Experts Group
MRI	magnetic resonance imaging
ms	milliseconds
MTC	musical instrument digital interface (MIDI) time code
mW	milliwatt

N

NAG	needed acoustic gain
NAS	network attached storage
NAT	network address translation
NAVA	National Audio-Visual Association
NAVED	National Association of Visual Education Dealers
NC	noise criteria
NCCER	National Center for Construction and Research
NEC®	*National Electrical Code*®
NESC®	*National Electrical Safety Code*®
NFPA	National Fire Protection Association
NIC	network interface card
nm	nanometer
NNTP	network news transfer protocol
NOC	network operations center
NOM	number of open microphones
NR	noise reference
NRC	noise reduction coefficient
NT-1	network termination type 1
NTSC	National Television System Committee

O

O/A	opposite/adjacent
O/H	opposite/hypotenuse
OC	operation center
OC	optical carrier
OCPD	overcurrent protection device
OD	outside diameter
OFDM	orthogonal frequency division multiplexing
OFE	owner-furnished equipment
OLED	organic light emitting display
OR	operating room
OS	operating system
OSI	Open Systems Interconnection
OSM	Office of Spectrum Management
OTC	over-the-counter

P

P	power
P2P	person-to-person
PA	public address
PACS	picture archiving communications system
PAG	potential acoustic gain
PAL	phase alternating line
PAN	personal area network
PAR	parabolic reflector
PAS	public address system
PBX	private branch exchange

PC	personal computer
PDA	personal digital assistant
PDP	plasma display product
PE	Professional Engineer
PF	power factor
PID	public information display
PIP	picture-in-picture
PMS	property management system
PO	purchase order
POP	Post office protocol
POS	point of sale
POTS	plain old telephone service
PPV	pay-per-view
PRI	primary rate interface
PSTN	public switched telephone network
PTP	point-to-point
PTZ	pan-tilt-zoom
PVC	polyvinyl chloride

Q

QoS	quality of service

R

R	resistance
RC	room criteria
RCA	Radio Corporation of America
RCDD®	Registered Communications Distribution Designer

RF	radio frequency
RFC	request for change
RFI	radio frequency interference
RFI	request for information
RFI	request for interpretation
RFID	radio frequency identification
RFQ	request for quote (or quotation)
RG	radio grade
RGB	red green blue
RGBHV	red green blue, horizontal sync, and vertical sync
RIDS	rail information display system
RMC	rigid metallic conduit
rms	root mean square
RT	reverberation time
RTS/CTS	request to send/clear to send
R-Y	red minus luminance

S

s	second
S/E	signal-to-error
S/PDIF	Sony/Phillips Digital Interface
SAN	storage area network
SAP	second audio programming
SC	subscriber connector
SCCP	skinny client control protocol
SCS	structural cable system
SCSI	small computer system interface
SD	schematic design
SDI	serial digital interface

SDTV	standard definition television
SECAM	Séquentiel Couleur Avec Mémoire (sequential color and memory)
SFF	small form factor
SG	study group
SH	screen height
SI	simultaneous interpretation
SIG	special interest group
SIP	session initiation protocol
SMATV	satellite master antenna television
SMPTE	Society of Motion Picture and Television Engineers
SMTP	simple mail transfer protocol
SNAP	Subnetwork attachment point
SNMP	simple network management protocol
SNR	signal-to-noise ratio
SOC	satellite operations center
SONET	synchronous optical network technology
SoW	scope of work
SP	service provider
SPD	surge protective device
SPID	service profile identification
SPL	sound pressure level
SPS	standby power systems
ST	straight tip
STB	set top box
STC	sound transmission class
STI	speech transmission index
STP	shielded twisted-pair
SW	screen width
SWL	safe working load
SXGA	super extended graphics array

T

TBC	time-base corrector
TCP	transmission control protocol
THD	total harmonic distortion
THD+N	total harmonic distortion plus noise
TIA	Telecommunications Industry Association
TMDS	transition minimized differential signaling
TN	twisted nematic
TR	telecommunications room
TRS	tip ring sleeve
TS	tip sleeve
TSA	Transportation Security Administration
TV	television
TVRO	television receive-only

U

UDP	user datagram protocol
UHF	ultra-high frequency
UL®	Underwriters Laboratories, Inc.®
U-NII	unlicensed national information infrastructure
UPD	unit power density
UPS	uninterruptible power supply
USB	universal serial bus
UTP	unshielded twisted-pair
UV	ultraviolet

V

V	volt
VA	volt-ampere
VA/m^2	volt-amperes per square meter
Vac	volts alternating current
VAV	variable air volume
VCA	voltage-controlled amplifier
VCR	videocassette recorder
V_d	voltage drop
Vdc	volts direct current
V-DSP	digital video signal processor
VDT	video display terminal
VGA	video graphics array
VHF	very high frequency
VIS	visual information systems
VLAN	virtual local area network
VoIP	voice over Internet protocol
VPN	virtual private network
VPRN	virtual private routed network
VSAT	very small aperture terminal
VTC	video teleconferencing
VTR	videotape recorder
VU	volume unit

W

W	watt
W/f^2	watts per square foot
W/m^2	watts per square meter
WAN	wide area network

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WAP	wireless access point
WEP	wired equivalent privacy
WG	working group
Wi-Fi	wireless fidelity
WLAN	wireless local area network
WLL	wireless local loop
WMA	Windows® media audio
WPAN	wireless private area network
WWW	world wide web
WXGA	wide extended graphics array

X

XGA	extended graphics array
XLR	X series, latch, rubber
XML	extensible markup language
XMOD	cross modulation

Y

Y	luminance
Y/C	luminance with sync/chrominance

Z

Z	impedance

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