STANDARDS

an American National Standard

ANSI/BICSI 007-2017

Information Communication Technology Design and Implementation Practices for Intelligent Buildings and Premises

BICSI®

ANSI/BICSI 007-2017

Information Communication Technology Design and Implementation Practices for Intelligent Buildings and Premises

Committee Approval: June 2017
ANSI Final Action: June 29, 2017
First Published: August 2017

BICSI International Standards

BICSI international standards contain information deemed to be of technical value to the industry and are published at the request of the originating committee. The BICSI International Standards Program subjects all of its draft standards to a rigorous public review and comment resolution process, which is a part of the full development and approval process for any BICSI international standard.

The BICSI International Standards Program reviews its standards at regular intervals. By the end of the fifth year after a standard's publication, the standard will be reaffirmed, rescinded, or revised according to the submitted updates and comments from all interested parties.

Suggestions for revision should be directed to the BICSI International Standards Program, care of BICSI.

Copyright

Published by:

BICSI
8610 Hidden River Parkway
Tampa, FL 33637-1000 USA

Notice of Disclaimer and Limitation of Liability

BICSI standards and publications are designed to serve the public interest by offering information communication and technology systems design guidelines and best practices. Existence of such standards and publications shall not in any respect preclude any member or nonmember of BICSI from manufacturing or selling products not conforming to such standards and publications, nor shall the existence of such standards and publications preclude their voluntary use, whether the standard is to be used either domestically or internationally.

By publication of this standard, BICSI takes no position respecting the validity of any patent rights or copyrights asserted in connection with any item mentioned in this standard. Additionally, BICSI does not assume any liability to any patent owner, nor does it assume any obligation whatever to parties adopting the standard or publication. Users of this standard are expressly advised that determination of any such patent rights or copyrights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard does not purport to address all safety issues or applicable regulatory requirements associated with its use. It is the responsibility of the user of this standard to review any existing codes and other regulations recognized by the national, regional, local, and other recognized authorities having jurisdiction (AHJ) in conjunction with the use of this standard. Where differences occur, those items listed within the codes or regulations of the AHJ supersede any requirement or recommendation of this standard.

All warranties, express or implied, are disclaimed, including without limitation, any and all warranties concerning the accuracy of the contents, its fitness or appropriateness for a particular purpose or use, its merchantability and its non-infringement of any third party's intellectual property rights. BICSI expressly disclaims any and all responsibilities for the accuracy of the contents and makes no representations or warranties regarding the content's compliance with any applicable statute, rule, or regulation.

BICSI shall not be liable for any and all damages, direct or indirect, arising from or relating to any use of the contents contained herein, including without limitation any and all indirect, special, incidental, or consequential damages (including damages for loss of business, loss of profits, litigation, or the like), whether based upon breach of contract, breach of warranty, tort (including negligence), product liability or otherwise, even if advised of the possibility of such damages. The foregoing negation of damages is a fundamental element of the use of the contents hereof, and these contents would not be published by BICSI without such limitations.

TABLE OF CONTENTS

This page intentionally left blank

INDEX OF FIGURES

This page intentionally left blank

INDEX OF TABLES

This page intentionally left blank

PREFACE

Revision History

August 12, 2017 First publication of this standard, titled ANSI/BICSI 007-2017, *Information Communication Technology Design and Implementation Practices for Intelligent Buildings and Premises*

Translation Notice

This standard may have one or more translations available for the convenience of its readers. As translated text may contain inconsistencies when compared to the original text, if differences between the translation and the published English version exist, the English text shall be used as the official and authoritative version.

This page intentionally left blank

1 Introduction

1.1 General

An intelligent building, or premise, utilizes communication technology to integrate building systems, allowing for intersystem connection and coordination that provides an environment which is safer, more comfortable, productive or efficient. As innovation occurs, systems and applications that have not been traditionally connected to a data or telecommunications network are now utilizing Ethernet and network infrastructure as a means to provide new or expanded functions or as an additional or alternative infrastructure solution. Also, given the increased use of information communication technology (ICT) transmission media (e.g., balanced twisted–pair, optical fiber, wireless) within these systems, the design and implementation methodology based on the historical practice of using legacy, proprietary or application specific cabling systems such as one or two pair solid copper conductor wire is now insufficient.

1.2 Purpose

This standard is intended to be used for any size building, and can be applied to residential and businesses (premises) in all markets. This standard is written for use in the design and implementation of the structured cabling systems used to support building or premise systems which can be integrated through the use of common infrastructure.

This standard may be used to determine design requirements in conjunction with the system owner, occupant, or other project consultants. This standard provides a reference of common technology and design practices, but is not intended to be used by design professionals as their sole reference or as a step-by-step design guide.

1.3 Categories of Criteria

Two categories of criteria are specified - mandatory and advisory.

- Mandatory criteria generally apply to protection, performance, administration, and compatibility; they specify the absolute minimum acceptable requirements.
- Advisory or desirable criteria are presented when their attainment will enhance the general performance of the building system infrastructure in all its contemplated applications.

Mandatory requirements are designated by the word *shall*; advisory recommendations are designated by the words *should*, *may*, or *desirable*, which are used interchangeably in this standard. When possible, recommendations and requirements were separated to aid in clarity.

2 Scope

This standard applies to building systems that utilize information communication technology components, systems and infrastructure to interconnect and share information between building systems. Examples of these systems include, but are not limited to:

- Building automation and management
- Energy and electrical power management
- Lighting
- Audio and video systems (e.g., digital signage, notification)
- Electronic safety and security (ESS) systems

The performance specifications for building systems are not offered in this standard unless they relate to the structured cabling system or other supporting systems requirements and recommendations found within this standard.

This page intentionally left blank

3 Required Standards and Documents

The following standards and documents contain provisions that constitute requirements listed within this standard. Unless otherwise indicated, all standards and documents listed are the latest published version prior to the initial publication of this standard. Parties to agreement based on this standard are encouraged to investigate the possibility of applying a more recent version as applicable.

Where equivalent local codes and standards exist, requirements from these local specifications shall apply. Where reference is made to a requirement that exceeds minimum code requirements, the specification requirement shall take precedence over any apparent conflict with applicable codes.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)

- ANSI/ASHRAE/IES Standard 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings

BICSI

- ANSI/NECA/BICSI 607, *Telecommunications Bonding and Grounding Planning and Installation Methods for Commercial Buildings*
- ANSI/BICSI 003, *Building Information Modeling (BIM) Practices for Information Technology Systems*
- ANSI/BICSI 005, *Electronic Safety and Security (ESS) System Design and Implementation Best Practices*
- ANSI/BICSI 006, *Distributed Antenna System (DAS) Design and Implementation Best Practices*

British Standards Institution (BSI)

- BS 6701, *Telecommunications equipment and telecommunications cabling. Specification for installation, operation and maintenance*
- BS 7671, *Requirements for Electrical Installations. IET Wiring Regulations*

Canadian Standards Association

- C22.1, *Canadian Electrical Code, Part I, Safety Standard For Electrical Installations*
- Z8000, *Canadian Health Care Facilities - Planning, Design and Construction*

European Committee for Electrotechnical Standardization (CENELEC)

- EN 50173-1, *Information technology—Generic cabling systems—Part 1: General requirements*
- EN 50174-1, *Information technology—Cabling installation—Installation specification and quality assurance*
- EN 50174-2, *Information technology—Cabling installation—Installation planning and practices inside buildings*

Institute of Electrical and Electronics Engineers (IEEE)

- IEEE 802.3, *IEEE Standard for Ethernet*

International Electrotechnical Commission (IEC)

- IEC 60364-4-43, *Low-voltage electrical installations – Part 4-43: Protection for safety – Protection against overcurrent*
- IEC 60364-5-52, *Electrical installations of buildings – Part 5-52: Selection and erection of electrical equipment – Wiring systems*

International Organization for Standardization (ISO)

- ISO/IEC 11801-1, *Generic cabling for customer premises – Part 1: General requirements*
- ISO/IEC 11801-6, *Generic cabling for customer premises – Part 6: Distributed building services*
- ISO/IEC 14763-2, *Information technology – Implementation and operation of customer premises cabling – Part 2: Planning and installation*
- ISO/IEC 18598, *Information technology – Automated infrastructure management (AIM) systems – Requirements, data exchange and applications*
- ISO/IEC 30129, *Information Technology – Telecommunications bonding networks for buildings and other structures*

National Fire Protection Association (NFPA)

- NFPA 70®, *National Electrical Code® (NEC®)*
- NFPA 72®, *National Fire Alarm Code*
- NFPA 99, *Health Care Facilities Code*
- NFPA 101®, *Life Safety Code®*

Telecommunication Industry Association (TIA)

- ANSI/TIA-526-7-A, *Measurement of Optical Power Loss of Installed Single-Mode Fiber Cable Plant, Adoption of IEC 61280-4-2 edition 2: Fibre-Optic Communications Subsystem Test Procedures – Part 4-2: Installed Cable Plant – Single-Mode Attenuation and Optical Return Loss Measurement*
- ANSI/TIA-526-14-C, *Optical Power Loss Measurements of Installed Multimode Fiber Cable Plant; IEC 61280-4-1 Edition 2, Fibre-Optic Communications Subsystem Test Procedure – Part 4-1: Installed Cable Plant – Multimode Attenuation Measurement*
- ANSI/TIA-568.0-D, *Generic Telecommunications Cabling for Customer Premises*
- ANSI/TIA-568.1-D, *Commercial Building Telecommunications Cabling Standard*
- ANSI/TIA-568-C.2, *Balanced Twisted-Pair Telecommunications Cabling and Components Standard*
- ANSI/TIA-568.3-D, *Optical Fiber Cabling and Components Standard*
- ANSI/TIA-569-D, *Telecommunications Pathways and Spaces*
- ANSI/TIA-606-C, *Administration Standard for Telecommunications Infrastructure*
- ANSI/TIA-607-C, *Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises*
- ANSI/TIA-758-B, *Customer-Owned Outside Plant Telecommunications Infrastructure Standard*
- ANSI/TIA-862-B, *Structured Cabling Infrastructure Standard For Intelligent Building Systems*
- ANSI/TIA-1005-A, *Telecommunications Infrastructure Standard for Industrial Premises*
- ANSI/TIA-1152-A, *Requirements for Field Test Instruments and Measurements for Balanced Twisted-Pair Cabling*
- ANSI/TIA-5017, *Telecommunications Physical Network Security Standard*
- ANSI/TIA-5048, *Automated Infrastructure Management (AIM) Systems – Requirements, Data Exchange and Applications*

4 Definitions, Acronyms, Abbreviations, and Units of Measurement

4.1 Definitions

For the purposes of this document, the following terms and definitions apply. Some terms and definitions may also be represented by an acronym as listed in Section 4.2.

above finished floor	The standard mounting height or vertical distance for a fixture, ceiling, device, or any other object measured from the finished floor surface to the center line of the object as the measurement point.
acceptance test	A test or set of tests performed to demonstrate satisfactory completion of a predetermined task or group of tasks on which acceptance is dependent.
as-built drawing	See *record drawing*
backbone	(1) A facility (e.g., pathway, cable, conductors) between any of the following spaces**:** telecommunications rooms (TRs), common TRs, floor-serving terminals, entrance facilities, equipment rooms, and common equipment rooms (CER). (2) In a data center, a facility (e.g., pathway, cable, conductors) between any of the following spaces**:** entrance rooms or spaces, main distribution areas, intermediate distribution areas, horizontal distribution areas, and TRs.
backbone cabling	See *backbone*.
building automation system	A control system comprised of hardware (e.g., controllers, cabling, input/output devices) and a software application or suite of software applications that automate the electrical and mechanical subsystems.
building management system	A system that provides centralized monitoring of two or more building systems that are typically controlled by a building automation system (BAS). A building management system (BMS) may also provide control functionality of the individual BAS systems.
campus	(1) The buildings and grounds having legal contiguous interconnection (e.g., college, university, industrial park, military installation). (2) A premise containing one or more buildings.
channel	The complete transmission path between two pieces of application-specific equipment.
component	Any part or subassembly of devices used in the construction of a system.
coverage area	The area or space served by a device.
coverage area cable	A cable that is used to connect a building system (e.g., building automation, electronic security) device to a service outlet or horizontal connection point.
cross-connect	A facility enabling the termination of cabling elements and their interconnection or cross-connection.
device	A general term given to the components of a system which perform one or more functions (e.g., detection, measurement, observation), but do not provide system management or complex control functionality.
direct connection	A connection method in which the horizontal cabling supporting a device may directly attach or connect the device through a connectorized cable or hard-wired termination, eliminating the need for an equipment cord and corresponding telecommunications or service outlet.
display	A device that shows images, text, or other content by converting analog or digital signals into visible form.

egress A point or means of exit from a building, property, or location.

equipment cord A length of cable with connectors on both ends used to join active equipment directly to other active equipment or the cabling infrastructure.

equipment outlet A generic term for the outermost connection facility in a hierarchical star topology. An equipment outlet is commonly classified as a telecommunication outlet or a service outlet.

equipment room (telecommunications) An environmentally controlled centralized space for telecommunications and data processing equipment with supporting communications connectivity infrastructure.

electronic safety and security system Systems that utilize analog and digital transmission of data in addition to mechanical or electrical methods to enhance the safety and security of a facility.

fire detection The means of detecting the occurrence of heat, smoke or other particles or products of combustion.

firestop The products, materials and methods used to seal penetrations of a fire resistive barrier that maintains the compartmentation in a building and limits the size and spread of fire and controls the movement of smoke.

gateway An internetworking service used to connect dissimilar applications running on different networks with different telecommunication protocols. Gateways normally operate at one or more of the top four layers of the Open Systems Interconnection (OSI) Reference Model.

horizontal cabling (1) The cabling between and including the telecommunications outlet and connector and the horizontal cross-connect. (2) The cabling between and including the building automation system outlet or the first mechanical termination of the horizontal connection point and the horizontal cross-connect. (3) Within a data center, horizontal cabling is the cabling from the horizontal cross-connect (in the main distribution area or horizontal distribution area) to the outlet in the equipment distribution area or zone distribution area.

horizontal connection point A connection point within horizontal cabling that is placed between the telecommunication room (TR) and equipment outlets or devices supporting intelligent building systems.

horizontal cross-connect A cross-connect of horizontal cabling to other cabling (e.g., backbone cabling, active equipment).

hybrid cable An assembly of two or more cables, of the same or differing types of media, categories designation, etc., covered by one overall sheath.

interoperability The ability of two or more systems to communicate and exchange data, while allowing any of the participating systems to use the exchanged information.

infrared electromagnetic radiation at frequencies just below visible light; i.e., 300 GHz to 430 THz (wavelengths of 1 mm to 700 nm).

intelligent building A term given to a building or premise that utilizes communication technology to integrate building systems, allowing for intersystem coordination that provides an environment which is safer, more comfortable, productive or efficient.

Listed Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction (AHJ), that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states either the equipment, material or services meets appropriate standards or has been tested and found suitable for use in a specified manner.

media (telecommunications) Wire, cable, or conductors used for telecommunications.

media converter — A device that converts from one type of media to another. Typically referring to a hardware device that connects different transmission media (i.e., from balanced twisted-pair to coax or from balanced twisted-pair to optical fiber).

modified permanent link — The permanently installed portion of horizontal cabling, excluding cords (e.g., test, equipment, patch) that supports a direct connection.

modular plug — The insert ("male") element of a telecommunications connector that may be keyed or unkeyed, typically has six or eight contact positions, of which not all the positions need to be equipped with contacts. A modular plug is named for the number of position and contacts it has (e.g., 8P8C for 8 positions, 8 contacts).

NOTE 1**:** The receptacle that a modular plug is inserted into is named a *modular jack*.

NOTE 2: Some specific configurations of a modular plug may be termed as a *registered jack* or *RJ##*. An example is a RJ45, which is equivalent to an 8P8C configuration.

panel — An electrical device consisting of an enclosure, box or surface that may contain switches, dials, displays or meters for controlling or monitoring other electrical devices.

patch panel — A connecting hardware system that facilitates cable termination and cabling administration using patch cords.

pathway (telecommunications) — A facility for the placement of telecommunications cable.

permanent link — The permanently installed portion of horizontal cabling, excluding cords (e.g., test, equipment, patch).

proprietary — A characteristic of a technique, technology, or device which is owned and controlled by a company or other party and is thereby only usable or adaptable as allowed by that party and not deemed to achieve interoperability.

raceway — An enclosed channel of metal or nonmetallic materials designed expressly for holding wires or cables. Raceways include, but are not limited to: rigid metal conduit, rigid nonmetallic conduit, intermediate metal conduit, liquid tight flexible conduit, flexible metallic tubing, flexible metal conduit, electrical nonmetallic tubing, electrical metallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways, wireways, and busways.

NOTE: Cable tray is not considered a type of raceway.

record drawing (as built) — The revised set of drawings submitted by a contractor or other identified party upon completion of a project or a particular job. Record drawings reflect all changes made in the specifications and working drawings during the construction process, and show the exact dimensions, geometry, and location of all elements of the work completed.

service outlet — An outlet that is used to connect a device or equipment to the ICT infrastructure. Service outlets are typically used by building systems and equipment that are not subject to occasional or frequent disconnections and relocations.

supervisory control and data acquisition system — A control system composed of programmable logic controllers (PLCs), data input to the PLCs, custom software, and electrically operated circuit breakers in the distribution gear, that allows automatic operation and monitoring of the electrical system through control panel workstations.

space (telecommunications) — An area whose primary function is to house the installation and termination of telecommunications equipment and cable (e.g., equipment room, telecommunications room, entrance facility).

telecommunications	Any transmission, emission, and reception of information (e.g., symbols, signals, writings, images, sounds) by cable, radio, optical, or other electromagnetic systems.
telecommunications connector	The receptacle and insertion elements which provide a means of aligning, attaching and achieving continuity between the conductors and optical fibers used within telecommunication and information communication and technology (ICT) applications.
telecommunications outlet	An assembly of which consists of a faceplate, body, housing, or supporting bracket, and one or more receptacles or jacks of a telecommunication connector. Telecommunications outlets are typically located to provide ease of connection for communication and data equipment (e.g., computer, phone).
telecommunications room	A telecommunications space that differs from equipment rooms and entrance facilities in that this space is generally considered a floor-serving or tenant-serving (as opposed to building- or campus-serving) space that provides a connection point between backbone and horizontal cabling.
termination	The physical connection of a conductor to connecting hardware.
topology	The physical or logical arrangement of a system.
uninterruptible power supply	A system that provides a continuous supply of power to a load, utilizing stored energy when the normal source of energy is not available or is of unacceptable quality. A UPS will provide power until the stored energy of the system has been depleted, or when the acceptable quality of either an alternative source of power (e.g., generator) or the normal source of power becomes available.
zone cabling	A design methodology that utilizes a connection point centrally located within areas with higher densities of telecommunications outlets and devices being served.

4.2 Acronyms and Abbreviations

Abbreviations and acronyms, other than in common usage, are defined below.

AC	alternating current
AFF	above finished floor
AHJ	authority having jurisdiction
AIM	automated infrastructure management
A/V	audio/visual
AWG	American wire gauge
BAS	building automation system
BIM	building information modeling
BMS	building management system
CATV	community antenna television
DAS	distributed antenna system
DALI	digital addressable lighting interface
DC	direct current
DDC	direct digital control
EF	entrance facility
EMI	electromagnetic interference
EMS	energy management systems
ER	equipment room
ESS	electronic safety and security
HCP	horizontal connection point
HDTV	high definition television
HVAC	heating, ventilation, and air conditioning
I/O	input/output
ICT	information communication and technology
IP	Internet protocol
IR	infrared
LAN	local area network
LCM	lighting control module
LED	light emitting diode
PDS	protected distribution system
PoE	power over Ethernet
PON	passive optical network
RF	radio frequency
RFID	radio frequency identification
RTLS	real time location system
SCADA	supervisory control and data acquisition
SNMP	simple network management protocol
SO	service outlet
TCP/IP	transmission control protocol/internet protocol
TE	telecommunications enclosure
TR	telecommunications room
UPS	uninterruptible power supply
WAN	wide area network
WAP	wireless access point
Wi-Fi	wireless fidelity wireless internet
WLAN	wireless local area network

4.3 Units of Measurement

The units of measurement used in this standard are metric. Approximate conversions from metric to U.S. customary units are provided in parentheses; e.g., 100 millimeters (4 inches).

Units of measurement used in this standard are defined below:

°C	degree Celsius
°F	degree Fahrenheit
A	ampere
ft	foot
ft2	square foot
H	hour
Hz	hertz
in	inch
kVA	kilovolt-ampere
kW	kilowatt
kWh	kilowatt-hour
lbf	pound force
m	meter
m2	square meter
MHz	megahertz
mm	millimeter
N	newton
VAC	volt alternating current
VDC	volt direct current
W	watt

This page intentionally left blank

5 Communications Infrastructure

5.1 Overview

Intelligent building systems may either share the collective set of cabling system components, cabling pathways, and related telecommunications spaces with a traditional voice/data ICT network or use separate dedicated networks operating in parallel. Regardless of the way these systems are deployed, telecommunications cabling infrastructure standards and telecommunications cabling installation best practices should be followed.

The basic elements of the communications infrastructure are the following:

- Topology
- Spaces
  - Equipment room (ER)
  - Telecommunications room (TR)
  - Telecommunications enclosure (TE)
- Cabling
  - Backbone cabling
  - Horizontal cabling
- Cabling pathways
- Telecommunications outlet (TO) or service outlet (SO)
- Coverage areas

This section addresses the best practices for the installation of a telecommunications infrastructure for intelligent building and premises systems to support a wide range of applications.

Telecommunications infrastructure should follow the requirements of telecommunications cabling standards. However, because cabling for many intelligent building devices are often application-specific there will be exceptions that need to be applied to these standards. When applying specific applications to these cabling systems, the user is cautioned to consult existing application standards, regulations, equipment vendors, and system and service suppliers for applicability, limitations, and ancillary requirements.

5.2 Topology

5.2.1 Requirements

The topology for horizontal and backbone cabling shall be a hierarchical star as per applicable standards (e.g., ISO/IEC 11801-6, ANSI/TIA-862-B).

NOTE: See Figure 5-1 for an example of a hierarchical star topology.

5.2.2 Recommendations

Ancillary systems cabling can be configured using additional topologies, such as those shown in Figure 5-2, depending on the application requirements. For example, ancillary systems may require application-specific cabling (e.g., coaxial cabling, two-pair balanced twisted-pair).

5.3 Spaces

5.3.1 Equipment Rooms

5.3.1.1 Introduction

Equipment rooms (ERs) provide connections between main system (headend) equipment and backbone cabling (the main cross-connect). Equipment rooms are considered to be distinct from telecommunications rooms because of the nature or complexity of the equipment they contain.

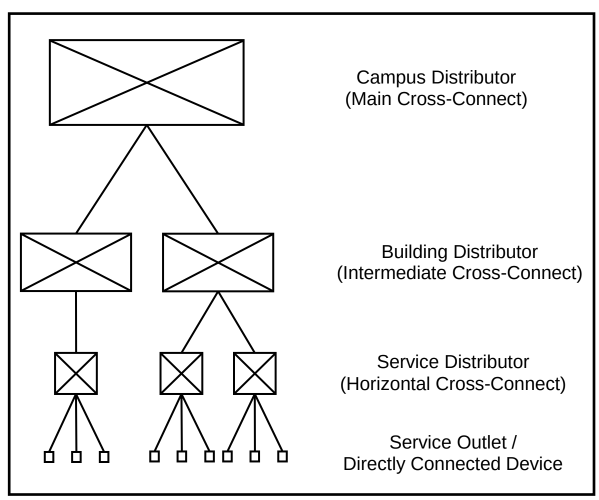


Figure 5-1
Hierarchical Star Topology

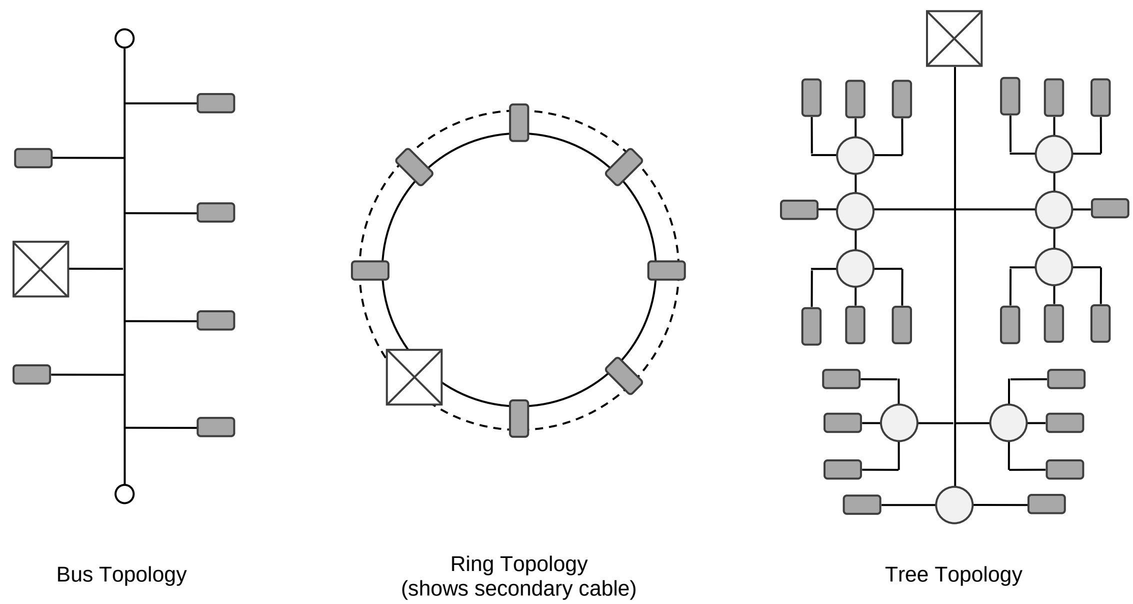


Figure 5-2
Examples of Non-star Topologies

5.3.1.2 Requirements

The design and provisioning of the equipment room shall be in accordance with applicable standards (e.g., ANSI/TIA-569-D, ISO/IEC 14763-2). The ER shall be able to contain telecommunications equipment, cable terminations, and associated cross-connect cabling.

An ER shall be sized and provisioned (e.g., power, lighting, backboards, pathways) to accommodate enough space for all planned equipment, offering suitable access to the equipment for maintenance and administration, including planned growth based on a five to ten year plan.

ERs shall be dedicated to the telecommunications function and related support facilities. Equipment not related to the support of the distributor room (e.g., water pipes, HVAC ductwork, pneumatic tubing) shall not be installed in, pass through, or enter the ER space. The ER shall be located at least 3.6 m (12 ft) from sources of EMI (i.e., elevator equipment, electrical power transformers, two way radio equipment, mechanical pumps and motors). The ER shall not be located in areas subject to flooding or ingress of water.

ERs shall be climate controlled to help assure proper operation of building system equipment. This will require the designer to provide the following information to personnel responsible for the engineering or operation of the applicable mechanical systems (e.g., HVAC) supporting the ER, in order to ensure proper operation:

- Building system equipment power and heat loads
- Building system equipment manufacturer/vendor specified operating temperature and humidity ranges and limits

Where building system equipment is required to share space within an ER or other telecommunications space with components of other building systems, the installation of the building system equipment and support systems shall:

- Comply with the requirements of applicable codes and standards (e.g., NFPA 70, CSA C22.1, BS 7671) for working space around electrical service equipment.
- Be sized appropriately to accommodate future planned and unplanned adds, moves and changes as the project and client requirements demand.
- Be separated from the other equipment in the ER (e.g., on a separate wall or in a separate equipment rack or cabinet). If building system equipment shares wall space or equipment rack or cabinet space, building system equipment shall be clearly labeled as the specific building system (e.g., BAS, EMS) equipment.
- Be designed to incorporate security measures to restrict unauthorized access to the space (e.g., card reader access).

5.3.1.3 Recommendations

The ER is the recommended space to install centralized building system equipment. Additionally, the ER should be located as close as practicable to the center of the area served. It should be located away from exterior walls, loading docks, mail rooms and public corridors.

Where dedicated building system equipment rooms are required, these equipment rooms should be planned to accommodate future expansion on a minimum of one side of the room. Dedicated building system equipment rooms should be located adjacent to flexible space, also known as soft space (e.g., storage spaces, conference rooms, unassigned coverage areas or other spaces not located within the life safety egress path) to allow for future expansion.

Additional space and pathway sizing should be incorporated into the design to accommodate the building system cabling systems. Refer to the BICSI *Telecommunications Distribution Methods Manual* for examples of ER designs.

When multiple ERs are located on the same floor, they should be interconnected by a minimum of one metric designator 78 (trade size 3) conduit or equivalent pathway.

The ER should not be shared with electrical installations other than those for ICT use.

Cross-connect connecting hardware (e.g., patch panels, connecting blocks) intended for use with specific building system equipment that is cross-connected to the backbone connecting hardware should be readily and uniquely identifiable (e.g., labeling and use of a different color than those used for voice and data interconnections or cross-connections).

Each cross-connect jumper or patch cable should be clearly labeled to identify the building system equipment it serves. The recommended color codes for cross-connect fields are shown in Table 5-1.

Table 5-1 Recommended Cross-Connect Color Codes

Color	*Service*
Orange	Demarcation point
Green	Network connections and auxiliary equipment
Purple	Common equipment, private branch exchange and local area networks (LANs), switching and data equipment
White	First level backbone
Gray	Second level backbone
Blue	Horizontal cable to TO or SO
Brown	Interbuilding backbone
Yellow	Misc. – auxiliary, alarms, security, building sensor and ESS devices
Red	Used in some areas for life safety alarm systems

Note: These color codes are aligned with ANSI/TIA-606-C

The equipment contained in an ER may present a specific risk or security concern. The need for and applicable methods of intrusion detection, access control and video surveillance at entrances and exits should be addressed during the electronic safety and security design.

Where equipment racks and cabinets are placed next to each other or assembled into rows, cabinets and racks should be aligned on the front edge and attached. An example of a mixed cabinet and rack layout is shown in Figure 5-3.

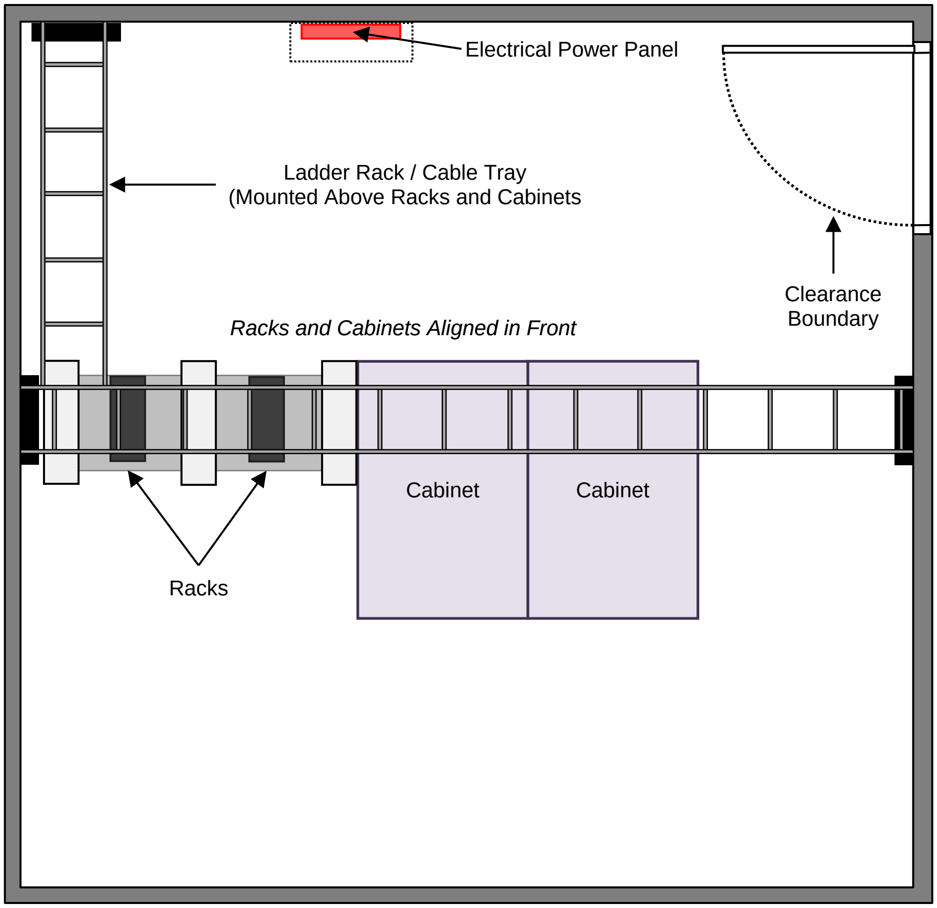


Figure 5-3
Example Layout of a Mixed Cabinet and Rack Row

5.3.2 Telecommunications Rooms and Telecommunications Enclosures

5.3.2.1 Introduction

Telecommunications rooms (TRs) and telecommunications enclosures (TEs) provide connections between backbone cabling and horizontal cabling via the floor distributor (horizontal cross-connect) and contain electronic equipment to support devices in the area served. TRs and TEs are typically environmentally controlled, centralized within the space they serve, and usually contain a floor distributor (horizontal cross-connect). The TR is typically intended to serve the occupants of a floor in a building. Multiple TRs may be deployed in large buildings or multitenant buildings. TEs are typically intended to serve a portion of a floor in a building.

5.3.2.2 Requirements

A TR is a common access point for cabling subsystems and building pathways. The TR shall be sized to contain telecommunications equipment, cable terminations, and associated cross-connect cabling.

TRs and TEs shall be sized and provisioned (e.g., power, lighting, backboards, pathways) to accommodate enough space for all planned equipment, offering suitable access to the equipment for maintenance and administration, including planned growth based on a five to ten year plan. The TR or TE shall be located as close as practicable to the center of the area served.

TRs and TEs shall be dedicated to the telecommunications function and related support facilities. Equipment not related to the support of the distributor room (e.g., water pipes, HVAC ductwork, pneumatic tubing) shall not be installed in, pass through, or enter the TR or TE spaces.

The design and provisioning of the telecommunications room or telecommunications enclosure shall be in accordance to applicable standards (e.g., ANSI/TIA-569-D, ISO/IEC 14763-2). Where building system equipment is required to share space within a TR, TE or other telecommunications space with components of other building systems, the installation of building system equipment and support systems shall:

- Comply with the requirements of applicable codes and standards (e.g., NFPA 70) for working space around electrical service equipment.
- Be sized appropriately to accommodate adds, moves and changes as the project and client requirements demand.
- Be separated from the other equipment in the TR (e.g., on a separate wall or in a separate equipment rack or cabinet). If building system equipment shares wall space or equipment rack or cabinet space, building system equipment shall be clearly labeled as the specific building system (e.g., BAS, EMS) equipment.
- Be designed to incorporate security measures to restrict unauthorized access to the space (e.g., card reader access).

Enclosures shall meet the requirements of Section 5.5.6. Enclosures installed outdoors shall be selected to meet or exceed the environmental conditions for the particular region. Enclosure design and selection shall accommodate the environmental ranges of the equipment to be installed.

TEs that support power and data transmission that are located in limited access spaces (e.g., above suspended ceiling, crawl spaces) shall be located so all enclosure doors or panels may open a minimum of 90 degrees. A working space shall be provided that has a minimum depth of 900 mm (36 in) and a minimum width being the greater value of the 760 mm (30 in) or the width of the equipment. An opening not smaller than 560 mm × 560 mm (22 in × 22 in) shall be provided for TEs above suspended ceilings and an opening not smaller than 560 mm × 760 mm (22 in × 30 in) for TEs located in crawl spaces.

5.3.2.3 Recommendations

The size of the TR should accommodate at least 50 percent more space than a TR intended to serve only voice and data networking applications. Increasing the scale of the TR space allows for future device connections to the network and adding parallel networks if reliability, redundancy, or AHJ requirements change.

Where dedicated building system telecommunications rooms or telecommunications enclosures are required, these rooms should be planned to accommodate future expansion. Planned accommodations should also include the connecting pathways to the TR or TE.

All TRs should have access to two horizontal cabling pathways on a minimum of two walls. Additional space and pathway sizing should be incorporated into the design to accommodate the cabling for all building systems. Refer to the BICSI *Telecommunications Distribution Methods Manual* for example TR and TE designs.

The TR should be located on the same floor as the area served. When multiple TRs or TEs are located on the same floor, they should be interconnected by a minimum of one metric designator 78 (trade size 3) conduit or equivalent pathway.

The TR or TE should not be shared with electrical installations other than those for ICT use.

Cross-connect connecting hardware (e.g., patch panels, connecting blocks) intended for use with specific building system equipment that is cross-connected to the backbone connecting hardware should be readily and uniquely identifiable (e.g., labelling, use of a different color than those used for voice and data interconnections or cross-connections).

Each cross-connect jumper or patch cable should be clearly labeled to identify the building system equipment it serves. The recommended color codes for cross-connect fields are shown in Table 5-1.

5.3.2.4 Example TR Layouts

TRs may be configured differently because of physical dimensions and systems to be supported. Figure 5-4 shows an example of a typical TR that supports a number of building systems. As some TRs have varying personnel access rules or support systems containing private or secured information, Figure 5-5 shows an example of a TR that has two spaces to support additional personnel access requirements in addition to data, communication, and building system support requirements.

NOTE: See Section 5.5.8 for additional information on secure areas.

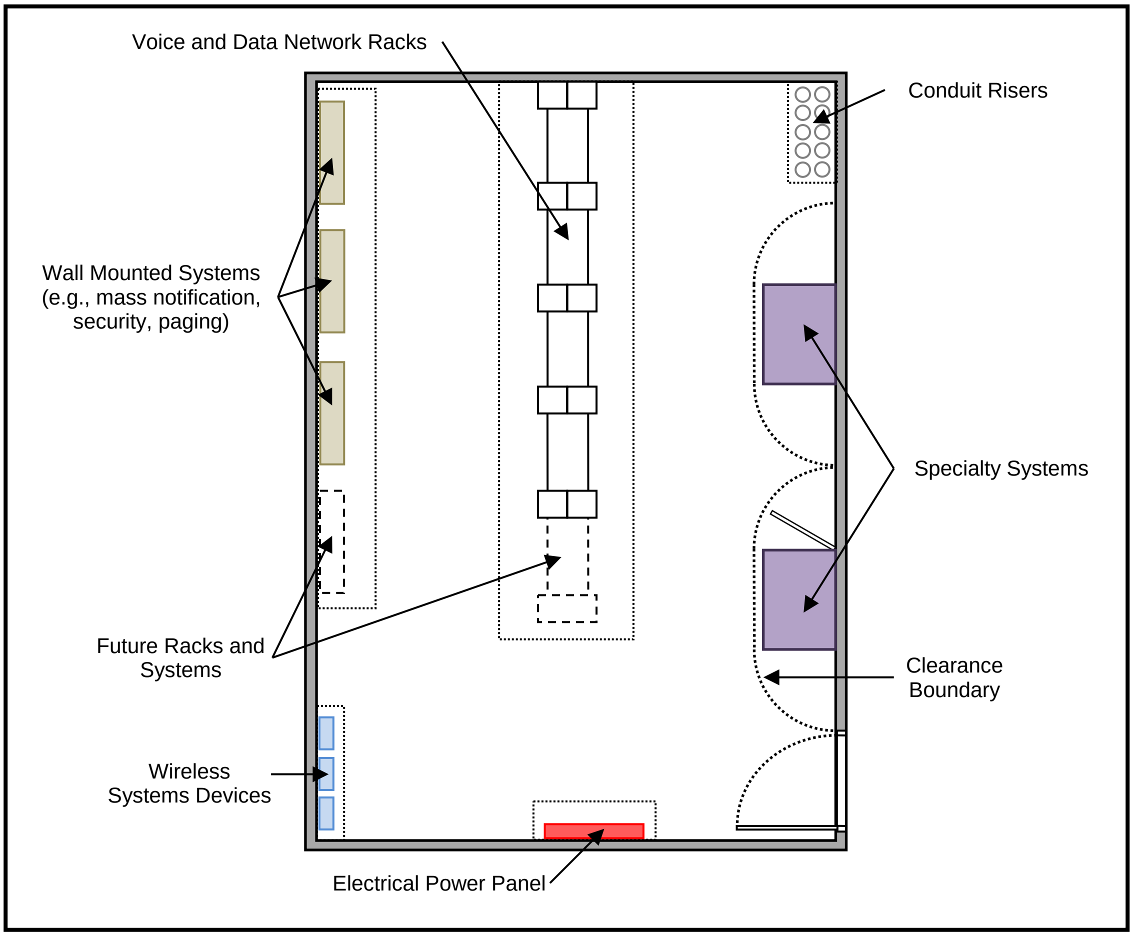


Figure 5-4
Example TR Supporting Multiple Systems

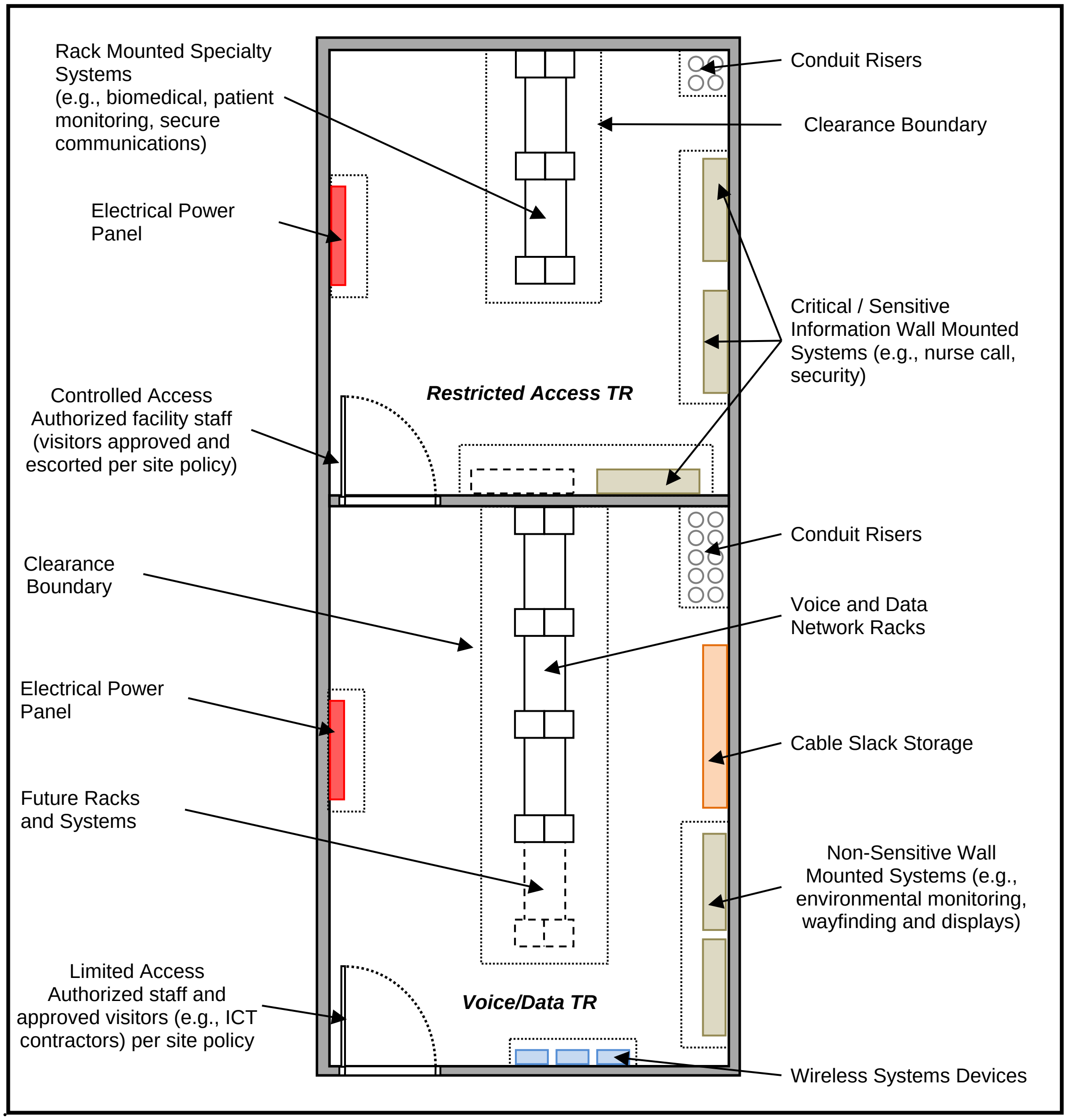


Figure 5-5
Example TR Providing Supporting Restricted Access

5.4 Cabling

5.4.1 Backbone Cabling

5.4.1.1 Introduction

Backbone cabling facilitates interconnections between the telecommunications rooms (TR), equipment rooms (ER) and entrance facilities (EF), whether for one building or a campus. The life span of the backbone is dependent on the service requirement level of the facility and ensuing changes of the telecommunications equipment and applications.

5.4.1.2 Requirements

Recognized cabling shall be as specified in the applicable telecommunications cabling standard being followed (e.g., CENELEC EN 50173-1, ISO/IEC 11801-1, ANSI/TIA-862-B). Backbone cabling installed outdoors in a campus environment shall follow the requirements of ANSI/TIA-758-B.

5.4.1.3 Recommendations.

While building services may share the same backbone as the data and voice network, the applicable AHJ may have requirements restricting or prohibiting this practice.

Designs for backbone cabling should accommodate projected system and application expansion, as well as increases in utilization and bandwidth capacity for a life cycle of at least ten years past the commissioning date.

It may be necessary to use more than one medium in the backbone cabling, depending on the distance and application being supported.

Refer to the BICSI *Outside Plant Design Reference Manual* for additional recommendations and information for campus environments.

5.4.2 Horizontal Cabling

5.4.2.1 Introduction

Horizontal cabling includes the terminations in the TR, the connecting cords and horizontal cabling between the TR or TE and the modular jack of the outlet. Figure 5-6 shows the elements of horizontal cabling for buildings systems.

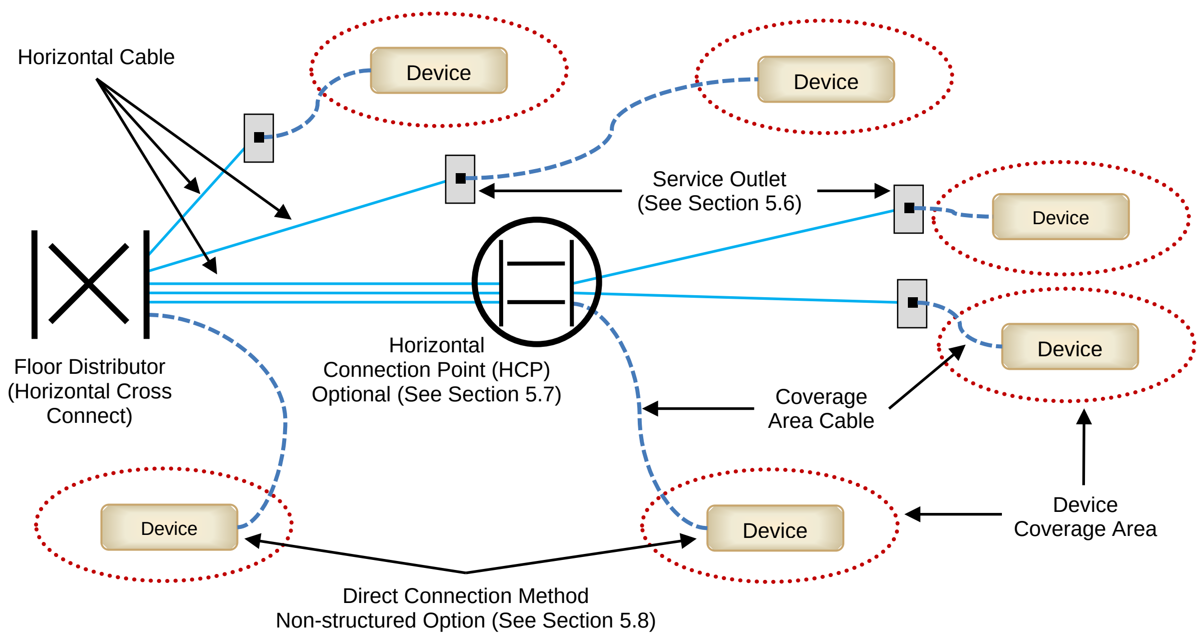


Figure 5-6
Building System Horizontal Cabling Elements within a Star Topology

5.4.2.2 Requirements

For new installations, horizontal cabling supporting intelligent building systems shall follow all applicable standards requirements and recommendations (e.g., ANSI/TIA-862-B, ISO/IEC 11801-6). Table 5-2 provides a summary of minimum and recognized cabling performance of balanced twisted-pair cabling media from TIA and ISO standards. Supported optical fiber cabling media includes OM3, OM4, and OM5 multimode fiber, and all forms of singlemode fiber.

For existing installations of intelligent building systems, the use of non-recognized horizontal cabling shall be allowed if the following conditions are met:

- Use of non-recognized cabling does not violate current Code or AHJ requirements
- The need for cabling is a result from the movement, expansion, or other alterations to an existing system
- The non-recognized cabling meets or exceeds the performance of the existing cabling in use by the specific system (e.g., may not use a Category 3/Class C cable to replace an existing Category 5e/Class D cable)

5.4.2.3 Recommendations

Where Category 6A/Class E_A cabling is not the minimum performance required, Category 6A/Class E_A or higher performing cabling is recommended.

Refer to the BICSI *Outside Plant Design Reference Manual* for additional recommendations and information for horizontal cabling to be installed outdoors.

Layout and selection of horizontal cabling should be planned to incorporate the deployment of numerous building systems – including, but not limited to, building automation, audio/visual, security cameras, access control devices, controller panels, and other specialty applications -- that may utilize the IP network. Some building systems may require cabling other than balanced twisted-pair or optical fiber because of system and application architecture or manufacturer requirements.

Horizontal cabling should be planned to accommodate future equipment needs, which includes transitioning from proprietary systems to IP-based structured cabling, increased system bandwidth requirements, and the need to provide or increase power supplied through communications media.

NOTE: See Section 6.3 for information on combined data and power transmission (e.g., PoE).

Horizontal cabling for intelligent building systems should be tested as part of the building's and premise's structured cabling solution.

5.4.2.4 Hybrid/Composite Optical Fiber and Sheath Sharing

The use of a hybrid or composite optical fiber with copper conductors can be employed for extended distances while offering power at the device end through the copper conductors. Sheath sharing may be restricted based on safety considerations, local codes, manufacturer requirements, regulations and the AHJ. See Section 6.2.4 for further requirements related to conductors used for power delivery within network applications and building systems.

Signals from systems, such as audio circuits (e.g., speakers and emergency sound) and some analog input/output circuits, have sheath-sharing restrictions and may require separate cables for each audio, digital, or analog circuit.

Table 5-2 Horizontal Balanced Twisted-Pair Cabling for Intelligent Buildings Applications

Category / Class	*Frequency Range of Interest*	*Associated Applications*	*Notes*
Category 6 / Class E	1-250 MHz	IEEE transmission protocols up to 1000BASE-T Ethernet	ANSI/TIA-862-B: Minimum performance required ISO/IEC 11801-6: Not recognized
Category 6A / Class E_A	1-500 MHz	IEEE transmission protocols up to 10GBASE-T Ethernet	ANSI/TIA-862-B: Recommended ISO/IEC 11801-6: Minimum performance required
Category 7 / Class F	1-600 MHz	IEEE transmission protocols up to 10GBASE-T Ethernet	TIA standards: Not recognized ISO/IEC11801-6: Recognized
Category 7_A / Class F_A	1-1000 MHz	IEEE transmission protocols up to 10GBASE-T Ethernet	TIA standards: Not recognized ISO/IEC 11801-6: Recognized

NOTE: Category 8 or Class I/II cabling is not recognized by TIA or ISO/IEC standards for use with intelligent building system applications.

5.4.3 Additional Cabling Considerations

Primary decisions for cabling type are often based on manufacturer requirements, signal type, distance and location, power requirement, and longevity of building occupancy.

Optical fiber cable offers many advantages over twisted-pair cable for IP based transmission as it has the ability to transmit higher bandwidth over greater distances. The use of optical fiber is widely used for outdoor applications because of its inherent immunity properties to lightning and other transient electromagnetic phenomena. Single-mode and multimode optical fiber types are recognized as transmission media for many building systems. Often the use of media converters will need to be installed between the end device and optical fiber cable if the device is not equipped with an optical fiber transceiver.

5.5 Cabling Pathways

5.5.1 Overview

There are many types of cabling pathways, which includes:

- Cable tray (e.g., solid bottom, ladder, mesh, center spine)
- Non-continuous pathways (e.g., J-hooks)
- Conduit (e.g., metallic, non-metallic)
- Surface raceway (e.g., metallic, non-metallic)
- Duct (e.g., wall duct, floor duct, trench duct, cellular floor)
- Access floor (also referred to as raised floor, computer room floor)
- In-floor systems such as floor boxes and poke-throughs
- Messenger/strand (e.g., cable suspended from its end points used to attach cabling)

System infrastructure installation varies greatly depending on the risk in each location. Pathways for a commercial business installation may allow for open cabling however pathways for the same equipment in a maximum security prison may require galvanized rigid conduit with malleable iron supports. Even within a given structure pathways may vary by location. For example, the wiring method in general office space may be different than the wiring method in highly secure storage areas.

Additionally, some systems within the same space may require different pathways than others, for example a fire alarm system in a high rise hospital may require conduit while the cabling for digital signage may be installed in cable tray.

5.5.2 Requirements

All applicable codes, standards (e.g., ANSI/TIA-569-D, ISO/IEC 14763-2, EN 50174-2) and requirements of the AHJ shall be met. Additional requirements specific to pathways for building system applications are presented in the following sections.

Each pathway shall be evaluated for risk prior to selecting the means and methods for installing pathway systems.

Systems designers are responsible to select the appropriate pathway infrastructure system design based upon the application(s) to be supported.

The following requirements offer cautionary guidance for the design and installation of cabling infrastructure associated with building system pathways.

- All cabling pathways shall be securely supported and meet applicable seismic requirements for the site.
- Cable ties shall not be used to support cables.
- Exposed raceways shall be installed parallel or perpendicular to the building structure (e.g., walls, ceilings).
- Walls, floors, and ceilings shall be restored to the fire, smoke and acoustical rating that existed prior to penetration using approved materials and methods.
- Penetrations of non-fire rated assemblies shall be filled with noncombustible materials.
- Installation of building system device boxes, enclosures and pull boxes shall be coordinated with other trades (e.g., electrical, mechanical) and finishes (e.g., drywall, tile).
- Cable tray fill ratio shall not exceed 50 percent. The maximum fill depth of any cable tray shall be 150 mm (6 in).

Cabling shall not be placed directly on the ceiling tile or ceiling rails or in any support structure or support system that is not specifically and exclusively designed for the purpose of supporting telecommunications cabling. Non-continuous pathway devices shall not be attached to the ceiling grid support system or any other support system that is not exclusively provided for the purpose of fastening the non-continuous pathway devices.

5.5.3 Recommendations

Non-continuous pathways (e.g., J-hooks) should be installed on a spacing typically between 1 m (3 ft) to 1.5 m (5 ft) centers. Non-continuous pathways should be capable of providing the following features:

- Capability of stacking in series and mounting in back-to-back configurations in various environments (e.g., threaded rod, I-beam, side of wire basket tray, wall, ceiling, floor).
- Option for a wire/cable retention device to help contain wires/cables within the device.
- Rounded edges to help avoid damage to wires/cables placed or pulled through device.
- Above pathways of egress (e.g., doorways, hallways, stairwells) where not already required by the AHJ, it is recommended to use supports that will not structurally fail (e.g., drop cable) during a fire event.

5.5.4 Pathway Separation from Power and EMI Sources

5.5.4.1 Introduction

Co-installation of telecommunications cabling and power cabling is governed by applicable electrical codes for safety. Consult with the AHJ for local compliance.

5.5.4.2 Requirements

The separation guidelines offered by applicable codes, standards and regulations and enforced by the AHJ shall be followed. Several examples of applicable codes and standards that offer separation guidelines include:

- BS 6701, *Telecommunications equipment and telecommunications cabling. Specification for installation, operation and maintenance*
- BS 7671, *Requirements for Electrical Installations. IET Wiring Regulations*
- EN 50174-2, *Information technology – Cabling installation – Part 2: Installation planning and practices inside buildings*
- IEC 60364-5-52, *Electrical installations of buildings – Part 5-52: Selection and erection of electrical equipment – Wiring systems*
- ISO/IEC 11801-1, *Generic cabling for customer premises – Part 1: General requirements*
- NFPA 70®, *National Electrical Code®*
- ANSI/TIA-569-D, *Telecommunications Pathways and Spaces*
- ANSI/TIA-1005-A, *Telecommunications Infrastructure Standard for Industrial Premises*

5.5.4.3 Recommendations

Separation between conductive media and EMI sources should be planned carefully. When specific cabling types or analysis has not been performed, the values listed in Table 5-3 can be used as a guide for unshielded or foil-shielded balanced twisted-pair communication cabling.

Table 5-3 EMI Separation Tables

EMI Source of Disturbance Distances	*Minimum Separation*	*Notes*
Building mounted lamps/luminaires (e.g., fluorescent, neon, mercury vapor)	130 mm (5 in)	The minimum separations may be reduced provided that appropriate cable management systems are used or product suppliers' guarantees are provided
High-intensity discharge lamps, arc welders	130 mm (5 in)	
Frequency induction heating	1000 mm (40 in)	
Transformers over 5 kVA	1200 mm (48in)	----
Radio, television and radar transmitter(s), hospital equipment	*Where product suppliers' guarantees do not exist, analysis shall be performed regarding possible disturbances (e.g., frequency range, harmonics, transients, burst, transmitted power)*	

5.5.5 Pathway Bonding and Grounding

5.5.5.1 Requirements

Pathways utilized for ICT cabling of all building systems shall meet all bonding and grounding requirements of applicable codes, the AHJ, and applicable standards (e.g., ANSI/TIA-607-C, ANSI/NECA/BICSI 607, IEC 60364-4-43, ISO/IEC 30129).

5.5.6 Enclosures, Pull Boxes and Splice Boxes

5.5.6.1 Requirements

The following requirements apply to the design of building system enclosures, pull boxes and splice boxes:

- Pull boxes and splice boxes shall be sized in accordance with applicable codes, standards and regulations.
- Covers for pull boxes larger than 0.5 square meter (5 square feet) shall be hinged.
- If locking boxes are required, key control plan or other access control shall be provided prior to installation.

  NOTE: Use mechanical tamper switches for all points of entry (e.g., doors, side panels) in enclosures and fixtures with covers in high security areas.
- Enclosures exposed to weather shall be corrosion resistant and meet applicable site specifications for resistance to moisture and dust entry.

  NOTE: Refer standards, such as NEMA 250, *Enclosures for Electrical Equipment (1000 Volts Maximum)* and IEC 60529, *Degrees of protection provided by enclosures (IP Code),* for more information concerning moisture and dust ingress ratings of enclosures.
- Penetrations of enclosures shall maintain and not reduce the designated enclosure rating (i.e. IP or NEMA classification)
- Outdoor enclosure penetrations shall be sealed with a sealant approved by the enclosure manufacturer to prevent moisture from entering.

5.5.7 Special Considerations

5.5.7.1 Requirements

- *Seismic requirements* – Codes, regulations and the AHJ may have specific operational parameters that designs shall address and may require or prohibit the use of specific installation methods.
- *Classified and hazardous environments* – Depending on the classification of the environment for hazardous atmospheres, additional measures, such as conduit seals or explosion proof apparatus may be required. Review of codes, regulations and AHJ requirements shall be accomplished to satisfy local requirements.
- *Existing conditions* – Surface mounted raceway, other types of compliant cabling pathways or other accommodations required when installing building system cabling in existing structures with limited or no existing cabling pathways.
- *Healthcare facilities* – Compliance with codes, standards and regulations (e.g., NFPA 99, CSA Z8000) pertaining to healthcare facilities, patient and information privacy, and public access is required.
- *Corrosion/corrosive environments* – All metallic cabling pathways (e.g., conduits, hangers and supports) shall contain corrosion protection or be resistant to corrosion when used in areas within corrosive atmospheres.
- *Wet and damp locations* – When metallic cabling pathways are installed in outdoor and indoor locations that may be considered to be wet or damp, appropriate cabling and metallic cabling pathway types shall be selected for use in these environments.

5.5.7.2 Recommendations

Additional special pathways and spaces considerations include:

- Environmental
  - *EMI* – Electromagnetic interference can disrupt transported signals on metallic media. Shielded cabling or metallic pathways may be employed to reduce the effects of EMI.
- Architectural
  - *Space* – New construction pathways should be coordinated with other trades in new construction. Building information modeling (BIM) should be used for this purpose.

List continues on the next page

  - *Existing conditions* – Surface mounted raceway, other compliant cabling pathways or other accommodations that be required when installing cabling in existing structures with limited or no existing cabling pathways.
  - *Rooftops* – The bottom of cabling pathways should be kept a minimum of 25 mm (1 in) above the surface of the rooftop to avoid significant cable heating. Cabling and pathways within 25 mm (1 in) may be subject to a significant increase in the ambient temperature used in calculations such as cabling ampacity and the minimum cable jacket temperature rating allowed.
  - *Access floors* –A clearance of least 50 mm (2 in) should be provided from the bottom of access floor tiles to the top of installed cable tray and installed cabling in other pathways (e.g., open top supports) to ensure that cables may leave the cable tray or pathway and are not damaged when the access floor tiles are removed and placed.
- Building Function
  - *Security / Sensitive information* – Physical protection of pathways and spaces should be considered to deter or prevent the building system systems from being accessed or compromised by unauthorized personnel.
  - *Places of assembly* – In theaters, carnivals and fairs, because of the presence of large groups of people, AHJ may have design or installation method restrictions so systems do not jeopardize the safety of occupants.
  - *Agricultural buildings* – Special considerations for bonding and grounding may be necessary to protect animals from stray voltages.

5.5.8 Secure Areas

5.5.8.1 Overview

Governments, military organizations, and other entities with critical facilities (e.g., data centers, healthcare, emergency services) handle sensitive and classified material over secure networks, which are located in areas most commonly referred to as secure areas.

Occasionally, telecommunications cabling for secured areas needs to be routed outside of the secured area. (e.g., backbone connection between two physically separated secured areas).

While there are different types of pathways that may be used, allowed pathways for secure area applications are collectively known as protected distribution systems (PDSs). PDSs protect sensitive cabling from unauthorized access outside of secure areas by enclosing the cabling in a sealed raceway or conduit system.

5.5.8.2 Requirements

Where not otherwise specified, cabling containing sensitive or classified information outside of a secure area shall be placed in metallic conduit per applicable standards (e.g., ANSI/TIA-5017).

5.5.8.3 Recommendations

Facilities with defined secure areas will typically have their own set of guidelines for PDS construction. The designer should check with the organization requiring the system for their particular guidelines.

PDSs should be located in common areas where they can be inspected on a regular basis for unauthorized access. Routing a PDS through a locked or seldom used area is not recommended. Refer ANSI/TIA-5017 for other measures that can be taken to improve the physical network security of telecommunications cabling infrastructure.

Within secure areas, the following recommendations are applicable for the design and selection of building system enclosures, pull boxes and splice boxes:

- Enclosures made from metal or similar materials that provide high strength, durability and tamper resistance should be used.
- Where permitted by the AHJ and where damage or degradation to the interior wiring/cabling and components will not occur as a result, “tack” or temporarily weld enclosures and fixture covers that are not needed for maintenance access.
- Use mechanical tamper switches for all points of entry (e.g., doors, side panels) in enclosures and fixtures with covers.
- It may be necessary to consider the use of mechanical (key or combination) or electrical (keypad or card) locksets on enclosures containing equipment in “high security” areas.
- High security access points should be alarmed, monitored by remote cameras, or both.

5.6 Outlets and Connectors

5.6.1 Overview

Outlets and their corresponding connectors provide the ability to easily connect equipment (e.g., computer, phone, security camera, wireless access point) to the ICT cabling system. A common example is a wall mounted connector within an outlet in which a cable or equipment cord for a telephone is inserted.

Outlets can be defined into the following two categories:

- Telecommunications outlet—used primarily in locations where the end device is administered by the user (e.g., computer, phone)
- Service outlet (SO)—connects a "non-telecommunications" device (e.g., door controller, security camera), and its location, media and topology is dependent on the application and location of the service.

Typically a service outlet becomes a part of the building system and is relatively permanent. Figure 5-7 illustrates both telecommunications outlets and service outlets.

From a technical and performance standpoint, the two types of outlets are the same, but only differ in their applications, location, and the person(s) who regularly accesses them. For example, a telecommunications outlet is considered a user-administered work area outlet, where any personnel may connect or detach equipment from outlets that are typically located between 450 mm (18 in) and 1200 mm (48 in) above the finished floor. In contrast, service outlets are frequently located behind the mounted device, at least 2.3 m (7.5 ft) above the finished floor, or otherwise located in a manner which deters access by non-authorized personnel.

5.6.2 Requirements

Telecommunication outlets and service outlets shall meet the testing requirements defined in Section 5.9 of this standard.

5.6.3 Recommendations

For service outlets and telecommunications outlets used for combined power and data (e.g., PoE) applications, an oversized wall box should be used to minimize physical space issues (e.g., cable separation, bend radius).

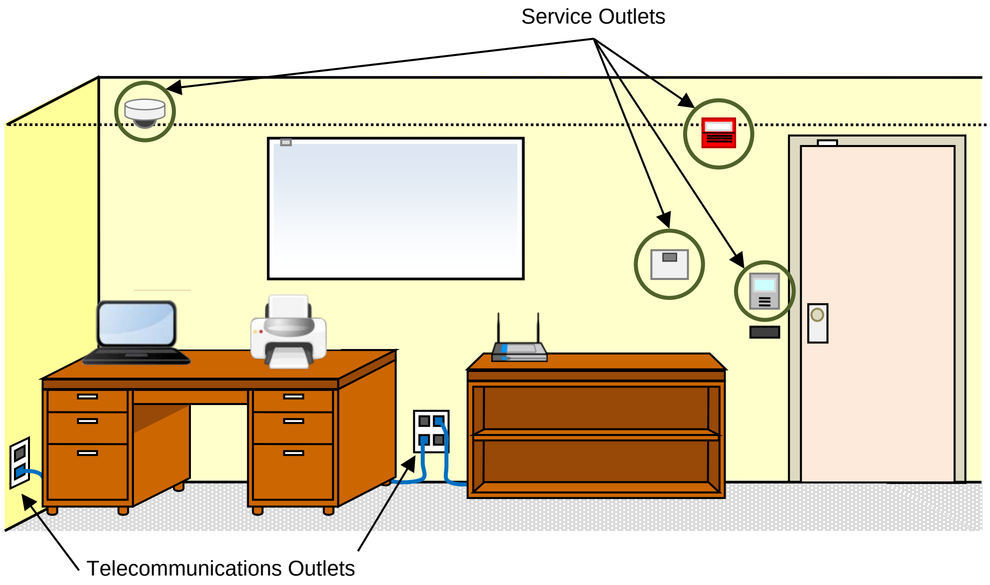


Figure 5-7
Types of Outlets Within a Building

5.7 Horizontal Connection Point (HCP)

NOTE: A service concentration point (SCP), as defined in ISO/IEC ISO11801-6, is analogous to a horizontal connection point. The requirements and recommendations of this section are applicable, except where otherwise noted.

5.7.1 Introduction

An HCP is a connection point within the horizontal cabling between the TR and the corresponding building service outlet or device, and is analogous to the consolidation point used within communication and data networks. HCPs often are the most efficient solution in areas where there is a high density of building system connections.

Figure 5-6 shows an example of an HCP implemented within horizontal cabling. HCPs are commonly used within zone cabling design, as the use of an HCP reduces the length of cable that may need to be pulled or changed as devices are added, moved, or removed. For most building systems, an HCP may be configured as an interconnect (i.e., one patch panel or connecting block) or a cross-connect (i.e., two patch panels or connecting blocks).

Figure 5-8 shows and example of an interconnect HCP mounted inside a ceiling enclosure.

5.7.2 Requirements

No more than one HCP shall be placed in a single cabling subsystem (e.g., horizontal link). Each cable extending from the HCP shall be terminated directly to a service outlet or to the device itself.

Cross-connections are allowed in the HCP. When cross-connections are used at the HCP, a service outlet shall not be installed as part of the horizontal cabling subsystem to ensure the cabling channel serving the building device contains no more than four connection points.

HCPs shall be located in fully accessible, permanent locations such as building columns and permanent walls. HCPs shall not be located in any obstructed area, and shall not be installed in furniture systems unless that unit of furniture is permanently secured to the building structure. If an HCP is installed above a suspended ceiling or other defined environmental spaces (e.g., plenum, riser), the HCP shall conform to applicable space and clearance requirements.

HCPs shall be administered in the same manner as telecommunications cabling, connecting hardware, pathways, and spaces as specified in applicable standards (e.g., ANSI/TIA-606-C, ISO/IEC 14763-2).

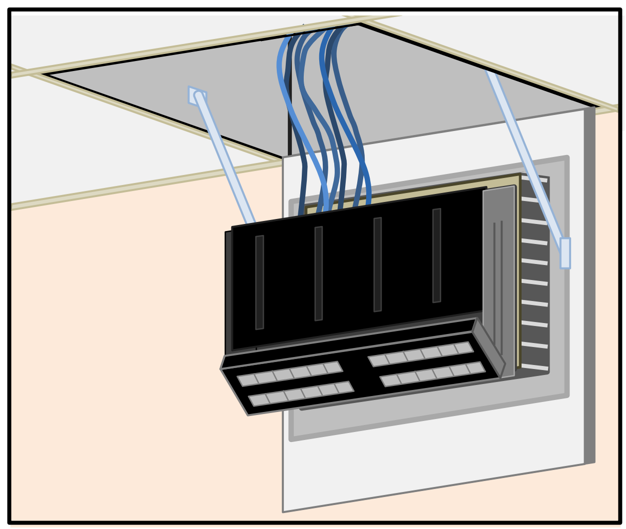


Figure 5-8
Example of an HCP Mounted in a Ceiling Enclosure

5.7.3 Recommendations

HCP design, including location, should be developed in accordance with the security plan of the building.

The HCP should be readily accessible and its location visibly marked allowing for ease of routine maintenance and reconfiguration. For balanced twisted-pair cabling, the HCP should be located at least 15 m (50 ft) from the distributor located in the TR or TE, in order to reduce the effect of multiple connections in close proximity on near end crosstalk (NEXT) loss and return loss.

The use of suspended ceiling space or access floor space for HCPs may be acceptable, provided the space is accessible without moving building fixtures, and it is reasonable to assume such space will continue to be in an open space such as a corridor or hallway. Enclosures for an HCP should be supported independent of the suspended ceiling structure.

When the HCP is configured as an interconnect, the use of a service outlet is optional and a device may be connected with a modified permanent link (See Section 5.8)

The functions of a consolidation point and an HCP can be combined within the same zone box. The number of building system links served by an HCP should not exceed 96.

NOTE: Spare capacity for future expansion should be considered when determining the size of the HCP.

5.8 Direct Connections

5.8.1 Introduction

In applications that extend outside traditional voice and data applications (telecommunications), there are circumstances that do not allow a jack-to-outlet scenario on the device end, because of safety, security or other concerns. Standards, such as ANSI/BICSI 005, recognize these circumstances and allow for the horizontal cable to directly connect to a device. This method creates a modified permanent link and is shown in Figure 5-9.

5.8.2 Recommendations

The direct connect method can be used in the following scenarios:

- In plenum spaces where an outlet or patch cord are not rated plenum and therefore is not feasible
- Where there is no room for a workstation outlet or patch cord
- Where it is not safe or secure for an exposed outlet or patch cord
- When the customer deems it is not aesthetical with the design of the facility
- When the building system cable is enclosed in conduit and is directly attached to the building system equipment

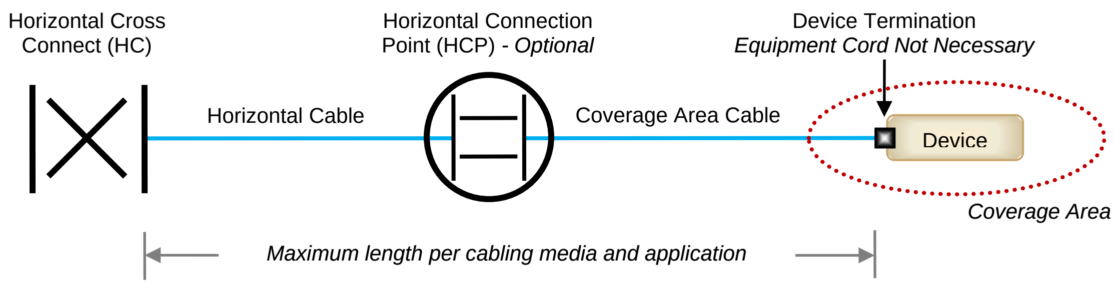


Figure 5-9
Example of Facility Connections Using a Direct Connect Method

Direct connections should be limited to devices in fixed locations that are not expected to be replaced, or that are required to be directly connected by the AHJ.

Direct connections should not be used with devices which may cause mechanical failure of the cable. Source of mechanical failure include repetitious motion, significant changes of speed or direction of motion, and connection locations on the device that require placement of cabling in a smaller than allowed bending radius.

When balanced twisted-pair cabling for direct connections is used, cabling with solid conductors and connectors designed for terminating solid conductors should be used.

5.9 Cabling Installation Requirements

5.9.1 Overview

This section applies to the installation of all forms of recognized cable and connecting hardware for telecommunications applications including:

- Optical fiber cabling
- Balanced twisted-pair cabling
- Coaxial cabling

5.9.1.1 Requirements

Cabling installation shall conform to applicable standards (e.g., ANSI/TIA-568-D Series, ISO/IEC 11801-1).

5.9.1.2 Recommendations

Cabling installation should conform to global best practices (e.g., BICSI *Information Technology Systems Installation Methods Manual*).

5.9.2 Bonding and Grounding Considerations

5.9.2.1 Requirements

Bonding and grounding shall meet the requirements and practices of the AHJ. In addition, the building telecommunications bonding and grounding system shall conform to applicable standards (e.g., ANSI/TIA-607-C, ANSI/NECA/BICSI 607, ISO/IEC 30129) requirements. Adherence to cable manufacturers' bonding and grounding requirements shall be followed when installing shielded cabling systems.

5.9.3 Transmission Performance Field Testing

5.9.3.1 Introduction

Field testing of installed cabling is typically conducted after balanced twisted-pair and optical fiber cabling links are installed. These cabling links may be pre-terminated or field terminated.

5.9.3.1.1 Requirements

Installed cabling shall be tested according to the cabling manufacturer's or project's testing plan to verify the installed cabling performance meets the requirements of applicable standards (e.g., ANSI/TIA-568.2-D, ANSI/TIA-568.3-D, ISO/IEC 11801-1).

Field test instruments used to test installed cabling shall meet the requirements of applicable standards (e.g., ANSI/TIA-1152-A, ANSI/TIA-526-7-A, ANSI/TIA-526-14-C). Test instrument documentation shall include certification of calibration performed to manufacturer's requirements as well as the date and time of the tester's current calibration.

5.9.3.1.2 Recommendations

All installed cabling (e.g., balanced twisted-pair, optical fiber, coaxial cabling) should be measured with the appropriate field-test instrument, in accordance with applicable standards. Testing of the permanent link in the horizontal cabling should be performed using permanent link requirements from the first connection at the horizontal cross-connect (floor distributor) to the service outlet, or the HCP if a service outlet is not present).

For testing a direct connection, either of the following two configurations may be used, as applicable.

Configuration 1 – Single connector modified permanent link set up for direct connection without HCP

A fixed length of horizontal cabling terminated to a randomly selected port of the near end patch panel and an eight position modular plug on the work area/device far end. The field-test instrument shall be fitted with the permanent link adapter on the near end and a channel adapter on the work area plug far end. (See Figure 5-10).

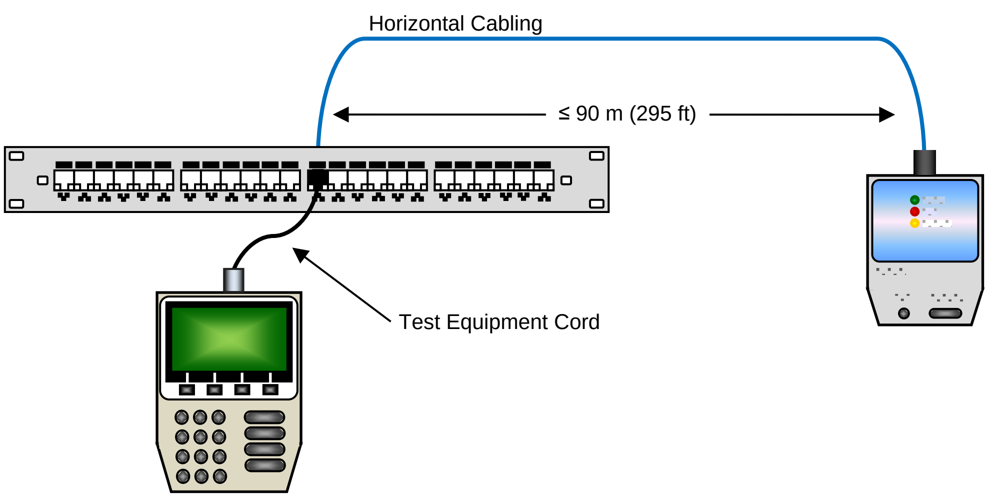


Figure 5-10
Configuration 1: Single Connector Modified Permanent Link Set Up for Direct Connect Without an HCP

Configuration 2 – Single connector modified permanent link set up for direct connection with HCP

A fixed length of horizontal cabling terminated to a randomly selected port of the near end patch panel with an HCP in close proximity to an eight position modular plug on the work area/device far end. The field-test instrument shall be fitted with the permanent link adapter on the near end and a channel adapter on the work area plug far end. (See Figure 5-11)

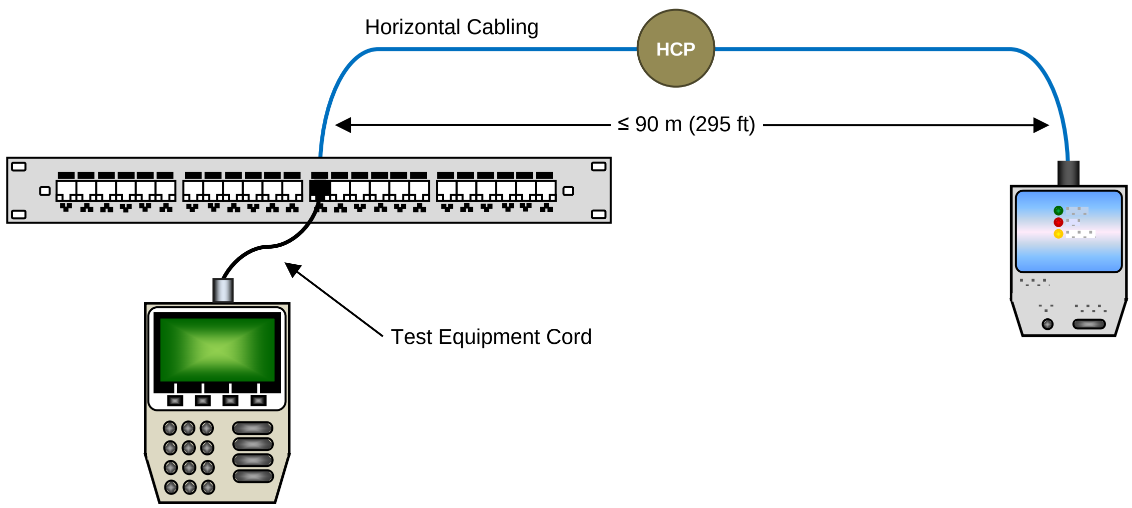


Figure 5-11
Configuration 2: Single Connector Modified Permanent Link Set Up for Direct Connect to a Service Outlet With an HCP

5.10 Administration

5.10.1 Requirements

Since building systems directly support many applications, administration is required. All applicable cabling, connectivity administration, and automated infrastructure management (AIM) systems shall comply with applicable administration standards (e.g., ANSI/TIA-606-C, ANSI/TIA-5048, ISO/IEC 14763-2, ISO/IEC 18598, EN 50174-1).

All applicable documentation, including accurate drawings (e.g., record), applicable to the work performed shall be provided by the installer upon work completion.

Building information management (BIM) documents created for the telecommunications systems shall comply with the requirements of ANSI/BICSI 003.

5.10.2 Recommendations

IDC blocks and patch panels used by a building system should be clearly identified for the particular service or system.

The use of automated infrastructure management systems should be considered for those portions of the network including:

- Work area outlets
- Service outlets
- Patch panel ports
- Patch cords
- Horizontal cabling
- Coverage area connectivity (outlet and equipment cords, if installed)
- Backbone cabling

5.11 Other Transmission Architectures

5.11.1 Wireless

5.11.1.1 Requirements

Cabling infrastructure used for wireless transmission within building devices shall conform to all requirements of Section 5.

Any distributed antenna system (DAS) used within a building system application shall conform to ANSI/BICSI 006. DASs shall also conform to the requirements of the AHJ, codes, and standards for the particular application (e.g., emergency mass notification, public responder) being served.

5.11.2 Passive Optical Networks

5.11.2.1 Overview

A passive optical network (PON) implements a point-to-multipoint architecture (i.e., tree topology), in which an unpowered splitter is used to enable a single optical fiber to serve multiple end-points. A PON consists of an optical line terminal (OLT) at the source or transmission and one or more optical network units (ONUs) or Optical Network Terminals (ONTs) located near the area to be served. An ONT will typically have from 2 to 24 ports, most commonly configured for the modular connector of balanced twisted-pair cabling.

5.11.2.2 Requirements

Cabling infrastructure used for PON shall follow all applicable requirements of Section 5.

5.11.2.3 Additional Information

PON architecture may not be suitable for all applications. However, PON architecture, because of its use of optical fiber and tree topology, may be an acceptable method when designing systems:

- Supporting building applications over long distances
- Within areas with increased levels of EMI/RFI
- Where existing pathways and spaces do not have the capacity for additional cabling.
- Where the number of devices/connections is not distributed evenly around the TR (e.g., sleeping room levels of a hotel)

5.12 General Site Conditions

Care should be taken to insure proper conditions are available and maintained. A clean, dust-free, maintained environment is critical. Such conditions should be coordinated well in advance and included as a line item on the construction schedule.

This page intentionally left blank

6 Design Considerations for Building Systems

6.1 Zone Cabling

6.1.1 Overview

Zone cabling supports a wide range of sensors, control panels, and detectors for lighting, security, and other building communications, such as wireless access points for WLANs. A zone cabling design consists of horizontal cables run from the telecommunications room (TR) to a horizontal connection point (HCP) that is typically housed in an enclosure located in the ceiling space, on the wall, or below an access floor. From the connection point, cabling is run to service outlets (SOs) for connections to devices. The use of zone cabling provides a flexible infrastructure to accommodate current and future data, voice, building devices, and wireless access points.

6.1.2 Service Outlet Coverage Areas

Like the building system device that may be connected to it, a service outlet can also be said to have a coverage area. The use of a uniform service outlet coverage shape, typically square or hexagonal, can approximate the typical circular coverage patterns of the device it supports, while ensuring that a given area is covered without gaps. See Figure 6-1 for examples of both coverage area shapes.

As different building systems often have devices in close proximity, the service outlet in the middle of a coverage area may represent one, two, or more service outlets. The use of an SO coverage area also allows the design process to move forward while the expected placement of the devices is determined.

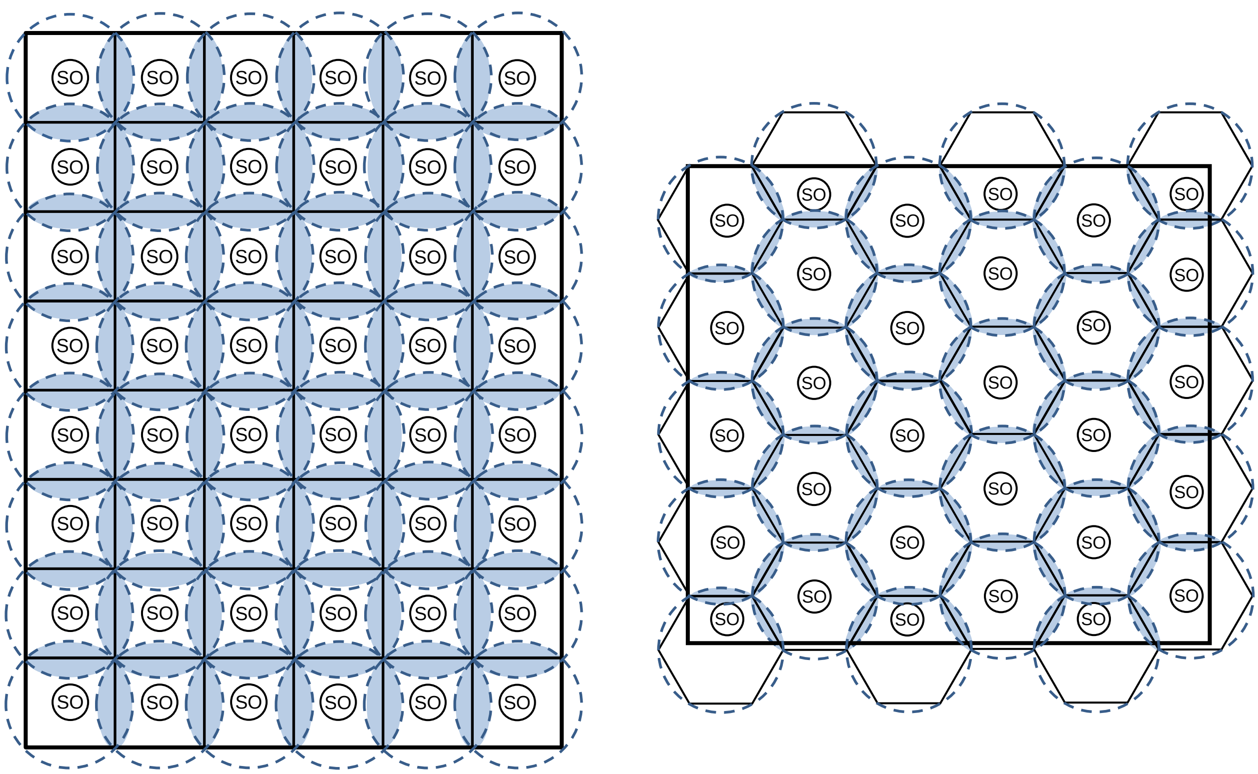


Figure 6-1
Example of Grid and Hexagonal SO Coverage Area Patterns with Circular Device Coverage Areas Shown

The size of a SO coverage area can vary, depending on the device coverage areas expected to be supported. However, as WAPs may be supported by zone cabling in addition to building system devices, the radius of the SO coverage area should not exceed 13 m (43 ft), which is equivalent to the following shape dimensions:

- Square - not to exceed 18.4 m (60 ft) length or width
- Hexagonal – not to exceed 22.5 m (75 ft) length by 19.5 m (65 ft) width.

Where possible, the number of partial SO coverage areas should be minimized

6.1.3 Service Outlet Coverage Area Zones

For SO coverage areas within 17 m (50 ft) of a TR, a connection point is not required, as cabling may be routed directly from the TR. For SO coverage areas further than 17 m (50 ft), the use of a HCP is recommended to consolidate cabling from the TR to near the SO coverage area. When HCPs are used, a HCP can typically serve 4-5 SO coverage areas, which creates a zone. Figure 6-2 illustrates both a grid and hexagonal pattern divided into zones with HCPs and service outlets shown.

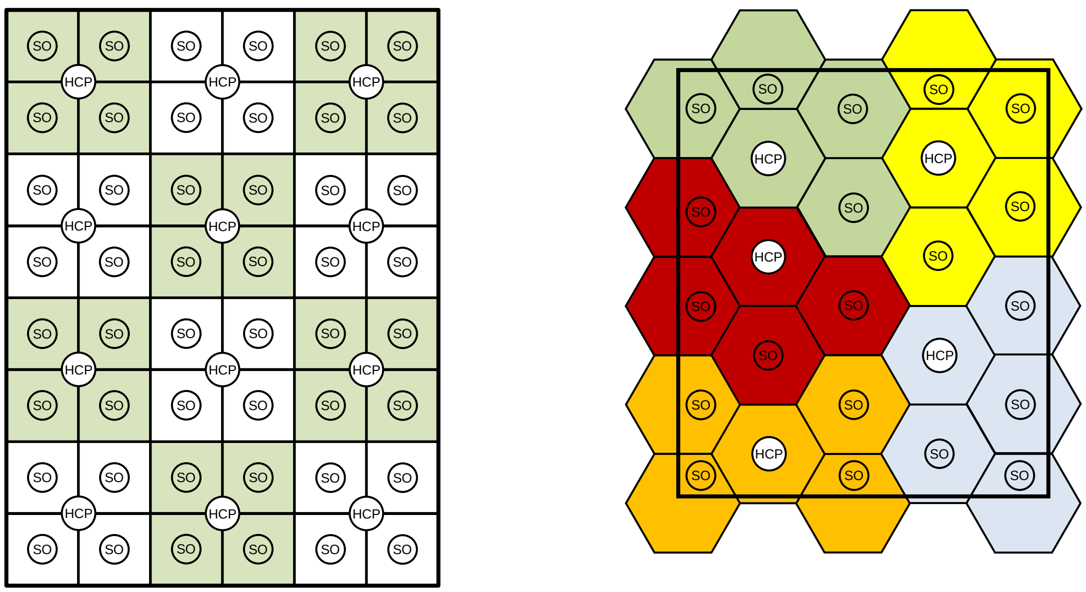


Figure 6-2
Example of Grid and Hexagonal Pattern Coverage Area Zones

The total number of SO coverage areas that can be served by a connection point is dependent on the number of devices that will be served. For example, in areas with a limited number of devices or for connection points dedicated to one type of device (e.g., WAPs), a connection point may be able to serve up to seven or eight coverage areas.

6.1.4 Device Density

For initial planning purposes, a sufficient number of cabling links should be provided for building systems, distributed across the floor space. ISO/IEC 11801-6 and ANSI/TIA-862-B provide information on typical building device density for various floor spaces and are presented in Table 6-1. The table provides the expected minimum number of device connections, as well as the recommended of connections to accommodate present and future services based on an allowance of 25 percent spare port capacity.

The size of the zone area should be decreased if more than 96 outlets are required at the connection point to support initial and projected device connections over a ten year period.

Table 6-1 Typical Building Device Density

Use of Floor Space	*Coverage Area Per Building Device*	*Number of Connections in the Connection Point Required per 2000 m^2 (21,500 ft^2) in a Hexagon Pattern(1)*		*Number of Connections in the Connection Point Required per 1400 m^2 (15,000 ft^2) in a Grid Pattern (2)*	
		Minimum	*Recommended*	*Minimum*	*Recommended*
Office, Retail, Classroom, Data Center, Hospital (3), Hotel, or Indoor Parking (4)	25 m^2 (270 ft^2)	80	96	56	72
Manufacturing	50 m^2 (540 ft^2)	40	48	28	36

Note 1: Each connection point is assumed to support four to five 425 m^2 (4575 ft^2) hexagon shaped coverage areas for a total maximum usable space of 2000 m^2 (21,500 ft^2).
Note 2: Each connection point is assumed to support four 350 m^2 (3775 ft^2) square shaped coverage areas for a total of 1400 m^2 (15,000 ft^2)
Note 3: Average value provided. The function of a specific space within a hospital may significantly change coverage area size and number of connection points required.
Note 4: ANSI/TIA-862-B provides an estimated coverage area per building device of 50 m^2 (550 ft^2) for indoor parking applications.

6.1.5 Device Connections

Each coverage area may have multiple SOs and direct connections from connection points to building devices. SOs in ceiling spaces are typically housed in outlet boxes, with outlet boxes typically having 2 – 6 ports or jacks.

6.1.5.1 Requirements

SOs and outlet boxes shall be Listed for the environment they are placed (e.g., plenum). A minimum of one permanent link connection is required to each building device. HCPs, if used, shall be Listed for the environment placed or placed in a suitable enclosure.

6.1.5.2 Recommendations

When devices are located in non-temperature controlled spaces, solid conductor cabling should be used. If stranded conductor cabling is used, cabling between the SO or HCP to the device should not exceed 5 m (16 ft).

For WAPs, in addition to the items listed for building devices, a minimum of two permanent link connections to each IEEE 802.11ac capable WAP is recommended to support link aggregation.

6.2 Electrical Power

6.2.1 Overview

The telecommunications industry has traditionally used DC to power communications equipment. With a DC-powered system, it is not necessary to invert the battery voltage to the load (change to AC) when batteries are used as an emergency or reserve power medium.

6.2.2 Power Supply Units

6.2.2.1 Overview

Power supply units typically convert the commercial AC power supply to DC operating voltages. DC voltages range from 12 to 48 V_{DC} for carrier modulation and 5 to 12 V_{DC} for circuit board logic voltage.

6.2.2.2 Requirements

If the equipment is operating from the power supply directly without using batteries, both the positive and negative leads to the supply shall be fused with the proper fuse size. This will prevent the equipment from becoming the return path for the system ground should the main ground fail.

If using a rectifier system to charge the batteries as well as operate equipment, the system shall be sized to fully charge batteries within 24 hours while allowing operation of equipment during charging.

NOTE: The charging system also should be able to equalize the battery system to extend the battery system life. The charge current is normally 1/10 of the capacity of the battery.

If using a battery and rectifier system, a DC distribution system with a low-voltage disconnect shall be included as part of the designed system. A low-voltage disconnect will prevent damage to the equipment or battery system by disconnecting the load either fully or in stages from the batteries to prevent the batteries from being fully discharged or damaged.

6.2.2.3 Recommendations

A designer should take into account the power requirements of all the equipment involved. This may entail uninterruptible power supply (UPS) systems that will generate 120/240 V_{AC} at 50/60 Hz, battery rectifiers that will operate the equipment as well as recharge the battery banks after a power failure, and wind and solar power generation systems for remote areas. Power requirements for equipment located outside of the equipment room (e.g., amplifiers used within distributed antenna systems) should also be included.

6.2.3 Uninterruptible Power Supplies

6.2.3.1 Overview

While there are different types of UPS systems, a static UPS is commonly used within ICT and building systems. A static UPS unit is a solid-state device designed to protect critical loads from most types of power fluctuations. There are three primary types of static UPS units, as listed below.

- Offline or Standby UPS Units
  Offline or passive standby UPS units are devices that power the load directly from the utility and only provide backup power when the utility power goes below preset tolerances. Offline or passive standby UPS units provide limited line conditioning and often have transfer times that exceed system tolerances. It is not recommended that standby power systems be used to support critical communications loads.
- Line-Interactive UPS Units
  Line-interactive UPS units are basically offline UPS units with line conditioning included. Electronic or magnetic energy storage is used to sustain the load during transfer to the inverter.
  These units work well in most circumstances, but they have the following limitations:
  - There is no frequency regulation.
  - Battery reserve time and recharge time may be limited.
  - May not be suitable for use with some generators.
  - The isolation of power source to load in a line-interactive UPS unit is less than that available with an online double conversion UPS unit.
- Online Double-Conversion Uninterruptible Power Supply UPS Units
  Online double-conversion UPS units completely rectify the ac line from ac to dc and use this dc to both charge the battery and power a dc to 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 battery.

  Online double-conversion UPS units exist in different designs. For ICT and building systems utilizing the data network for power (e.g., PoE), the online double-conversion UPS system is the most frequently used.

6.2.3.2 Requirements

For the UPS requirements of the equipment needed, determine the full load power required in both watts and volt/amps. Determine how long the UPS should support the required load as well as any future growth.

Refer to local codes regarding the potential need to de-energize equipment connected to UPS’s when water/fire suppression systems are activated.

6.2.3.3 Recommendations

For critical systems, both standby power (e.g., emergency generator) as well as short-term battery backup should be planned and provided. This allows equipment to be minimally affected by power fluctuations during short outages. If it is a longer duration outage, the standby power source will power the system for a limited time until facilities can be restored.

There may be advantages to providing an UPS system to supply power to all building systems, rather than specifying individual UPS units for each building system. UPS systems utilizing single-module UPS units are the easiest systems to design. However, if the critical load is large or if a high level of redundancy or reliability is required, multiple UPS units, operating in parallel, may be necessary. Refer to standards, such as ANSI/BICSI 002, for recommendations when designing parallel UPS systems.

6.2.3.4 Additional Information

An important item to include within design considerations is when the power goes out, unless the entire facility is on a backup generator, the air-conditioning system will no longer operate. In most facilities, the room air temperature will quickly rise to unsafe levels for both the equipment and personnel. While some configurations allow fans to continue functioning to slow the rate of heat increase, the power to run the fans will also be coming from the UPS system.

6.2.4 Electrical Conductors

6.2.4.1 Requirements

Sizing and other requirements applicable to electrical conductors for powering building systems shall comply with applicable codes and AHJs.

Do not use communication cabling media (e.g., Category/Class balanced twisted-pair) as a substitute for one or two pair wire for transmitting electrical power, unless explicitly allowed by applicable codes and the AHJ.

It is important the designer size the copper conductors for power to the load of the equipment and the overall length of the conductors to determine voltage loss. For the equipment to operate properly, the supplied voltage must be within the manufacturer's recommended range.

6.2.4.2 Recommendations

Increasing the wire size of the conductors is one method to overcome voltage loss because of the length of the conductors.

6.3 Simultaneous Data and Power Transmission

6.3.1 Introduction

Power over Ethernet (PoE) and other practices (e.g., HDBaseT) allow the transmission of DC power and data simultaneously over balanced-twisted pair and other forms of communication cabling.

NOTE: When hybrid copper/optical fiber cabling is used to support data and power transmission, only the data signal is transmitted over the optical fiber strands. Power is supplied through integrated conductors within the cabling sheath.

There are several variations of PoE, noted as Types. Each successive type allows for an increase in power that may be transmitted while being backwards compatible. HDBaseT currently has two levels of specification, but both share identical power profiles. PoE types and HDBaseT are summarized in Table 6-2.

Table 6-2 PoE and HDBaseT Power Specifications

Transmission Method	*Power at Source (W)*	*Maximum Current per Conductor (A)*	*Notes*
PoE Type 1	15.40	0.175	IEEE 802.3af, uses two pairs to transmit power
PoE + Type 2	30	0.3	IEEE 802.3at, uses two pairs to transmit power
PoE ++ Type 3	60	0.3	IEEE 802.3bt, uses all pairs to transmit power
PoE ++ Type 4	100	0.5	IEEE 802.3bt, uses all pairs to transmit power
HDBaseT	100	0.5	HDBaseT 1.0 and HDBaseT 2.0 have the same power specifications. Also known as POH (power over HDBaseT)

6.3.2 Power Injectors

Power injectors are used to provide, maintain or increase power available to the panel, appliance or device that receives its power from the data cabling. For short distances or low levels of required power, power injectors may not be necessary. As the power required for the building systems, the size or distances supported increases, the need for power injectors also increases.

Power injectors are available for all common communication media, the most common type accommodating balanced twisted-pair cabling used with applicable IEEE 802.3 PoE specifications.

6.3.2.1 Requirements

Power injectors shall be Listed for the purpose and AHJ requirements. Power injectors shall be implemented and installed in a manner meeting meet applicable codes and requirements of the AHJ(s).

CAUTION: The use of unlisted or non-compliant equipment may provide higher than standardized power levels, causing a cable's temperatures to be in excess of the maximum cable jacket temperature. Overheating the cable beyond its temperature rating may affect the ability of the cable to transmit data, result in violation(s) of applicable Codes, permanently alter or damage the cable, or create a safety hazard.

6.3.2.2 Recommendations

Power injectors should be installed as close as possible to the receiving equipment or device to minimize power loss and heating of the cabling.

For systems implemented external to a building:

- Power injectors supporting these systems should be installed within an enclosure.
- Lightning or other surge protection should be considered where not required by the AHJ.
- Implemented surge suppressors should not attenuate the DC voltage powering the remotely mounted unit or affect network signals passing through it.

6.3.3 Cabling and Installation

6.3.3.1 Requirements

Cabling implementations that support data and power transmission shall conform to the requirements of local codes, national codes (e.g., NFPA 70), regulations and the AHJ, both for the premises and the application being served.

For both new and existing installations of systems utilizing simultaneous data and power transmission, the cabling requirements of Section 5.4.2 apply. Additionally, for existing installations that meet the conditions for the use of non-recognized cabling, any non-recognized cabling to be installed shall have conductors with a minimum size of 0.205 mm^2 (24 AWG).

6.3.3.2 Recommendations

Equipment cords and coverage area cables used for data and power transmission should have conductors with a minimum size of 0.205 mm^2 (24 AWG).

PoE Type 3, PoE Type 4, HDBaseT and other data and power methods capable of supporting a minimum of 5GBase-T transmission should use cabling containing solid conductors.

For new installations, consider using cabling with 0.326 mm^2 (22 AWG) conductors if:

- The specific building system (e.g., audio systems, video displays) is expected to require power exceeding 50W during the life cycle of the building
- Future flexibility is desired in the types of systems that could be supported.

NOTE: General trends within intelligent building systems include the continued integration of multiple functions within one device (e.g., LED light with integrated environment sensors, IP audio speaker, and wireless access point) and increases power and data bandwidth requirements.

6.3.3.3 Cabling Bundles

When power is applied to twisted-pair cabling, the temperature of the cabling will rise slightly because of resistive heat generation in the conductors. The level of temperature rise will increase when cables are bundled. The electrical performance of the cable will also degrade slightly because of the temperature rise. The level of temperature rise can also be affected by the construction of the cabling and pathway type.

Depending on the amount of power per conductor and the other factors listed above, it is possible for cables within the center of the bundle to exceed the Listed temperature on the cable jacket. While many AHJs prohibit installation methods that cause a single cable's jacket temperature to be exceeded, some AHJs have also enacted limits on the number of cables contained within a bundle, to further decrease the possibility of excess cable temperature.

The operating temperature of cabling should not exceed 60 °C (140 °F), regardless of the cable jacket rating. Documents such as TIA TSB-184-A and ISO/IEC TS 29125 provide additional information about cable bundle sizes and their effect on operating temperature.

6.4 Device Mounting Heights

6.4.1 Requirements

Mounting heights shall conform to applicable codes and standards as applied by the AHJ. The following criteria shall apply:

- Special accommodations provided for the occupants of the facility shall be incorporated into the specifications and installations of device mounting heights.
- Codes may determine minimum and maximum mounting heights.
- Code and manufacturer specific coverage area requirements of selected devices shall be considered when placing ceiling mounted devices.

Installation of building system device boxes shall be coordinated with other device trades (e.g., electrical, mechanical) and finishes (e.g., drywall, tile).

6.4.2 Recommendations

Codes may only provide minimum and maximum mounting height. When mounting heights are not specified, convenience of users should be considered when determining mounting height including users with disabilities.

General guidelines include:

- Wall mounted socket outlets should be located between 450 mm (18 in) and 1200 mm (48 in) AFF with a preference for the lower end of the range
- Switches for permanently wired appliances should be located between 400 mm (16 in) and 1200 mm (48 in) AFF unless needed at a higher level for particular appliances
- All switches and controls that require precise hand movements should be located between 750 mm (30 in) and 1200 mm (48 in) AFF

Typical examples of mounting heights include:

- Fire alarm pull station – Not less than 1.1 m (3.5 ft) and not more than 1.2 m (4 ft) above finished floor (AFF)
- Fire alarm horn/strobe – Not less than 2 m (6.5 ft) and not greater than 2.4 m (8 ft) AFF.
- Intercom – 1.2 m (4 ft) AFF
- Nurse call stations – 1.2 m (4 ft) AFF
- Buzzers or bells – 2 m (6.5 ft) AFF or 150 mm (6 in) below ceiling
- Clocks – 2.4 m (8 ft) AFF or 150 mm (6 in) below ceiling
- Access control card/badge reader – 1 m (3.3 ft) AFF

Clients may provide specifications for mounting heights that differ from the typical examples offered above.

NOTE: For systems used with fire, life and safety application, professional designers or engineers specific to these systems should be consulted to help assure compliance with applicable regulations and requirements.

6.5 Special Building Areas

6.5.1 Water and Wet Areas Requirements

In facilities with systems and devices located within water and wet areas, designers shall consult with the applicable electrical and building codes, as well as all AHJs.

Requirements and restrictions may vary greatly between regions and nations. For example, within the United States, NFPA 70 provides a distinction between power (electrical) wiring and low-voltage (telecommunication) cabling, whereas within Europe for wet areas, low-voltage cabling shall adhere to the same requirements as electrical wiring.

Wet area rating consideration shall be given when designing system devices, cable, and termination hardware to be located within these areas.

6.5.2 Hazardous Areas Requirements

In facilities with systems and devices located within areas rated hazardous (e.g., explosion risk), designers shall consult with the applicable electrical and building codes, as well as all AHJs.

Consideration shall be given when designing system devices, cable, conduit, electrical grounding, and termination hardware to be located within these areas to ensure compliance with all applicable codes, regulations and requirements.

6.6 Building Systems Equipment

6.6.1 Introduction

The location of system level controllers and other core building system equipment is a decision best made early in the design process. There are two common methods for placement of this equipment: the distributed building equipment method and the centralized building system equipment method.

6.6.1.1 Distributed Building Equipment Method

By using the telecommunications spaces present for voice and data systems, equipment (e.g., controllers) for building systems can be distributed across the building or premise. When using a TR as the connecting point for horizontal cabling and pathways for all voice, data, video, and building system services, this creates a secure area for all cabling and eliminates the need for a separate equipment areas.

Structured cabling architecture makes it possible to:

- Locate system-level controllers in a mechanical area or the TR.
- Reduce the number of system-level controllers by consolidating multiple locations in the TRs or ERs.
- Minimize effects from controller failures by using redundant infrastructure and automatic rerouting of services.
- Use the TR to create a secure location for housing all the telecommunications and building system controllers serving a floor or floor area.

With the distributed building equipment method, any power required for operation of devices (e.g., fire alarm strobes or variable air volume boxes) can be distributed from the TRs or provided locally.

6.6.1.2 Centralized Building System Equipment Method

The centralized building systems equipment method places all of the equipment within a single location and is comparable to the use of centralized optical fiber cabling for data networks. While practical for small buildings and premises, it is often impractical for large or multistory buildings as the cabling for all devices, subcontrollers and other connected equipment all must route to the one location.

NOTE: A centralized equipment approach does not mean centralized intelligence since most modern building systems use distributed intelligence (e.g., small capacity controllers distributed through a building).

When centralizing the system-level controllers, structured cabling architecture makes it possible to:

- Use all the available ports anywhere in the building via the backbone cabling
- Reduce the number of system-level controllers further as compared to the distributed building equipment methods
- Provide centralized administration
- Recover from equipment failures by retranslating software programming and rerouting building system services by using spare controller ports
- Reduce system installation, testing, equipment, and electrical costs by consolidating equipment areas

Centralizing building system equipment may necessitate additional hardware (e.g., power supplies) in the TRs or near the system’s devices, appliances and other elements as cabling lengths are typically longer, thus increasing power loss as the end of the cable. Additionally, large capacity system-level controllers (e.g., in excess of 32 ports) may not be available for some building systems, increasing the amount of system-level equipment at the centralized location.

6.6.2 Recommendations

Distance limitations associated with the expected system equipment and devices should be verified prior to selecting and implementing a design method. In some cases, an additional equipment location for consolidating controllers may be necessary.

Locating all systems in a common area simplifies installation, maintenance and administration of the systems, while reducing the cost and improving overall security of the systems. However, this may create new security issues where there are non-telecommunications personnel accessing an ER or TR to service the building systems. Where security concerns are a priority, an appropriately sized space directly adjacent to the ER or TR for non-telecommunications building systems or utilizing a secured enclosure to secure telecom equipment should be considered.

6.7 Network Convergence

6.7.1 Overview

The aim of the designer should always to be to provide a single converged network to support all of the building systems. Where this is not possible the quantity of networks should be kept to a minimum. The advantages of this approach are:

- Reduced cost of provision – resources can be shared to reduce quantity required, reduced numbers of vendors and installers.
- Reduced cost in use – less networks to administer and maintain
- Flexibility – the network infrastructure can be used for different applications and quantity of applications as the building use changes over time

The converged network(s) can be:

- Physical – using the same cables, pathways and spaces for all or some systems
- Logical – using the same cables, pathways, spaces and active network components for all or some systems

Where logically converged systems are designed the systems should be separated into groups using virtual LAN or other technologies to ease administration and improve security.

6.7.2 Network Protocols And Gateways

In order to converge the logical network, a common network protocol must be used. This will normally be IP in order to make use of standard physical network designs as described in relevant BICSI, TIA, EN and ISO standards. The selection of applications and hardware should utilize common protocols as far as possible into the application system while taking into consideration practicalities and economics.

6.7.3 Network Convergence Challenges

6.7.3.1 Timing

The convergence of the building network onto a common platform that includes data, telephony and other applications that are not normally available until shortly before the building is because occupancy can create problems with timing. Applications such as BMS, lighting control and access control may be required to be operational much earlier than the usual network applications to facilitate testing and commissioning.

6.7.3.2 Demarcation

In some building types such as multi-tenant commercial offices the procurement of some or all of the building infrastructure systems is normally carried out by the developer or landlord, while the ICT infrastructure will normally be left for the Tenant to procure to their specific requirements. The intelligent building with a consolidated network however requires the infrastructure to be provisioned, at least in part, from the outset. Table 6-3 provides an example of the recommended extent of infrastructure provision through the development stages, with Table 6-4 showing this applied to two building systems.

Table 6-3 Example Infrastructure Provisions for Phased Development

Development stage	*Description*	*Responsibility*	*Pathways and spaces*	*Cabling*	*Network equipment*
Shell and core/base building	Substructure and superstructure of building, utilities and central plant	Developer / landlord	All riser spaces and cable containment required to link systems between landlord and tenant. Space for WAN cables to link tenant systems to private or public networks. Entrance facility space with power, cooling and other infrastructure for network providers equipment and demarcation points. Equipment room space with power, cooling and other infrastructure for shell and core networks. Space adjacent to each tenant with power, cooling and other infrastructure for distribution of Category A systems as described below.	Cables required to link systems between landlord and tenant areas. Backbone fiber and copper cables from entrance facility(ies) to each tenant area for systems as specified.	Active network devices to allow shell and core systems described below to operate and communicate.
Category A fit out	Floors and ceilings, together with lighting and HVAC systems for open plan offices.	Developer / landlord or tenant	Pathways for category A systems cables as described.	Cables to link central systems to category a systems	
Category B fit out	Partitioning and adaptation of lighting and HVAC systems to suit. Other fit-outs specific to Tenant operations. Power and data connections to desks.	Tenant (but sometimes carried out by the developer / landlord on the tenant's behalf.			

Table 6-4 Demarcation of Systems

System	*Area*	*Development stage*	*Responsibility*
Lighting control	Common parts, external	Shell and core	Developer/landlord
	Provision to extend system into tenant's area	Shell and core	Developer/landlord
	Extension of system into tenant's area	Category A fit-out	Developer/landlord or tenant
	Adaptation of system to suit tenant requirements	Category B fit-out	Tenant
Building management system	Central plant	Shell and core	Developer/landlord
	Provision to extend system into tenant's area	Shell and core	Developer/landlord
	Extension of system into tenant's area	Category A fit-out	Developer/landlord or tenant
	Adaptation of system to suit tenant requirements	Category B fit-out	Tenant

7 Building Monitoring Systems

7.1 Utility Metering

7.1.1 Introduction

Utility metering provides the service provider and the owner a method for measuring and managing utility usage.

This is accomplished by physically reading the meter or via the use of smart meter technology. Smart meter technology allows the service providers to communicate with the meter data using radio frequency (RF) transceivers. Smart meters may also have a data connection for owner connection to the building management system.

Owners may also elect to monitor meters. Owner monitoring may occur at the main meter location, a sub-meter location, or at control panel locations.

7.1.2 Utility Provider Metering

Utility service providers are transitioning to the use of smart meters. These devices typically use RF technology to communicate bi-directionally with the service provider. Meters are typically located at:

- Electric utility provider – each main electrical meter (there main be a number of service mains per site)
- Gas utility provider – at the main gas meter location
- Water utility provider – at the main water meter location
- Steam utility provider – at the main steam meter location

There may also be utility provided sub-meters. These sub-meters may utilize a smart meter and have a data connection. All utility provider connection requirements should be coordinated with the utility provider during the design phase.

7.1.3 Owner Metering

Owner metering of utilities are typically provided by the owner to manage their utility usage, and possibly to allow sub-billing of services to tenants. Sub-metering can be achieved via sub-meters installed by the utility provider or owner. These owner installed meters may have the capability to communicate with the building management system or an independent equipment vendor via RF, cellular, or hard wired data connection. Systems that an owner may select to sub-meter include:

- Water consumption (e.g., potable, heated, chilled)
- Natural gas consumption
- Electrical power consumption
- Electrical power generation (e.g., fuel cell system, photovoltaic system, or other technology)
- Electrical lighting power consumption
- Steam

7.2 Building Automation System (BAS)

7.2.1 Introduction

A building automation system (BAS) can be defined as a control system comprised of hardware (e.g., controllers, cabling, input/output devices) and a software application or suite of software applications that provide automation, typically for electrical and mechanical systems. Automated building systems typically include power, lighting, heating/ventilation/air conditioning (HVAC) systems, plumbing, security, telecommunications services, and life safety systems.

BAS hardware is typically represented by inputs, outputs, and controllers. A control unit, based on the information supplied by its associated input devices, as well as preset instructions, runs the system it is associated with. Cabling is used to link the control unit to the input and output devices.

Structured cabling provides several benefits to BAS, including systems that use IP based protocols and open protocols such as LonWorks®, BACnet®, and Modbus®. A standards-compliant structured cabling system provides a generic cabling system that can transport a wide range of protocols, allowing the BAS to evolve without changing cabling. A generic, standards-compliant, structured cabling system is also designed to support a wide variety of other applications such as voice, network data, and video. This allows the installed cabling to be efficiently utilized for multiple applications and services without running new dedicated cable. A structured cabling system is easier to administer and troubleshoot than an unstructured cabling system.

The disadvantage of structured cabling is that some proprietary or legacy BAS equipment may not function properly on standard-compliant structured cabling, thus requiring the installation of two parallel networks, which should be segregated to minimize maintenance errors.

For the purposes of this standard, automated controls will be defined as a system that provides for monitoring and control of mechanical, electrical, lighting, life safety, and electronic systems designed for a specific process or operation, such as automatic door openers, conveyor systems, or manufacturing machinery.

7.2.2 BAS Hardware

7.2.2.1 Introduction

A BAS system includes the following components:

- Input devices – a device that measures the value of a variable and relays the information to the associated control panel
- Output devices – a device that receives a control signal and causes a mechanical action (e.g., actuation of a switch, rotation of a valve stem, etc.)
- Field-level controllers – these are network enabled control devices that provide control functions for a single system (e.g., air handling unit (AHU), boiler, water pump, lighting system)
- System-level controllers – these provide control functions for one or more field-level controllers, or complex mechanical systems such as chilled water systems
- Management-level processors – these control one or more unitary or system level controllers, and can include a connection for a laptop computer, one or more installed workstations, and servers that provide database functions.

Microprocessor-based controllers have led to a hierarchical configuration with several levels, or tiers, of processors and controllers and are categorized as follows:

- Field-level controllers (e.g., zone-level controllers)
- System-level controllers (e.g., automation-level controllers)
- Management-level processors

7.2.2.1.1 Field-Level Controllers

Field-level controllers are typically designed for DDC of unitary equipment and specific HVAC, energy management systems (EMS), and access control application requirements.

These controllers can:

- Provide limited port capacity for direct connection of sensors and output devices.
- Support and execute resident DDC programs and EMS software.
- Initiate sequences that provide processing of specific device data.
- Usually operate with limitations in a stand-alone manner.

Controllers are networked on a bus to allow information sharing with processors at the system and management levels. Some field-level controllers have a port or communications channel for a portable operator’s terminal during initial setup and subsequent adjustments.

Mechanical equipment (e.g., chillers, boilers, air handlers) may have self-contained field-level controllers and devices pre-cabled by the mechanical equipment manufacturer. This configuration will typically only require a connection from the self-contained field-level controller on the mechanical equipment to the system-level controller or communications bus.

7.2.2.1.2 System-Level Controllers

Microprocessor-based system-level controllers have greater processing capacity than field-level controllers. They interface with controlled equipment directly through cabled sensors and devices, or indirectly through communications links with field-level controllers.

System-level controllers are also used to:

- Maintain databases
- Collect operational information
- Coordinate the operation of field-level controllers
- Provide communication capabilities between field-level controllers and higher-level management systems

System-level controllers that incorporate communication connections are usually applied to major pieces of mechanical equipment (e.g., chillers, air handlers), lighting control functions, fire alarm, or security points. As part of a continuing trend toward distributed control, sophisticated field-level controllers are more likely to be applied to mechanical equipment.

System-level controllers are usually linked via a communications bus to management-level processors, enabling the uploading of data and downloading of application programs. Like field-level controllers, system-level controllers also provide system survivability by operating in a stand-alone mode if the communications bus is lost.

Systems integration for BAS (e.g., fire, security, HVAC, EMS) usually takes place at this level by providing common control, interface, and global activity as a result of specific subsystem events (e.g., temperature control based on input from occupancy sensors).

7.2.2.1.3 Management-Level Processors

At the top of BAS hierarchy is the management-level processor. Management systems are CPU-based and can be as simple as a stand-alone computer or may be a more sophisticated SCADA or server-based design. The systems can utilize most any input or output device including printers, plotters, video displays, touch screens displays, keyboard, mouse, and many other specialized I/O devices. These systems are used to exercise control and management over the various BAS categories by requesting data from and issuing commands to points anywhere in the system.

The management-level processor primarily collects, stores, and processes historical data (e.g., energy usage, operating costs, and alarm activity generating reports) that provide a tool for the long-term management and use of the facility.

In addition to handling alarms, executing applications programs, and handling daily activities, the management-level processor can provide for:

- System programming, including sequences, limits, set points, times, and parameters for system- and field-level controllers
- Retrieval of system data and historical database information
- System security
- Maintenance management and scheduling
- Remote notification of personnel of alarm conditions
- Standard and custom reports
- Site-specific customization
- Graphical display of system information

At this level, it is easy to integrate multi-vendor systems with software and communication technologies. And by using a wide area network, operations and maintenance personnel can remotely access, control, and manage a building.

7.2.3 BAS Software

7.2.3.1 Introduction

While hardware enables operator interaction and the display and printout of data, the software determines how the:

- Human interaction takes place
- Data is displayed
- Printer output is formatted

Most BAS software is run on computer-based operating systems and uses what is usually referred to as a graphical user interface (GUI). This allows the user to use standard drag and drop conventions, either with a mouse, touch screen, or other point/click device. It also allows the user to access other applications on the same machine, which may support BAS management and reporting requirements (e.g., word processors, spreadsheets, and databases).

Other standard programs are often embedded in BAS software. A spreadsheet may be an integral part of the trend report utility. This allows the operator to view the output of the requested report and review and edit the report in the spreadsheet format. The spreadsheet also can be called up as a stand-alone utility.

Typically, software at the field- and system-level controllers is to communicate using a peer-to-peer configuration, but these levels may communicate using master/slave token passing. Software at the management level communicates with all system- and field-level processors in a peer-to-peer fashion.

When using multiple management-level processors, one is defined as the database server where all current databases reside. Databases also may reside in each system-level controller to provide a more robust system (e.g., one that keeps working if a single system-level controller fails).

Any management-level processor may initiate a system change (e.g., graphic or text modification, operator assignment, schedule), but all changes are made within the server database and are downloaded to field- or system-level controllers. The server is a software function that may be a dedicated computer or any other LAN processor.

NOTE: All LAN based processors periodically receive database updates from the server. When the server is down, the processors operate from their own database. This same method of operation also applies to the system- or field-level controllers that can operate independently in the event of a management-level processor failure.

7.2.3.2 Communications Protocols

Communications protocols are an essential element of the BAS configuration because of the amount of data transferred from one point to another, and because distributed processors may be dependent on each other for data pertinent to resident programs. Communications links, or buses, generally use either a poll-response or a peer to peer protocol.

Early BAS used poll response protocols where most system intelligence and data processing was at the central processor. Today, most BAS use peer protocols at the management level and share the communications bus equally among all bus devices with no master device.

A peer-based communications protocol has the following advantages over poll-response communications protocol:

- Communication is not dependent on a single device, such as a master controller.
- Direct communications between connected devices occurs without going through the BAS central processor.
- Global messages can be transmitted to all connected devices.

In token-based peer communications, a time slot is automatically passed from one bus-connected device to another as a means of designating when a device has access to the bus. Since the time slot passes in an orderly sequence from one device to the next, the communications network is sometimes termed a ring. However, the bus is not necessarily physically looped nor the devices physically connected to form a ring. Any device on the bus can be designated as the first to receive the time slot ‘token’ and any other device the next to receive it, and so on.

Some of the commonly used BAS protocols include:

- Building automation and control networks, such as BACnet, Modicon®, and Modbus
- European installation bus
- Local operating network talk, known as LonWorks
- Internet protocols, such as transmission control protocol/Internet protocol (TCP/IP) and extensible markup language (XML)
- OLE (object linking and embedding) for process control, commonly known as OPC

While a specific BAS discipline (e.g., ventilation, sensor actuator) may use a specific standardized protocol, interoperability and standardization between different BAS disciplines varies. As such, coordination between different BAS vendors or disciplines may require the use of additional software or equipment.

7.2.3.3 Requirements

Where a data center is part of the project scope, monitoring of BAS alarms associated with data center support utilities shall be made available in the data center’s operations center, or a similar location where the network is being monitored.

7.2.3.4 Recommendations

The structured cabling system designer should verify the interoperability and specific functionality of the products and protocols intended to be supported.

Many mechanical and electrical systems manufacturers are using open protocols for BAS connections, such as BACnet, LonWorks, SNMP, and HTTP. Each protocol has advantages and disadvantages, and each owner/operator will use different criteria to choose which system(s) to use. Typically, however, control and headend systems can be designed to communicate with mechanical systems using any of these open protocols.

Where a data center is part of the project scope, the building automation should interface with the data center central Power and Environmental Monitoring and Control System (PEMCS). The PEMCS should include a remote engineering console and manual overrides for all automatic controls and set points.

7.2.3.5 Additional Information

Proprietary communications are becoming less common, but may still be an issue in an existing facility with an older BAS system. Where newer BAS systems are added in such a facility, gateways can possibly be used to translate existing proprietary protocol(s) to a modern open protocol.

BASs that perform systems integration can communicate with mechanical systems and associated controllers supplied by different manufacturers, even if the BAS, mechanical systems, and controllers are installed at different times. The use of open protocols is essential to the success of systems integration.

7.3 Designing and Planning Building Management Systems

7.3.1 Planning

7.3.1.1 Recommendations

The designer should work with the BAS vendor to:

- Identify the BAS mechanical equipment locations (e.g., air handlers, chillers)
- Identify or determine the backbone and horizontal cable pathways and delivery methods
- Identify BAS input and output device locations
- Identify which devices will be connected to each horizontal cable run, or determine the horizontal cable density by size and type of coverage area
- Determine the location of each BAS controller
- Select the type and size of cable(s) to be used in the backbone and horizontal distribution systems.
- Coordinate design drawings and records to avoid duplication of efforts
- Determine how the systems and cabling will be managed upon completion of the installation (e.g., cable management, facilities management)
- Define the work operations and responsibilities of each contractor
- Define testing and certification criteria

NOTE: A building or facilities manager typically manages the BAS and a telecommunications/ICT manager manages voice and data systems. It will require cooperation and coordination with both these department managers when designing the ICT cabling distribution system.

Early planning is critical for determining the optimal placement of system-level controllers by the chosen design methodology (e.g., distributed, centralized), TRs, and pathways in conjunction with the mechanical/ electrical areas. When designing these spaces, all controller ports should be connected to the cross-connect field in order to avoid future recabling within the controllers.

7.3.2 General Requirements and Recommendations

7.3.3 Requirements

Active components and equipment shall only be installed at the ends of the link.

7.3.3.1 Recommendations

Selected building management systems should be capable of being supported by the infrastructure listed in Section 5.

Building management systems should conform to an open architecture specification for interfaces to the equipment and systems to be monitored, and support SNMP to report status to other management systems.

7.3.4 Resiliency

7.3.4.1 Requirements

Building management system networks supporting mission-critical facilities shall be highly reliable and available. To ensure system availability, the design and construction shall take into account the potential for network survivability. Specifically:

- Dual (or multiple) network cabling may be considered to interconnect vital equipment and platforms; the dual network cables should be installed along different paths to minimize the chances of being damaged at the same time
- Separate TRs may be utilized to host applicable redundant equipment and be placed with sufficient physical separation to reduce the chances of all the equipment being damaged at once because of a localized fire or other event.

7.3.4.2 Recommendations

All hardware should be fault tolerant, where a failure may result in a condition that maintains the systems in a stable operating condition. This may be in the open, closed, on, or off position depending on the specific system configuration.

In the presence of equipment and cable faults, such as power outage, fires and broken cables, the building management system communications should be designed to provide extended operations without interruption as long as possible within safety guidelines.

7.3.5 Power

Receive verification from a licensed electrical engineer that the system meets power, vendor, system, and life-safety requirements.

Some BAS controllers and power supplies are current limited (e.g., fused) at a current capacity that is larger than recommended limit of telecommunication or ICT cabling. As such, use of these controllers and power supplies should be avoided.

NOTE: Recommended and maximum current capacity is determined in part by size of conductor. Connectors or other terminations may also affect the recommended and maximum current capacity of the cabling link.

When the use of alternative controllers or equipment is not possible:

- Verify that the intended implementation complies with codes (e.g., NFPA 70) and the AHJ.
- Verify that the current to be supported does not exceed the maximum allowed for any element (e.g., cabling, connector, port) used within the cabling channel.
- Employ methods, if allowed, to limit the current on the communication cabling (e.g., use of a positive temperature coefficient (PTC) resistor).
- Use “keyed” or other connectors which minimize the risk of inadvertent conductor reversals.

7.3.6 Controllers and Devices

Typically, building management systems require dedicated interconnect wiring between the inputs/outputs and the associated field-level controller. In most modern systems, this level of cabling is typically proprietary or nonstandard communications cabling. Because of the inherent limitations this type of cabling may have, these peripheral devices should be located within close physical proximity to the associated field-level controller.

7.3.7 Structured Cabling Infrastructure

7.3.7.1 Requirements

All requirements of Section 5 shall apply. Requirements of Section 5 may be modified or replaced by requirements found in Section 7.3.7.

7.3.7.2 Coverage Area

Zone cabling should be used for building management system devices (See Section 6.1). If the device locations are unknown, required connections (devices) should be calculated based on the maximum usage for the size and type of space.

7.3.7.3 Horizontal Connection Point (HCP)

When using an HCP configuration, the BAS cable termination hardware in the TR can be terminated via separate termination strips/blocks.

Connecting hardware can be consolidated, however, a combined configuration may not allow for bridging or chaining of BAS devices. When consolidated, connecting hardware fields should be separated.

7.3.7.4 Horizontal Cabling

7.3.7.4.1 Requirements

Building management system signals from different functions (e.g., fire alarm, security, HVAC, lighting, EMS) shall not be combined on the same horizontal cable.

7.3.7.4.2 Recommendations

Horizontal cables (as defined in Section 5.4.2) should serve one device per cable run to provide maximum flexibility for future changes. However, a horizontal cable may support multiple devices that are bridged together as allowed per system manufacturer.

7.3.7.4.3 Additional Information

Traditional BAS wiring uses copper conductors ranging from 0.326 mm^2 (22 AWG) to 1.31 mm^2 (16 AWG). A larger diameter conductor size allows more BAS devices to be connected, resulting in the use of less horizontal cable in certain cabling topologies.

BAS channel lengths up to 1220 m (4000 ft) are possible when using a combination of the horizontal and backbone cabling without the use of extenders or repeaters. When repeaters are used, extensions of up to three or four times this distance are possible.

Media conversion is employed whenever two different media interface to create a communications link. For example, a balanced twisted-pair to fiber media conversion unit may be used at the ends of an optical fiber link to allow for equipment with balanced twisted-pair ports to communicate with each other through longer distances or within an environment with a higher EMI potential, depending on its pathway environment.

Note: Some devices may require cable types not typically used in structured cabling. This may prevent future upgrades or vendor replacement.

This page intentionally left blank

8 Lighting

8.1 Overview

Traditionally, lighting control systems only provided illumination and used stand-alone or independent controls. With the integration of occupancy and light sensors, a lighting system can be integrated with others building systems to provide enhanced occupant comfort and optimize energy use. Examples of such integrations include:

- HVAC and other environmental systems to provide the desired operational or living environment for occupants.
- Automated shading and intelligent glass in order to manage interior light levels based on exterior solar conditions and desired room environments.
- A/V control systems within conference rooms, board rooms and interactive classrooms to manage light levels based on activity or time of day.
- Theatrical lighting and performance systems within performance spaces (e.g., lecture halls, auditoriums, event centers, arenas) for theatrical and other types of performances (e.g., amusement park attractions, concerts).
- Life safety and security systems to illuminate paths of egress with colored lights, illuminate camera fields of view during an intrusion, and warn occupants of potential or imminent threats (e.g., weather)
- Management systems to provide a centralized control and operations solution as well as a common interface and ‘dashboard’ functionality.

As lighting may account for up to 40 percent of the electrical operation costs in a commercial building, lighting control systems can be used to meet required lighting levels and achieve energy efficiency as required by applicable codes and regulations.

8.2 Lighting Control Systems

8.2.1 Overview

There are many products used in low-voltage lighting control systems. Examples of these products include:

- Lighting control panels
- Relay panels/modules
- Dimming panels
- Light wall-box dimmers (e.g., slide, rotary)
- Manual switchers
- Maintained or momentary wall switches with pilot light
- Occupancy sensors
- Photosensors
- Light sensors for dimmable ballast
- Infrared sensor receiver/transmitter

Lighting control should provide, at a minimum, the ability of switching light fixtures to ensure they are providing specified light levels for the safe and efficient use of the space when occupied while minimizing energy use by turning off fixtures when they are not required.

Optional additional functionalities of lighting control systems are:

- Timing controls
- Dimming according to user control, scene settings or to reduce energy use when sunlight is available
- Automatic switching by signals from other systems (e.g., access control)
- Load shedding of lighting in abnormal conditions, such as when the building is on standby generation power supply

8.2.2 Topologies

Lighting control topologies fall into 4 categories:

- Dimming racks
- Modular lighting control module (LCM)
- Hardwired digital addressable lighting interface (DALI) control
- Extra low voltage lighting control

8.2.2.1 Dimming Racks

In this topology individual or groups of light fixtures are cabled back to a rack of dimmers which modulate and switch line voltage to suit requirements. This type of installation is common in theatres, entertainment venues and high end conference venues. It has little opportunity to interface with other systems so is not considered further in this standard.

8.2.2.2 Modular LCM

In this topology, as shown in Figure 8-1, each light fixture is connected, usually by a flexible cable, to a port on a lighting control module. Depending on the system, 4-8 ports may be available on each module.

The modules can switch the power supply to each light fixture according to a signal from a sensor attached to the module. More sophisticated systems can take signals from other modules via the network to switch individual or groups light fixtures.

The cable connecting from the LCM to the light fixture can also incorporate a control pair to dim the fixtures using a 0-10 V or DALI protocol to directly interface with the fluorescent ballast or LED controller in the fixture.

The interface between the lighting zone-control and the LCM is typically wired in a ring topology. While several solutions utilize proprietary communication methods to interface between the LCM and lighting zone controller, ISO/IEC 14543-3 defines the KNX protocol which provides increased interoperability with non-lighting systems.

The zone controllers can be networked together, often using IP protocol to provide interfaces with other intelligent building systems together with control and monitoring by software on a computer or server. The user interface is often a web page.

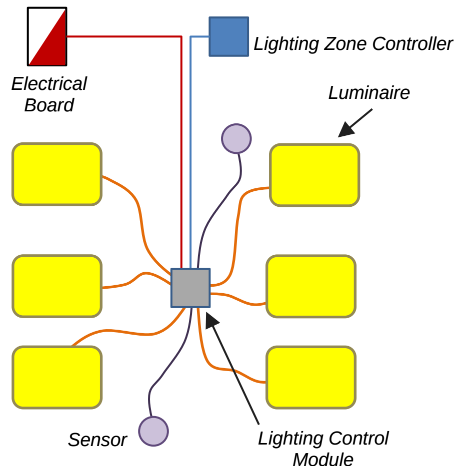


Figure 8-1
Modular LCM Lighting Control Topology

8.2.2.3 Hardwired DALI Control

DALI is an International Standard (IEC 62386) for the control of electronic ballasts, transformers, LED's, emergency lights and exit signs in an easy to manage digital lighting control system. Many manufacturers of fluorescent ballasts and LED controllers now offer this control interface as a standard option.

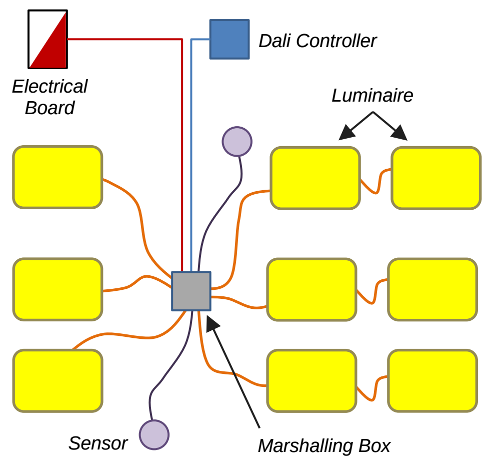


Figure 8-2
Hardwired DALI Lighting Control Topology

In this topology, as shown in Figure 8-2, up to 64 addressable elements (e.g., lights, sensors) can be interfaced with a controller. This controller communicates with the ballast or controller within each fixture to switch or dim the light according to inputs from sensors or external sources.

Interfacing with other systems in this topology is normally by a gateway at the controller’s cabinet.

8.2.2.4 Extra Low Voltage Lighting Control

8.2.2.4.1 Overview

LED lights consume much less energy than other types of lamps so it becomes possible to connect them using extra low voltage DC current from a central controller using PoE or other methods. The advantages of this topology (see Figure 8-3) include installation cost savings relating to cabling because the category cables are used for power and control, and in many locations are not subject to regulations applicable to mains power voltages (e.g., 120, 230, or 277 V_{AC}). Disadvantages include that all light fixtures must be fitted with a controller compatible with the proprietary network protocol and sensors must also be compatible.

Cabling may be brought back to the same floor distributor as other intelligent building systems, data and telephony and separated at the patch field. Cable terminations at the light fixtures are unlikely to be changed for other uses, so these may terminate with a modular plug (e.g., RJ-45) for connection directly to the LED controller.

Interfaces with other systems together with user control and monitoring is normally by an IP network connection to the matrix controller. Lighting controls ease the interfacing with other systems, as each light fixture becomes a network port and are able to provide switching, dimming and other advanced features such as color changes of the LED's.

8.3 Task Tuning / Fixed Power Reduction

Fixed power reduction is one of the simplest forms of lighting control. It allows lighting levels to be varied according to the type of space or the requirements of occupants in the space. It provides sufficient light for the areas or tasks being performed in the building, but it uses less power than the full light output of the system. This configuration provides consumption and demand savings directly proportional to the power level setting and can be adjusted up or down as the lighting requirements change.

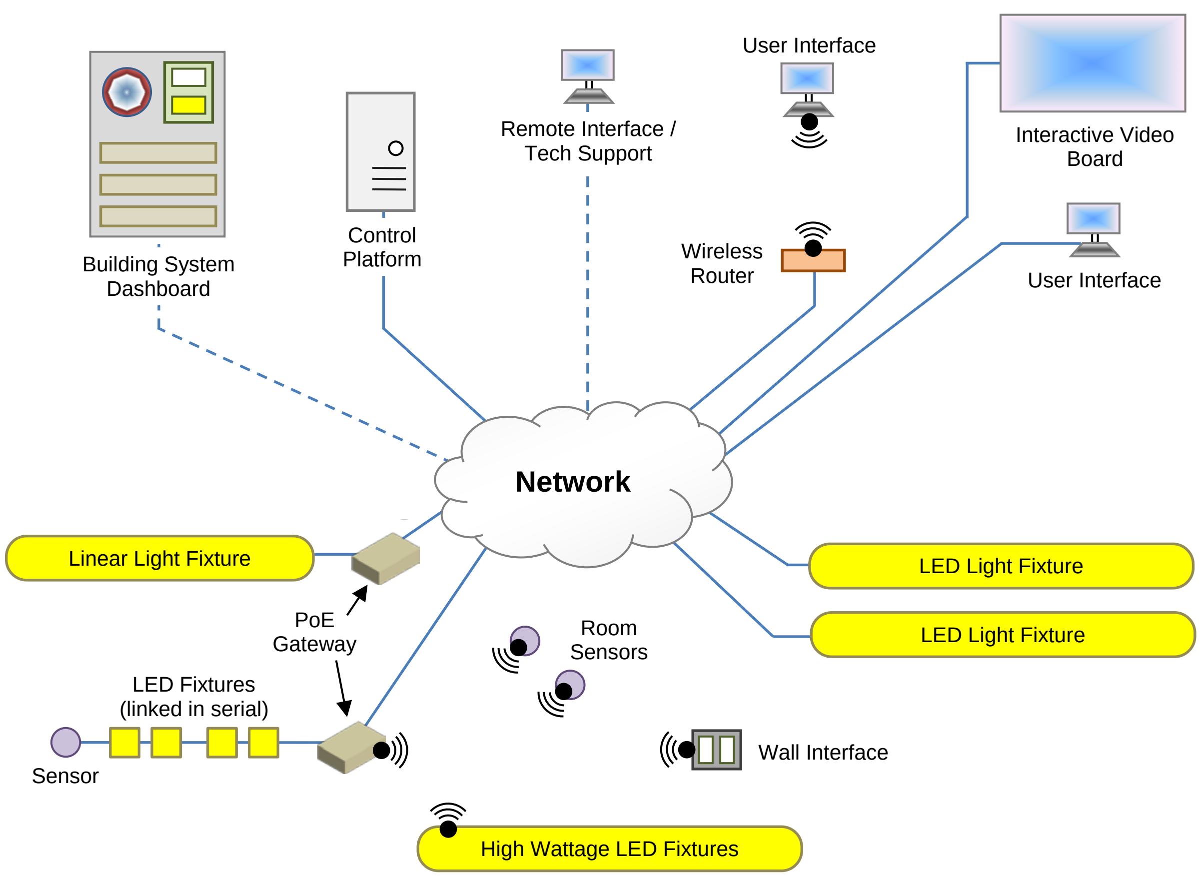


Figure 8-3
DC Lighting Power Supply and Control Topology

8.3.2 Multilevel Lighting

Energy codes may require that lighting have different light levels, providing occupants of spaces with the capability of reducing light levels manually. This can be accomplished by turning on and off lamps within multilamp luminaries, turning on and off some of the luminaires in areas or through the use of architectural dimming systems.

Dimming a set of luminaires can set a mood in an area of a room and saves energy. Gradual dimming limits the inrush current, prolonging lamp life. Dimmers capable of gradually varying light levels do not overwhelm occupants with sudden, bright light. Fading gradually dims lamps until they are completely off. Preset dimmers may include multiple preset dimming level options.

For controlling luminaires, dimming systems may use:

- Individual ballast control (typically requiring additional control wiring to the luminaire)
- Radio / wireless signals
- Lighting control panel(s) with related hardware and software.

Dimming can also be part of a load shed energy reduction plan or after-hours control.

8.3.3 Scheduling or Occupancy-Based, Time of Day, and On/Off Control

Occupancy-based lighting control uses several methods to reduce energy consumption. It can be applied to full lighting during normal working hours with reduced levels by setting a time of day parameter in the software program and adjusting the power output from the lighting controller.

Further reduction and savings can be accomplished by using centralized management for on/off control, along with vacancy sensors to reduce lighting in strategic areas when the cleaning staff has completed their tasks. When using this method, individual occupants should be able to easily schedule or control lighting in areas with safe entry and exit when working after hours. Vacancy sensors also can be utilized to control lighting in rooms or areas that are not always occupied (e.g., conference rooms, restrooms, individual offices).

8.3.4 Vacancy-Based On/Off Control

Sensors can be programmed only to determine when spaces are vacant to turn off lighting. Vacancy sensors save more energy than older style occupancy sensors because the occupants determine when lighting is needed, reducing power consumption when rooms are occupied and automatic turn on is not necessary. Examples are when someone enters an office just to drop something on a desk or when a window allows enough light for the tasks being performed. Sensors shall be clearly defined for a building as the national and local codes (e.g., California Title 24, ASHRAE 90.1, *International Energy Conservation Code*) may require vacancy sensors to turn off other systems such as power outlets and have occupancy sensors turn those systems on while leaving the lights off when required by building and energy saving codes.

8.3.5 Daylight Harvesting

The use of daylight to reduce the need for artificial lighting is a strategy typically applied to new buildings since the building needs to be designed for glare control, proper work area orientation, and windows that permit enhanced daylight penetration. Ambient light sensors are placed where they can measure all sources of light. The sensor sends a signal to the lighting controller to adjust the artificial light delivered by luminaires in the sensors zone to maintain a constant light level when combined with the amount of available daylight. The technique of daylight harvesting may provide energy consumption savings of approximately four percent for an average building.

8.3.6 Demand Limiting or Load Shed

Demand limiting via time-delayed dimming can be accomplished by signaling the lighting controller to dim the lights a predetermined amount when the kilowatt demand exceeds a predetermined kilowatt rate. The controller responds to the signal by gradually dimming the lights (e.g., time-delayed dimming) to a predetermined point.

When the kilowatt demand level drops below the kilowatt set point, the lighting control system gradually increases the lighting power to the normal level. This technique of demand lighting has the advantage of providing a kilowatt reduction directly proportional to the amount the lights are dimmed and is accomplished in a manner unnoticeable to the occupants.

8.3.7 Trimming or Lumen Depreciation Compensation

The light output of fluorescent lamps deteriorates over a period of three years, stopping at approximately 70 percent of the light output of a new lamp. This is called lumen depreciation.

A lumen depreciation compensation strategy provides comfortable light levels at all times. A common strategy is to specify a sufficient number of luminaires to produce the desired light level at 70 percent of a new lamp, and using a lightning controller to adjust the power output to compensate as light output changes because of depreciation or replacement. Lumen depreciation strategies typically provide energy costs savings when contrasted with a fixed level power strategy to lamps and luminaries

For an LED luminaire, the time to reach output that is 70 percent of the original luminous flux defines the longest useful life of a luminaire under the same test conditions as those for the packaged LEDs. This has been called the “entitlement” for lifetime. All other failures will reduce this time to a greater or lesser extent depending on design, operating conditions, environment, and other factors.

NOTE: LED package lumen depreciation is not a replacement for luminaire life because of the presence of other failure modes.

Similar to fluorescent lighting, designing LED lighting at an initial 80 percent of full light output allows for gradual power increase to compensate for LED light quality decline and can prolong the time needed to replace the LED luminaire.

8.4 Controller Connectivity and Cabling Infrastructure

8.4.1 Introduction

The network connectivity required for automation and control functionality of a low-voltage lighting system may be provided by a cabling connection or through a wireless connection.

Systems that utilize a wireless controller typically utilize electrical wire to connect the controller to the lighting functions, though communication media may also be used. Lighting systems that utilize a cabling connection for connectivity are typically a combined power and data cabling infrastructure (e.g., PoE).

8.4.2 Requirements

Where communications cabling media is used, it shall follow all of the applicable requirements as specified in Section 5. Additionally, the following requirements shall be met.

- Cabling implementations shall conform to the requirements of local codes, national codes (e.g., NFPA 70), regulations and the AHJ, both for the premises and lighting applications being served.
- For existing systems, if balanced twisted-pair cabling is to be replaced or added, Category 6 or higher performance balanced twisted-pair cable shall be used.
- For systems that do not exceed 0.3 A per conductor, conductors shall be a minimum size of 0.205 mm^2 (24 AWG). For systems that have greater than 0.3 A, but do not exceed 0.5 A per conductor, conductors shall have a minimum size of 0.258 mm^2 (23 AWG). For systems over 0.5 A per conductor, but do not exceed 1 A per conductor, 0.326 mm^2 (22 AWG) shall be the minimum size of conductor.

  NOTE: These requirements differ than those in Section 6.3 in order to reduce risk of safety issues from future equipment changes being performed without proper verification of the existing cabling infrastructure.

8.4.3 Recommendations

The operating temperature of cabling should not exceed 60 °C (140 °F) regardless of the cable jacket rating, as decreased data transmission performance and increased signal errors rate may occur.

Where data cabling is used to supply power for a low-voltage lighting system, the maximum number of cables placed in a bundle should not exceed 24, where systems:

- Are installed in environments with ambient temperatures not exceeding 35 °C (95 °F), and
- Do not exceed 0.5 A per conductor.

Where system do not exceed 0.5 A per conductor and are installed within environments with ambient temperature between 35 °C (95 °F) and 40 °C (104 °F), the maximum bundle size:

- Should not exceed 12, where the conductor size of the cabling is 0.258 mm^2 (23AWG)
- Should not exceed 24, where the conductor size of the cabling is 0.326 mm^2 (22 AWG).

For systems using over 0.5A per conductor, but not exceeding 1 A per conductor, the maximum bundle sizes listed Table 8-1 per maximum ambient temperature should be followed.

Where ambient temperatures are over 40 °C (104 °F), cabling should not be bundled.

Table 8-1 Recommended Maximum Data and Power Cabling Bundle Sizes for Systems Over 0.5A per Conductor

	Jacket Listing 60°C (140°F)			*Jacket Listing 75 °C (167 °F)*		
	30 °C (86 °F) Maximum Ambient Temperature	*35 °C (95 °F) Maximum Ambient Temperature*	*40 °C (104 °F) Maximum Ambient Temperature*	*30 °C (86 °F) Maximum Ambient Temperature*	*35 °C (95 °F) Maximum Ambient Temperature*	*40 °C (104 °F) Maximum Ambient Temperature*
0.5 > A ≥ 0.7	24	12	12	24	24	24
0.7 > A ≥ 1	12	6	6	12	12	12

8.5 Energy Reduction and Lighting Guidelines

8.5.1 Recommendations

Where not already required by the AHJ, energy reduction guidelines offered by applicable building codes, standards and regulations should be followed. Several examples of applicable energy codes and standards that offer lighting guidelines include:

- 2015 *International Energy Conservation Code®*
- ANSI/ASHRAE/IES Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*
- CEC-400-2015-037-CMF, *Building Energy Efficiency Standards For Residential and Nonresidential Buildings*
- EN 12464-1, *Light and lighting. Lighting of work places. Indoor work places*
- EN 12464-2, *Light and lighting. Lighting of work places. Outdoor work places*

9 Other Building Systems

9.1 Digital Signage and Wayfinding

9.1.1 Overview

Information can be provided to persons within the facility through the use of digital and video displays. Common applications include:

- Wayfinding – building/tenant location information (directory), event/meeting information (location, time), transportation mode information (schedules, arrivals/departures, status, alternate routes).
- Organization and commercial information (e.g., advertisements, promotions, news).
- Visual paging and message boards.
- Presentation and training (e.g., meeting /conference rooms, classroom facilities).
- Building/facility status/emergency information (e.g., incident notification, egress, condition/status of infrastructure)

9.1.2 Digital Displays

9.1.2.1 Types

Types of digital displays include:

- Front/Rear Projection
- Flat Panel
  - Liquid crystal display (LCD)
  - Light emitting diode (LED)

9.1.2.2 Modes of Operation

There are three basic modes of operation for a display.

- Static display (basic text or still image)
- Animation (e.g., flashing, scrolling, reversing text/background)
- Full-motion video

Some displays may also provide capability to interact with the viewer through the use of “touch-screens” or connected sensors.

9.1.2.3 Information Sources

Most displays typically utilizing one information source for their primary function. However, displays may provide information from multiple sources as need or usage plan details. Locations of these sources include:

- On-site computers and servers – can include interfaces to other local building systems e.g., (fire-life safety, audio/visual)
- Integral to display (pre-programmed or programmed remotely via a network connection)
- Centrally located servers within premises – includes interfaces to other local building systems (e.g., fire-life safety, audio/visual)
- Remote data/video feeds (e.g., off-site commercial or organizational broadcast feeds. network television, local CCTV feeds)

9.1.2.4 Video Inputs

Displays should have more than one type of input method to provide flexibility in connecting information sources. Most digital displays have at least two ports which can support digital video sources, and a port that can support analog video sources. Video inputs include:

- Digital
  - HDMI (also transmits audio signals)
  - DVI
  - VGA (also supports analog input signal)
- Analog
  - Component video (also known as “RGB video”)
  - Composite video (also known as “yellow plug”)

Displays may also have connection means for Ethernet or other network connectivity through wired (e.g., RJ-45 connector) or wireless options.

9.1.3 Usage Conditions

The following items may affect the final location or positioning of a display for optimum viewing:

- Degree of environmental control in installation area (e.g., indoor versus outdoor)
- Mounting location – mounting arrangements can include wall, ceiling or floor
- Field of view – will influence the size of the display, the mounting arrangements and legibility of the information presented
- Lighting and visibility conditions – natural or artificial lighting can affect visibility and legibility, also visibility can be affected by items such as smoke, fog, mist, or rain. Dust or other particulate matter collecting on a display can also reduce visibility.

9.1.3.1 Viewing Distance

9.1.3.1.1 Overview

Viewing distance is a concept used to capture attention for an image on display. Viewing distance is also closely related with the resolution and size of an image.

The concept of viewing distance requires an understanding of perspective theory as the resolution of the image, and its detail, is always taken from where the viewer is positioned and whether the viewer is standing, walking, sitting or viewing from a moving vehicle. The clarity of atmospherics such as light and shade and weather conditions also plays a part in viewing distance.

The perception of the human eye varies from person to person, and some people are vision impaired, so the only true viewing distance comparison is the distance at which most people can see the image or sign.

9.1.3.1.2 Recommendations

For general applications, a 50 mm (2 in) minimum letter height provides visual legibility to a maximum of 15 m (50 ft).

Other recommended minimum letter heights for various applications include:

- Vehicular direction signs, internal roads, carparks and service areas: 60 mm (2.4 in)
- External pedestrian direction signs: 60 mm (2.4 in)
- Internal direction signs: 30 mm (1.2 in)
- Building directory listings: 20 mm (0.75 in)
- Door signs: 17 mm (0.7 in)

9.1.3.2 Readability

The following recommendations can assist in the optimal readability of signage:

- Utilize contrasting colors

  Note: The use of black and white negates color related readability issues for all types of color vision deficiency
- Provide a lighting contrast between the background and the letters and graphics
- Use a combination of uppercase and lowercase letters is easier to read than all uppercase
- The size, type and layout of lettering on signs should be clearly legible and easily understood

  Note: Typefaces that are Sans Serif (e.g., Arial, Tahoma, Geneva) are preferable
- The size and spacing between letters and words should be in proportion to the size of the display and amount of information provided
- Displays should have low or non-reflective surfaces
- Position lighting to reduce glare on displays with reflective surfaces
- For wayfinding systems, maintain a consistent form and layout

9.1.4 Design Considerations

9.1.4.1 Requirements

The location, pathways required, and installation of all digital signage and displays shall conform to applicable codes, requirements of the AHJ, standards, and regulatory documents (e.g., *American with Disabilities Act*).

Displays used for wayfinding shall have a consistent physical placement and installation relative to the floor and other building features (e.g., doors, hallway intersections).

Displays which may present private or confidential information or other materials which are governed by codes, the AHJ or other regulatory documents (e.g., *Health Insurance Portability and Accountability Act [HIPAA]*, *General Data Protection Regulation [GDPR]*) shall be located and installed per all applicable requirements.

NOTE: This may include displays that are located in secure or limited access areas, such as healthcare procedure rooms.

9.1.4.2 Recommendations

Displays showing the same content should have the same screen aspect ratio.

When locating the display,

- The person closest to the display should not be closer than the width of the video image.
- Viewers should have no more than 15 degrees of eye rotation to the center and 30 degrees to the top of the image.

9.1.5 Wayfinding Recommendations

Displays should be placed in transition areas or where multiple paths intersect.

The maximum distance between information or directional signs in long corridors should be no greater than 30 m (100 ft).

Maps may be used to supplement directional information at key decision points to reduce the amount of directional displays needed.

9.2 Sound and Acoustical Systems

Information that is intended to reach multiple individuals in a building, or is necessary to be sent to an individual or group whose exact whereabouts in a building may not be readily apparent, can be successfully be communicated via a sound system. Additionally, sound systems allow audio information to be sent to the entire premises, selected rooms/floors/sections, and provide reinforcement (i.e., amplification) to ensure the information is intelligible, and has sufficient volume to overcome any noise or attenuation factors.

9.2.1 Purposes of Sound Systems:

- Time and facility schedule information (e.g., class periods, shift changes)
- Organization and commercial information (e.g., advertisements, promotions, news).
- Paging (e.g., personnel location/direction, general announcements)
- Environmental and ambient sound control (e.g., background music)
- Presentation and training (e.g., meeting /conference rooms, classroom facilities).
- Building/facility status/emergency information (e.g., incident notification, egress, condition/status of infrastructure)

9.2.2 Sound Systems

9.2.2.1 Types

- Distributed – utilizes an engineered number of speakers located within a space to provide uniform coverage of the space. Distributed systems are typically:
  - Constant voltage outputs from central amplifiers to speakers
  - VoIP connections to individual integrated amplifier/speaker units
- Standalone audio/visual – speakers can be associated/integrated with individual visual display locations
- Integrated audio/visual – combines characteristics of both distributed and standalone systems into an integrated system

9.2.2.2 Modes of Operation:

- Automated (e.g., pre-recorded, scheduled)
- Ad-hoc (e.g., via user microphone or telephone set)

9.2.2.3 Information Sources

- Local on-site computers or servers
  - Centrally located servers within premises – can include interfaces from other local building systems (e.g., fire-life safety, audio/visual) to sound system signal processors/mixers and amplifiers
- Remote Data/Audio Feeds:
  - Off-site commercial or organizational broadcast feeds via wired or wireless connectivity (e.g., AM/FM radio, background music)

9.2.2.4 Inputs and Outputs

- Digital transmission protocols, such as Ethernet, are used within VoIP systems and can provide common audio and control inputs and outputs to most of the components of a sound system, including integrated amplifier/speaker assemblies.
- Analog audio inputs from audio sources to signal processors and amplifiers
  - Telephone grade (300-3400 Hz)
  - Voice audio grade (300-5000 Hz)
  - Mono audio grade (300-8000 Hz)
  - High fidelity stereo audio grade (20-20,000 Hz)
- Analog audio outputs between amplifiers and speakers:
  - 8-ohm
  - Constant voltage (typically 25 or 70 volts)

9.2.3 Sound System Design Conditions:

- Degree of environmental control in coverage area (e.g., habitable indoor space, industrial space subject to temperature or humidity ranges outside of those of a typical habitable indoor space, outdoor areas)
- Speaker mounting locations, number of coverage areas and zoning requirements
- Acoustic considerations:
  - Amount of ambient noise in coverage area
  - Physical dimensions of coverage area
  - Architectural finishes and surface conditions in coverage area

9.2.4 Integration

Integration between sound systems and other intelligent building systems can include:

- Building clock and time distribution systems
- Building telephone systems
- Fire detection and alarm/life safety systems, including hazardous material detection systems

9.2.5 Code and AHJ Requirements

Sound systems intended for use as primary mass notification systems (MNS) for building emergency notification purposes shall meet applicable AHJ and Code requirements (e.g., NFPA 72).

AHJ and code requirements may require that sound systems utilizing constant-voltage distribution methodologies utilize separate pathway/raceway systems for audio output wiring (between amplifiers and speakers) from those utilized for other building ICT functions.

9.3 Intercom System

9.3.1 Overview

Intercoms can incorporate connections to landlines, cellular telephones, and other intercom systems over telephone or data lines. Intercoms may also utilize both audio and video transmissions to identify visitors who seek access to limited-access or secure rooms and areas. IP-enabled intercom systems consist of one or more servers, control stations and substations.

9.3.2 Components

Communication servers are modular and can utilize various communication protocols dependent upon the manufacturer. Communications stations consist of one or more control stations and substations.

9.3.2.1 Servers

The servers are typically installed in a communications ER or TR. IP-enabled intercom systems use servers to interface to Ethernet switches for communications to control stations and substations.

9.3.2.2 Control Stations

Control Stations are typically installed in spaces where an attendant is continuously present, such as a command and control center, security office, or reception desk. Control stations typically have a numeric keypad and multiple function keys that perform different functions with one or more connected substations.

9.3.2.3 Substations

Substations are installed at remote locations as required by the facility design program. Substations typically have a single push button to initiate voice communications between the substation and an assigned control station.

9.3.3 Operation

The voice communication channel is normally initiated at the substation. By pressing the push button at the substation, a voice channel is opened to an assigned control station. The voice channel can be programmed to forward to an alternate control station if the assigned primary control station fails to answer the call within a set duration of time.

9.3.3.1 Infrastructure and Protocols

Control Stations and substations support either the TCP/IP protocol or a manufacturer's proprietary serial protocol. TCP/IP systems are designed to use Category 5e or higher performing balanced twisted-pair cable.

A serial communications based system typically uses a 2 or 4 conductor cable, and is wired point-to-point between the control station/substation and communication server.

9.3.4 Integration

Integration of intercom systems is typically with security systems, such as video surveillance and access control.

In integrating Intercom with video surveillance, the system will typically monitor the voice channels between control stations and substations. It will then call up associated video surveillance cameras for audio/visual verification of the calling party. The video and audio content could also be recorded for forensic review at a later time.

For access control, when a card reader is associated with a substation it can display a stored badge photograph and unlock an access control door using a control station function key.

Communication or device failure alarms can be programmed at the security management system (SMS) to detect a failure within the intercom system.

Intercom substations can be shown on the security management system's graphical user interface.

The icon for the Intercom station could be interactive and open a voice channel between the selected substation and its associated master station.

9.4 Electronic Safety and Security Systems

9.4.1 Overview

Electronic safety and security (ESS) systems are focused on the protection of life, property and assets. ESS devices and systems include, but are not limited to:

- Safety systems (e.g., fire detection and suppression, emergency mass notification)
- Physical access control
- Video surveillance
- Intrusion detection systems

The design and installation of systems are often under the governance of an AHJ and may require the inclusion of authorized personnel through some or all facets of the project.

9.4.2 Requirements

ESS systems shall be designed and installed per applicable codes (e.g., NFPA 72, NFPA 101) and standards (e.g., ANSI/BICSI 005).

9.5 Real Time Location Systems (RTLS)

9.5.1 Overview

Real time location systems are just as they are titled. They are systems which are used to locate people or devices in real time. These differ from RFID (radio frequency identification) systems which are often used to identify if a person or device crosses a certain threshold or portal. Oftentimes these two systems are referenced interchangeably, but they are not the same. However, the technologies used in RFID systems are often used in RTLS systems.

9.5.2 Active and Passive Systems

A RTLS may be either active or passive. Active systems are "locate-able", while passive systems are "track-able". Locate-able is when the real time location of the device is always known and in continuous contact. Track-able systems use sensors to determine last known location or choke point. The tag location is only known when it is close proximity of the sensor.

Active systems use battery powered devices, also known as "tags" or "beacons", which intermittently or continuously broadcast a signal. Active tags are used to accurately track the real-time location of assets, such as wheelchairs in a hospital. Active tags provide a much longer read range than passive tags, but they are also much more expensive.

Passive systems use tags that are powered by the electromagnetic energy transmitted from an RFID reader. Passive tags are used for applications such as access control cards, theft protection, pharmaceutical tracking, file tracking, event (race) timing, and more. The lower price point per tag makes employing passive systems economical for many industries.

9.5.3 Common Methods of Transmission

A RTLS may use one or more of the following technologies:

- RF (radio frequency): Tags transmit a signal every few seconds and RF receivers/antennas receive the signals and by using RF triangulation between multiple receivers, the device is located.
- Wi-Fi: Similar to RF, a wireless Ethernet signal is transmitted from the device and the wireless access points receive and locate the device via triangulation.
- Infrared: Infrared RTLS technology uses Infrared light to transmit and receive line-of-sight infrared light. Whereas RF and Wi-Fi signals can pass through walls and thus potentially falsely locate devices in adjacent rooms, IR technology provides a positive location within a room using only line-of-sight light waves. In many systems, both IR and RF (or Wi-Fi) is combined to provide a more accurate system.
- Ultrasonic: Another technology uses ultrasound signals instead of RF or IR signals. Similar to IR, ultrasound waves do not penetrate walls the way RF signals do so positive room location can be achieved.
- Bluetooth / BLE: Bluetooth or Bluetooth Low Energy (BLE) systems use a Bluetooth transceiver built into devices and can use triangulation to locate the transceiver. The potential use of Bluetooth for location includes smartphones and other personal electronic devices which have this technology integrated.

9.5.4 Uses

RTLS (and RFID) are used for a variety of industries for a plethora of use cases. Commons uses include:

HealthCare

- Work flow optimization (staff tracking and management)
- Pharmaceutical tracking
- Medical device loss protection and safety
- Equipment tracking and theft
- Wayfinding
- Patient tracking/wandering
- Infant Abduction

Manufacturing / supply chain / distribution

- Materials management
- Theft control
- Asset tracking
- Supply chain logistics
- Work-in-process tracking

Retail

- Wayfinding
- Theft deterrence / protection
- Customer experience/engagement
- Point-of-sale
- Supply chain logistics

10 System Integration

10.1 Overview

The integration of building systems allows various systems to share information, command, and control with a range of other systems, including:

- Data networks
- Building automation
- Fire-life-safety
- Energy and lighting management
- Automated infrastructure management (AIM) systems

Figure 10-1 shows an example how different building systems may be interconnected through a central location.

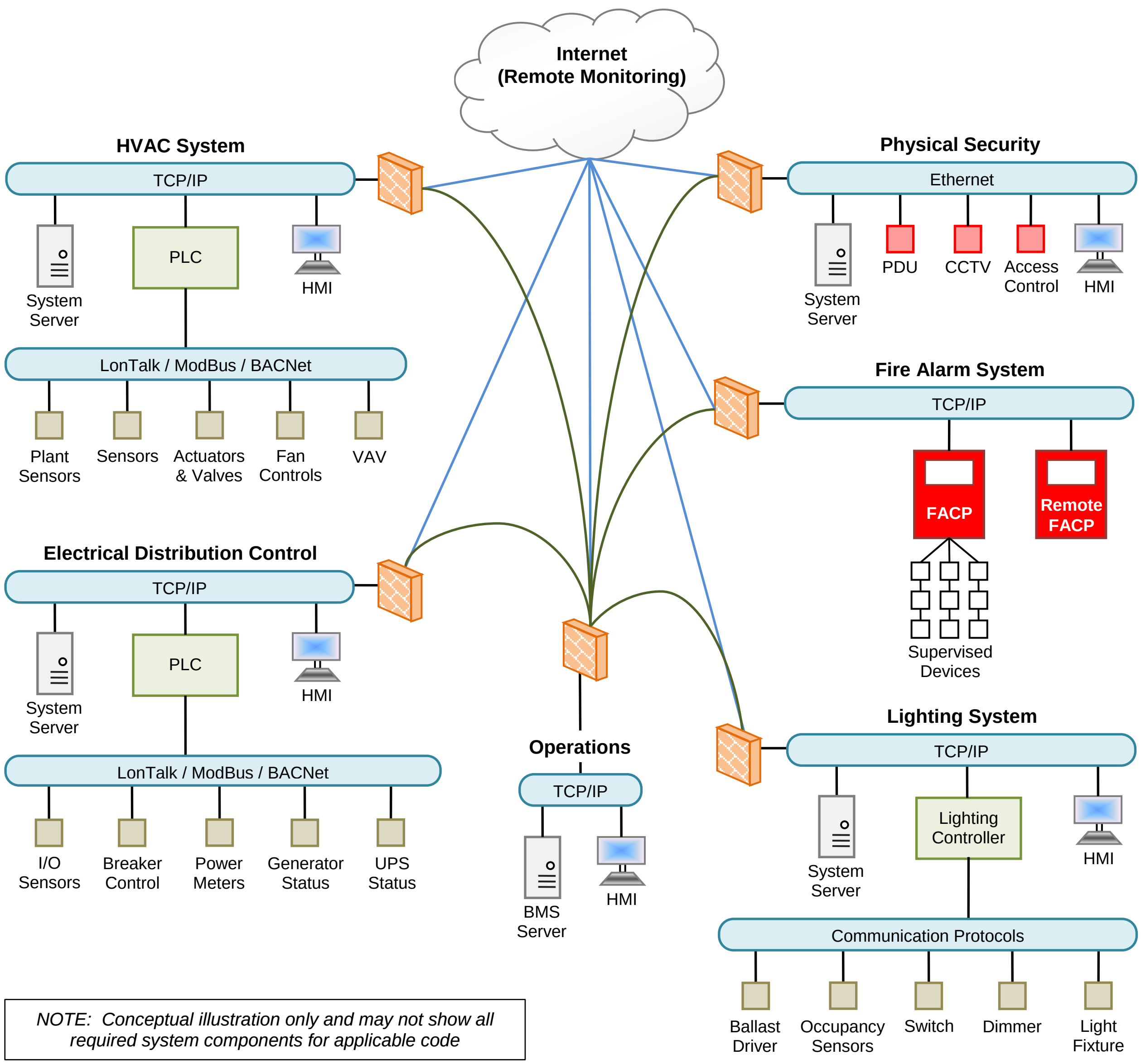


Figure 10-1
Example of Integrated Systems in a Building

Table 10-1 provides a matrix of commonly integrated systems. The list of possible system integrations is only limited by the capability of the system, code and regulatory issues, and the perceived value of the integration.

Table 10-1 Matrix of Common System Integrations

	Integrates With																		
System	*Data Network*	*Structured Cabling*	*Grounding System*	*VoIP*	*Wireless System*	*Video Distribution System*	*Audiovisual System*	*Access Control System*	*RTLS*	*Surveillance / CCTV*	*Intrusion Detection*	*HVAC / BAS*	*EMS*	*Lighting*	*Fire Systems*	*Building Transport (Elevator)*	*Facility Management*	*SCADA*	*HR Systems*
Data Network	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Structured Cabling	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Grounding System	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
VoIP	X	X	X	X	X							X				X			
Wireless System	X	X	X	X	X	X	X		X	X		X							
Video Distribution System	X	X	X			X		X		X									
Audiovisual System	X	X	X			X	X												
Access Control System	X	X	X				X	X	X	X	X								
RTLS	X	X	X		X	X	X	X	X	X									
Surveillance / CCTV	X	X	X			X	X	X		X									
Intrusion Detection	X	X	X					X		X	X								
HVAC / BAS	X	X	X	X	X							X	X	X	X	X	X	X	X
EMS	X	X	X									X	X	X		X	X	X	
Lighting	X	X	X			X						X	X	X	X	X	X	X	
Fire Systems	X	X	X				X	X		X		X	X	X	X	X	X		
Building Transport (Elevator)	X	X	X	X				X		X		X	X	X		X			
Facility Management	X	X	X									X	X	X	X	X	X	X	
SCADA	X	X	X		X				X	X	X		X				X	X	
HR Systems	X	X	X					X									X		X

10.2 Integrated Services, Design and Integration

10.2.1 Public Network Services

10.2.1.1 Introduction

Public network services are often referred to as the public switched telephone network (PSTN). This is the global network of circuit-switched telephone networks available to the general public. The PSTN consists of telephone lines delivering user services via some combination of infrastructure. This infrastructure includes optical fiber cabling, microwave transmission, cellular networks, communications satellites, and undersea telephone cabling, all of which is interconnected by switching centers (e.g., telephone company central office locations), thus allowing any telephony device (e.g., fixed line, mobile phone) in the world to communicate with any other such device.

The technical operation of the PSTN utilizes standards created by the International Telecommunication Union (ITU). These standards allow different networks in different countries to interconnect seamlessly. Industry standards provide for a global numbering system to assign telephone numbers. The interconnected networks and the global numbering system make it possible for any telephony device to connect to any other telephony device in the world.

Options for integrating with public network services are typically defined by the service provider. Examples include:

- Public switched telephone network (PSTN) (e.g., lease line service, message telephone service (dial-up) ISDN, DSL)
- Ethernet network (e.g., LAN/WAN)
- Cellular wireless (e.g., TDMA, CDMA, GSM)
- Mesh and Point-to-point (PTP) wireless (e.g., terrestrial microwave, satellite)

10.2.2 Design and Selection of Components

10.2.2.1 Requirements

The functional requirements provide the criteria for the design and selection of components. The criteria is categorized based on performance, operational and functional considerations and codes and standards. Criteria shall include:

- Codes and standards
- Quality
- Capacity
- Performance

10.2.3 Integration

10.2.3.1 Requirements

Integrated systems shall meet all requirements of all applicable codes and AHJs.

NOTE: Integration of systems with fire, life or safety systems may cause the integrated system to be classified as a fire, life or safety system.

10.2.3.2 Recommendations

Systems should be integrated using network protocols. The control systems of an integrated solution should employ:

- Web servers
- Graphical user interfaces (GUIs)
- Database technologies
- Software components (e.g., intelligent agents)
- Similar decision support and active response systems

10.3 Building Automation Systems (BAS) Interfaces with Other Systems

10.3.1 Fire Alarm Systems

BAS sequences that may be operated by the fire alarm system include:

- HVAC fan and damper control used to restrict the spread of smoke, heat, and fire through duct systems, minimize ignition sources, keep evacuation routes clear, and pressurize stairwells.
- Secured doors unlocked and powered doors released for manual operation during evacuation.
- Interior doors closed, but not locked, to prevent the spread of fire and smoke.
- Emergency power and standby batteries for the fire alarm, related systems operation, exit signs, and lighting for evacuation routes.
- Elevator capture and shutdown.
- Update BMS of status of BAS sequence(s) initiated by the fire alarm system.
- Display video or visual information on specified display(s) within the area of initiation of the alarm and routes of egress.
- Transmit information, procedures and site conditions specific to the type of alarm to all specified parties (e.g., emergency coordinator, site management, event responders).

10.3.2 Electronic Access Control System

This integration may involve components and devices offered by different manufacturers, or it may simply involve the integration of a single vendor security system with other BAS (e.g., lighting and access control systems).

Operational benefits include the sharing of database records (e.g., those associated with access control and security clearance) along with having only one integrated cabling system to administer. Additional database sharing may involve the fire safety system for the purpose of disabling secured exits (e.g., opening or changing to manual operation) from a building in the case of a fire emergency. The fire alarm system could initiate a sequence of events, which then changes the security system status for fire exit doors, allowing them to open for access to or egress from the building. Building management systems may have the ability to provide visual feedback via a graphic that secured exits have changed state in the case of a fire emergency.

10.3.3 Video Surveillance

Video surveillance is used in conjunction with security systems to generate video signals, control and transmit/display video signals, and store real-time video signals/alarm events. As part of BAS, video surveillance requirements should be considered.

10.4 Energy Management System (EMS)

An EMS reduces energy or electricity costs while providing an optimal and safe environment for the building occupants.

Some common strategies for the control and monitoring of power include:

- Scheduling (e.g., time of day or preprogrammed scheduling).
- Peak demand load shedding (e.g., variable or cycled control to minimize energy demand).
- Event-initiated control (e.g., preprogrammed responses to certain sets of conditions).
- Energy consumption and demand monitoring.
- Optimal starting and stopping of equipment.

A fundamental knowledge of electrical rates is needed to fully understand how an EMS can reduce energy costs.

Most utility companies base their monthly electricity charges for commercial users on two separate items:

- Consumption (e.g., kilowatt-hour [kWh])
- Demand (e.g., kilowatt [kW])

The consumption charge is based on the total amount of electricity used during the monthly billing period (i.e., total monthly kWh multiplied by the electrical rate in cents per kWh). For example, if a commercial building used 10,000 kWh of electricity in a month and the electrical rate was 10 cents per kWh, the monthly charge for consumption would be $1000. Demand is the peak rate at which electrical energy is used. Most utilities calculate the demand by measuring the electricity being used during any 15-minute interval during the monthly billing period. The highest of these 15-minute measurements establishes the peak kW the utility uses for billing. An example of typical demand charge billing can be shown by assuming a 100 kW peak usage of electricity in a month and a kW demand charge rate of $5 per kW. In this case, the demand charge billing for the month would be $500.

Most utilities also have other charges, including fuel adjustment charges, surcharges, and taxes, which are added to the basic electrical rates. Carefully planned EMS strategies can reduce all types of energy costs since they can reduce both consumption and demand.

To accomplish this goal, controllers can combine control, monitoring, and energy management functions to allow sensor and data file sharing and program coordination to:

- Improve HVAC system efficiency.
- Implement lighting control strategies.
- Integrate maintenance management and scheduling.
- Map loading of the specific system (e.g., information technology, manufacturing) utility demand to the building utility demand.

10.5 Integrated Energy Management and Heating, Ventilation, and Air-Conditioning (HVAC) Systems

In most midsized to large buildings, energy management is an integral part of the HVAC system with optimized control performed at the system level and with management information and user access provided by the BAS host. In addition to having cabled points associated with the HVAC equipment and work spaces to control energy usage, points for low-voltage relays that control power may be part of the motor control center, typically located in the main electrical room.

Energy management in the HVAC system is typically a function of the microprocessor-based DDC controller.

EMS functions are implemented with cabled analog/digital inputs/outputs and pseudo points that can be developed via:

- Computer statements that denote specific DDC operations to be performed in the controller.
- Mathematical functions.
- Time clock values.
- Separate program subroutines.

A network of microprocessor-based controllers ensures the HVAC equipment is operated at minimum cost and that temperatures are controlled for maximum efficiency within user defined comfort boundaries. Energy strategies encompass the entire mechanical plant and interface with other BAS systems, making network communications essential. Load leveling and demand control, along with starting and loading of the central plant, based upon the demands of air handling systems, require continuous system coordination.

HVAC energy management BAS host functions include the following:

- Efficiency monitoring and recording
- Energy usage monitoring and recording:
  - Energy summaries
  - Energy usage by source and time period
- On times, temperatures, and efficiencies by system, building, or area
- Curve plots of trends
- Map the loading of the ICT demands on the building’s or premise’s HVAC or utility system.
- Access to energy management strategies for continuous tuning and adapting to changing needs:
  - Occupancy schedules
  - Comfort limit temperatures
  - Parametric adjustments (e.g., integral gain) of DDC loops
  - Set point adjustments
- Duct static pressures
- Room temperature settings
- Economizer changeover values
- Water temperatures and schedules
- Modifying and adding DDC programs (on premises and remote)

A summary of EMS programs possible for integration into microprocessor-based controllers includes:

- Optimum start – Minimizes HVAC operating time by calculating how to achieve occupancy temperature at start of day (e.g., delays start as long as possible).
- Optimum stop – Minimizes HVAC operating time by calculating how long stored energy can maintain occupancy temperature at end of day (e.g., turns equipment off before quitting time).
- Night cycle – Maintains a low- or high-temperature limit during unoccupied periods by closing outside damper and cycling air handling unit.
- Night purge – Uses cool, night outdoor air to precool the building before mechanical cooling is turned on.
- Heat content – Selects the air source, a combination of return and outdoor air that requires the least total heat removal for cooling.
- Load rese – Assures that only the minimum amount of cooling or heating energy is used to satisfy load requirements.

List continues on the next page

- Zero energy band – Provides a dead band where neither heating nor cooling energy is used (e.g., space temperature floats between minimum and maximum values).
- Distributed power demand – Monitors electrical demand and shares demand with controllers by load shedding.
- Alarm monitoring – Monitors the functions of the operating systems and provides notification to personnel.

10.6 Automated Infrastructure Management (AIM) with Other Building Systems

10.6.1 Recommendations

AIM should be considered as an additional means to enhance the performance of other building systems. The following list of automated administration functions and features may be integrated into other building systems.

- Detect changes to patch cord connectivity
  Unauthorized changes to the patch cord connectivity should be detected and reported to the appropriate authority in real time. Real time event notification may be sent to the network manager using a variety of methods (e.g., email, text messaging, and SNMP traps). It is also useful to forward such events to network monitoring applications to enable a consolidated view of all activities on the network.
- Port status information
  All ports on the network including network equipment, switches, patch panels and telecommunication outlets should be monitored in real time for the purpose of detecting unexpected or unauthorized activities. Any port usage changes should be communicated to the network manager using variety of methods (e.g., email, text messaging, and SNMP traps.)
- Device alarms
  The AIM system should be capable of detecting and reporting device connection or device disconnection and identify the associated location. This information can be used to establish whether this is an authorized connection or disconnection in order to ensure the security of the network is not compromised.
- Security camera integration
  The AIM system should be capable of being integrated with security cameras, to activate these during unauthorized events and provide access to recorded content.
- Communication with other systems
  The AIM system should be able to communicate or exchange data with and consolidate information from other systems and databases. The information available to an authorized network manager should also be made available to an authorized program that needs AIM information.
- Emergency call origination location
  The AIM system should have the capability to be queried and report the location of a connected device based on a port and outlet connection. This location information may be utilized to enhance the ability of the voice/emergency response system to identify the originating location of a call.
- Secure communications and operation
  The AIM systems should protect itself from unauthorized access by using secure access to AIM components. This may include one or more of the following methods: log in security credentials at AIM access points, locked rooms/cabinets, access control systems for rooms/cabinets that contain AIM equipment, security cameras.

10.7 Vertical Transportation Interfaces In Intelligent Building

10.7.1 Building Management

Vertical transportation units are frequently interfaced to a building management system (BMS) within an intelligent building or premises. These units may consist of:

- Elevators (passenger and freight)
- Dumbwaiters
- Escalators
- Moving walkways

A BMS is typically used to receive status and alarm information from vertical transportation controllers. This information can include items such as:

- Main power on/off
- Unit operating/out of service
- Mode of operation (local/express, local/remote, change to direction of travel, etc.)
- Unit condition and emergency alarms,
- Unit component status

Typically, the vertical transportation controllers are interfaced either through a gateway device to the BMS or may be interfaced directly to the BMS via a serial or Ethernet data port connection. These connections can include types such as RS-422, RS-485 or modular connectors (e.g., RJ-45). A gateway device may be used to provide protocol and data connection conversions (e.g., serial to Ethernet) to provide a compatible interface to the BMS.

The BMS can transport vertical transportation control, status and alarm information either within the premises to areas such as security posts and on-site maintenance and repair personnel. Also, information can be transmitted off-site if contract maintenance is used, or can be used to notify on-call personnel during off-hour (nights, weekends, holidays, etc.) periods.

10.7.2 Changes in Operational Movement

Changes in modes of operation can be done remotely to address fluctuations in passenger traffic because of premises operating hours, peak passenger movement times and similar situations. Examples of changes include assigning elevator cars to serve in an “express function” or to stop escalators and moving walkways as part of an energy management program or to allow for routine maintenance to be performed during light traffic periods.

CAUTION: Site-applicable codes and the AHJ may not permit remote operations for the starting, stopping, or the direction reversal of some vertical transports (i.e., escalators, moving walkways). For these sites, these functions must be performed by an authorized person locally at one end of the transport. Some jurisdictions will permit remote stoppage, provided the transport can be brought to gradual halt from the normal operational speed to avoid injury to people that may be on the unit.

10.7.3 Fire Detection and Alarm System

In many areas, the AHJ and applicable codes (e.g., NFPA 72, NFPA 1221) require control interfaces between the building/premises fire detection and alarm system (FDAS) and the vertical transportation elements to address life/safety concerns. Typically, these interfaces are used for:

- Elevator recall – in the event of a fire alarm condition, elevators within a building or premises will be sent automatically to the lowest floor (typically surface or street level) and be placed in an out-of-service mode.
- Escalator/moving walkway shutdown– in the event of a fire alarm condition, units traveling towards a building or premise area with an active fire alarm condition may be stopped to assist in evacuation of the area in alarm.

An interface with the building management system (if present) may allow visual feedback via a graphic or video that elevators have recalled and other transportation systems have shutdown.

Interfaces between the FDAS and the vertical transportation unit controllers is normally done by direct connections between the FDAS and the controllers by dedicated supervised circuits under the sole control of the FDAS. Typically, the interfaces are arranged to require the following two-step restoration process, once the FDAS alarm condition is no longer active:

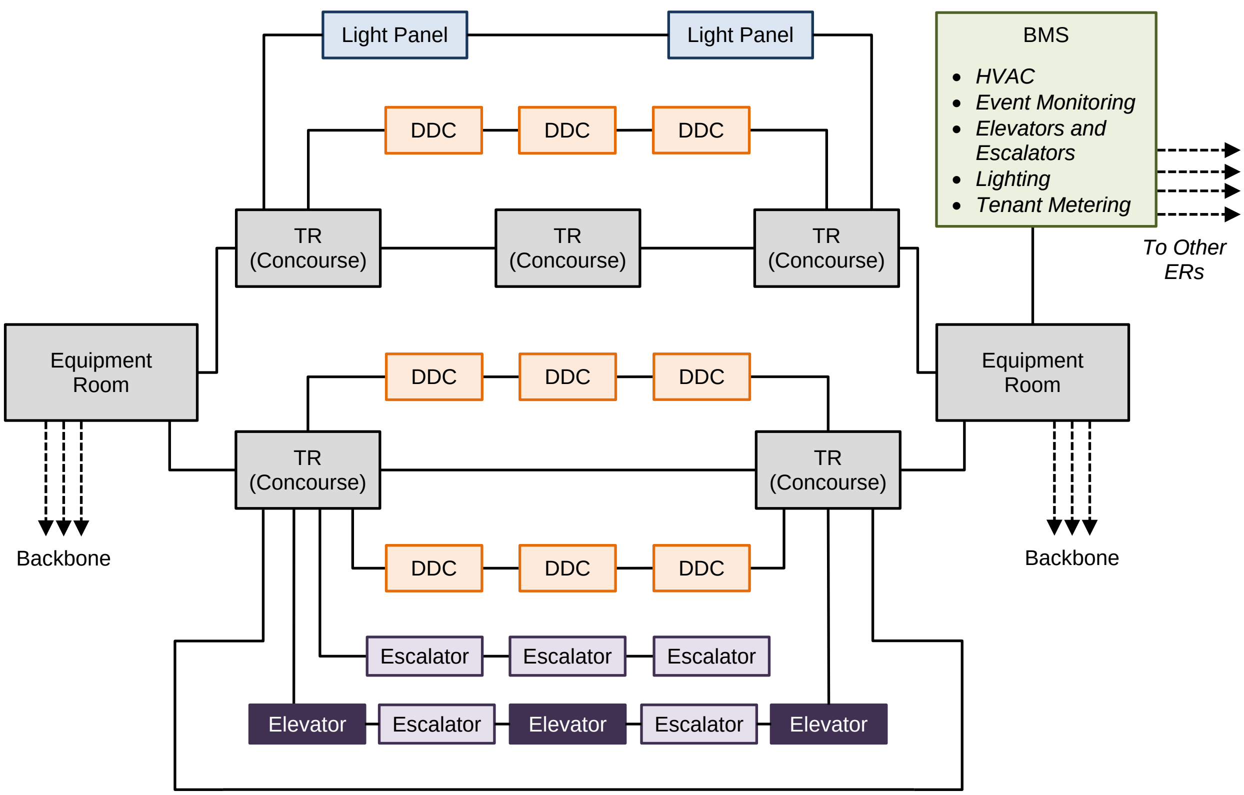
- Release the control circuits at the FDAS (usually performed by first responder or FDAS maintenance personnel)
- Restart vertical transportation unit operation, at the unit controllers,

Vertical transportation units have emergency override operations functions which are typically accessed through key-operated switches located at landings and within elevator cabs. This allows first responders to utilize these units for response, while still preventing general access from non-authorized personnel.

10.7.4 Security and Passenger Communications Systems

Vertical transportation units will typically have CCTV coverage of public areas for security monitoring. Additionally, emergency/assistance telephone and intercom units may be required by the AHJ to allow for passengers to request assistance or report an emergency situation while using, or attempting use of, a vertical transportation unit. Security and passenger communications systems will typically report to an on-site location for monitoring and response, or alternately, may report to an off-site location, particularly during off-hour periods. These systems may be stand-alone or integrated with the building/premises security and telephone systems.

NOTE: In all cases, interfacing with Vertical Transportation units requires careful coordination with the applicable design/engineering, vendor, contractor and maintenance personnel to ensure proper operation and response. Also, compliance with applicable AHJ requirements and codes (e.g., ASME A17 series) shall be adhered to.



Note: Direct digital controller (DDC) for thermostats, sensors, valves, and other devices

Figure 10-2
Simplified Example of a Transit Center Concourse with Multiple System Integration

10.8 A/V Room Automation

10.8.1 Overview

The activation of audio visual equipment can automatically control lighting levels, window shades, motorized screens and monitors, camera lighting, and A/V equipment. Within theatrical or media production spaces, (e.g., auditoriums, stages lecture halls, night clubs) it is common to integrate sound mixing boards, theatrical lighting control boards, dimmers, special effects devices, digital signage, intercom, and A/V equipment. Typical integration methods include:

- Infrared controls
- Contact closures or relays
- Serial (RS232 / RS485) protocol
- Network (IEEE 802.3.11) protocols
- DMX-512
- One-way communication input or output

Figure 10-3 shows a simplified example of an integration of lighting and a BMS with A/V elements.

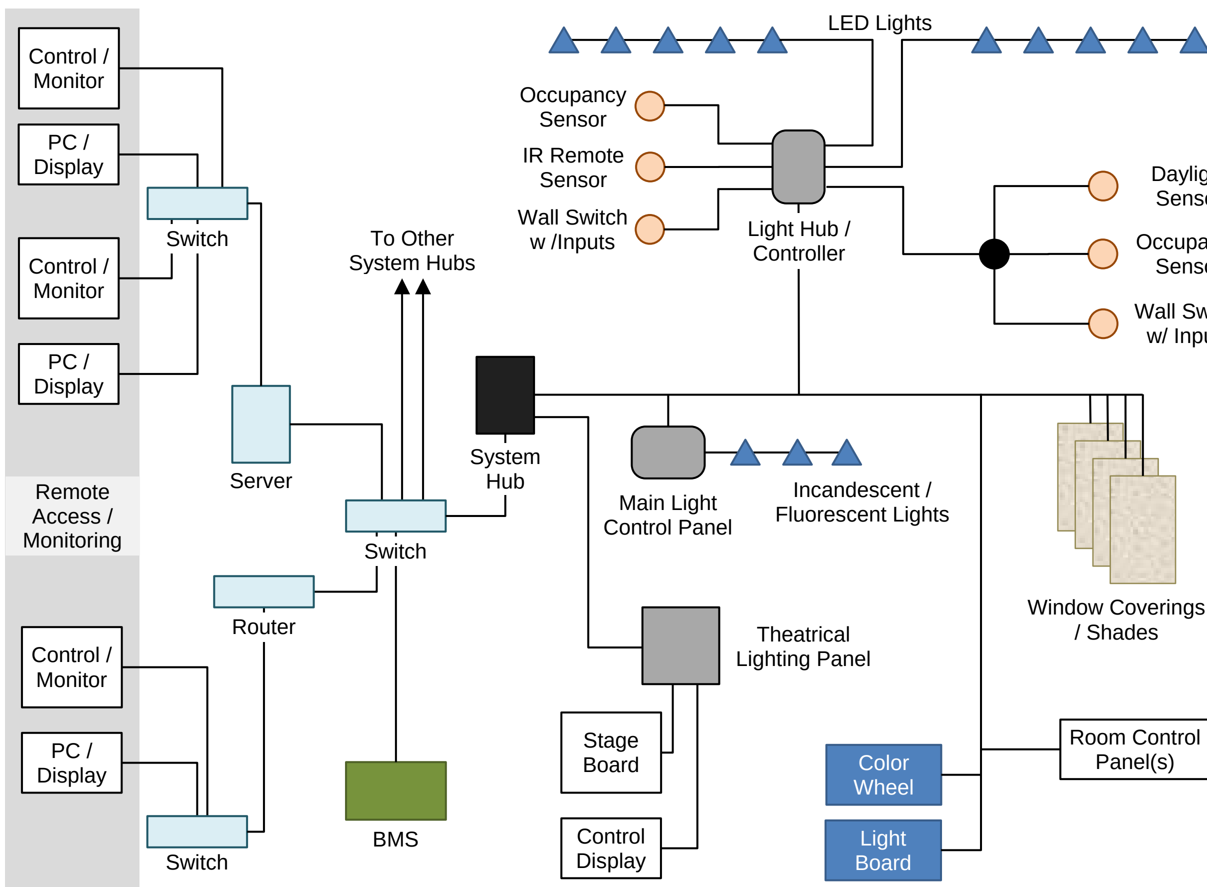


Figure 10-3
Example Integration with A/V Elements

10.8.2 Building Management Systems

Building management systems can provide individual room lighting level control, energy saving lighting control strategies, centralized control of lighting in multiple spaces, efficient monitoring of energy usage by lighting equipment, early detection of problems. Common integration methods include:

- Contact closures
- BACnet
- LonWorks
- Modbus

10.8.3 Strategies

The following strategies, when appropriately combined with cabled points, sensors, and energy management software, may reduce the energy demand and consumption of the lighting system in a facility:

- Task tuning / fixed power reduction
- Occupancy-based, time of day (e.g., load cycling), and on/off control
- Vacancy sensors
- Daylight harvesting
- Demand limiting (e.g., peak demand load shedding)
- Lumen depreciation compensation

Lighting controls depend on the occupancy of the space and type of tasks; consequently it is important to understand programing of spaces to install appropriate controls and provide adequate lighting levels.

10.9 Global Positioning System

10.9.1 Overview

Location systems such as a global positioning system (GPS) provide two kinds of information:

- Physical
- Symbolic

A GPS provides physical positions. A physical position may be augmented to provide corresponding symbolic information with additional information, infrastructure, or both. GPS uses space satellites as reference points for Earth locations. Distances are measured from a minimum of three satellites and are used in triangulation calculations. The exact locations are pinpointed using these calculations.

GPS tracking works on the following principles:

- The basis of GPS, which is triangulation from satellites.
- To triangulate, a GPS receiver measures distance using the travel time of radio signals.
- To measure signal travel time, GPS needs very accurate timing, which it achieves by applying special methods.
- Along with distance, the location of the satellites needs to be determined.

10.9.2 Requirements

Designs incorporating a GPS shall allow for correction to compensate for any delays the signal experiences as it travels through the atmosphere.

For proper communications, a robust, continuously connected wireless national data network is required. As an alternative communications link, a satellite network is required for areas where a ground-based wireless signal is weak.

10.10 Software

10.10.1 Overview

The functionality and reliability of an integrated system relies heavily on the system management software and underlying system software. The selection of the system and software is a critical step in purchasing and implementing a project.

Software poses the biggest risk to most integrators because of the lack of in-house capabilities to make modifications to the software beyond the standard configuration. An additional concern is the lack of access to the source code required for vendors to make changes to commercial off-the-shelf software platforms, or integrators to make changes to proprietary software platforms.

The development of an integrated system at the vendor level is often based on the current version of the database and operating system software available. The change from one operating system to another is a major undertaking by a vendor and of strategic importance in the marketplace.

There is often a tradeoff between delivering a system on the latest software platform and fielding a robust or reliable system. Some vendors offer choices in the database and operating software, and there are tradeoffs with any choice.

Similar to any technology-based product, significant problems may be encountered on systems deployed with recently released operating system platforms.

10.10.2 Databases

10.10.2.1 Overview

The selection of database software is typically based on availability from the hardware vendor or compatibility with existing systems, between integrated systems, or with client databases. Selections can be based on personal preference or experience of the integrator, client, or AHJ.

10.10.3 Control and Monitoring

10.10.3.1 Overview

Many vendors offer control or monitoring software in the form of an enterprise solution. This allows the control and monitoring of multiple server systems from a central location. Some vendors provide management software to facilitate the integration, control, and monitoring of individual systems. Other systems facilitate the integration of ESS, fire detection, building management, and human resources systems, amongst others.

10.10.4 Scalability, Resiliency, and Reliability

10.10.4.1 Introduction

The ultimate goal in selecting a software platform is to meet not only the current system needs but also the needs of the system in the future. This is particularly true of an installation for a new client or a client in a new facility.

Systems are often expanded during the installation phase or just after when the client begins to understand the system capabilities. Expansion plans for the facility and the procurement of additional facilities play a role in determining the long-term system requirements.

The procurement of additional facilities or the installation of systems in additional existing facilities may warrant an enterprise approach to facilitate single point monitoring and control.

The anticipated number of devices and users will be a deciding factor in the selection as well.

The criticality of the system operation and assets protected also determines the software selection. The need for a fail-safe system often requires the use of servers with robust storage solutions such as redundant array of independent disks (RAID) systems. The implementation of these scenarios now or in the future will have a significant impact on the selection of a software platform.

10.10.4.2 Recommendations

The system should have the capability of being scaled to meet the current and future needs of the client.

10.11 System Configuration and Expandability

10.11.1 Overview

Planning for expandability can be incorporated into the design process. Input and output points will be identified in the design, but additional inputs and outputs are usually required during the installation phase to accommodate additional sensors, functions, and modifications to the original design.

An error, such as not providing adequate motion detection or the presence of an unaccounted tamper switch, can be costly if the hardware and software do not have room for expansion. The addition of an inexpensive tamper switch may ultimately cost thousands of dollars, as it could require a power supply, or infrastructure to support the additional hardware.

The expansion capability of the system hardware is based on the as-built and future expansion capability. The as-built capability is the number of available physical connections, while the future capability is how much the system can be physically expanded by adding hardware. The physical layout of a system may also impact its ability to expand.

10.11.2 Input/Output Matrix

10.11.2.1 Introduction

The completion of an input/output matrix is a vital step in determining system expansion requirements for larger complex systems.

10.11.2.2 Requirements

The matrix shall be configured for a specific system and needs to contain the following basic information:

- Input or output type and number
- Processor or field panel number
- End device type (e.g., environment sensor, card reader) and number
- Zone number (input/output grouping)
- If an input or output is active 24 hours a day

10.11.3 Maps and Icons

10.11.3.1 Introduction

Maps and icons should be coordinated with the AHJ and end user to enhance the ability of the operator to monitor the system. The maps should be configured to provide an overview of the system and allow the operator to select or drill down into the submaps. Each alarm or event that needs a map display will need to be evaluated to determine the lowest level map to effectively display the location.

The display of a detailed map of a particular floor of a building may not suffice on a site with multiple buildings with similar layouts. The site map, or a portion thereof, may be the lowest level map to show the location of an event or alarm. The operator can then select the icon to display the detailed map.

The icon should readily display the status of an event or alarm and should change as the state of the associated device changes.

Another effective tool is to assign one icon per zone, area, or building on a site in a manner that allows the site map to provide an overall status view of the system. The operator can view one map to determine the status of a large area, while the submaps are only accessed to view particular devices.

10.11.3.2 Recommendations

The maps should be configured such that any additions to the system are readily incorporated.

System maps should be configured to match the expansion capability of the installed system hardware and reflect AHJ and end user inputs on future plans. The addition of event or alarm icons to the maps may necessitate a reconfiguration of the mapping system.

10.11.4 System Response Times

10.11.4.1 Requirements

The response times shall be calculated for peak use times. Distributed processing reduces the response times significantly.

10.11.4.2 Recommendations

The system response times should be calculated because they are an effective tool in determining the need for lighter system loading on a distributed system. The goal of system response times is to determine the processing and reporting times for alarms or system requests.

11 Commissioning

11.1 Overview

Commissioning is often one of the most neglected aspects of system installation. A system that is properly tested and commissioned will provide the designer, installer, and client with a system that functions correctly, meets the client's requirements, and can help foster a continuing professional business relationship between the designer and client for future work.

Commissioning a system should clearly identify real and potential issues with the system and the affiliated subsystems during all phases of the project.

Commissioning verifies that systems operate consistent with the contract and specification documents and includes:

- Operation and maintenance documentation
- Cleaning
- Labeling devices, cabling, and equipment
- Testing, adjusting, and settings
- Training for client personnel

Appendix A contains an overview and general fundamentals of the commissioning process, with the remainder of this section detailing further requirements and recommendations for specific elements of commissioning.

11.2 Plans

11.2.1 Commissioning Plan

11.2.1.1 Overview

Commissioning the intelligent building should account for the completion of all infrastructure and subsystems Timing must be considered in development of all documentation and planning of all testing activities. Activities completed in the wrong order may impact conducting and documenting all testing activities.

11.2.1.2 Recommendations

For some systems, system training should be scheduled to occur prior to testing, so the client can become more familiar with the system, assist with the commissioning, and allow for knowledgeable acceptance.

11.2.2 Preliminary Testing and Calibration Plan

11.2.2.1 Requirements

The plan shall include each device in the system. The plan shall be based on the manufacturer's standard written commissioning procedures and include the manufacturer's standard field checkout sheets as part of the final project documentation.

11.2.3 Acceptance Testing Plan

The acceptance testing plan will be used by the client during the final acceptance test as part of the turnover documentation.

11.2.3.1 Requirements

Testing documentation shall include full details of all commissioning tests as well as factory testing reports provided by the manufacturer with the equipment.

The plan needs to include checklists and procedures with specific areas for recording and documenting all tests and inspections and a summary statement and signature block at the end of the plan.

11.2.3.2 Recommendations

Clear acceptance testing guidelines should be provided in the construction specification documents. The guidelines shall define the performance requirements for the system.

The test plan forms and checklists should list any deficiencies and fully document the test results of each acceptance test performed. The client should also document all observed tests and create a punch list of deficiencies that need to be corrected and retested.

11.3 Documentation

11.3.1 Overview

Clients and contractors alike often overlook the importance of commissioning documentation, which is critical for the successful operation and maintenance of the installed system.

11.3.2 Requirements

Documentation shall be produced to support each phase of the commissioning process.

11.3.3 Record Drawings

11.3.3.1 Requirements

Record drawings indicating final configuration of the systems shall be included in project documentation and applicable operation manuals.

NOTE: Record drawings should be used and kept current throughout the life cycle of the system.

The record drawings shall also include the identification of each component and cable termination that corresponds with the cable labeling and component nameplates. Equipment loading schedules, clearly identifying terminations and spare capacity, are also a critical part of accurate record drawings that are invaluable in the maintenance and future moves, adds, and changes (MACs) to the system.

11.3.3.2 Recommendations

Record drawings should contain the manufacturer and model number of each component as well as its location and orientation, raceway, and cable tray locations and sizes.

11.3.4 Operation and Maintenance Manuals

11.3.4.1 Requirements

The operation and maintenance manuals shall include detailed installation, operating, troubleshooting, and maintenance procedures. Security contractors shall not simply submit manufacturers' user manuals as the required documentation. It is important that system contractors also prepare site-specific instructions for routine and emergency operations and maintenance.

Warranty cards or other documents that are required to be returned to the manufacturer shall be completed by the applicable contractor(s) and returned with copies within the final documentation given to the client. The manufacturers of each system component shall be listed along with contact details and part numbers, including any custom manufactured components.

Any certifications provided by the manufacturer that indicate compliance with any regulatory requirements, codes, or standards shall be included in the operation and maintenance manuals.

11.3.4.2 Recommendations

The operation and maintenance manuals should contain complete warranty information, including the client's responsibilities for maintaining the warranty in full force.

11.4 System Testing

11.4.1 General

Testing occurs in the stages described in the following subsections, with each section having additional requirements or recommendations.

11.4.1.1 Testing Requirements

Equipment shall be calibrated according to the manufacturer's recommendations and whenever damage is suspected. Calibration certification shall be kept on record and copies for each tester provided in turnover documents.

11.4.1.2 Testing Recommendations

Test equipment should be of an accuracy required to test system performance within the tolerances specified by the construction and manufacturer's documents. Generally, the accuracy of any sensor should be at least twice that of the device being tested.

11.4.2 Preinstallation Testing

11.4.2.1 Overview

Preinstallation tests may reveal components that have been damaged in shipment and need to be replaced. Some subsystems may have components that have been pretested prior to installation. Examples of such subsystems are operable vehicle barriers, gates, and other major subsystems.

11.4.2.2 Recommendations

Components (e.g., cameras, sensors) also should be run through a quick functional test prior to installation. Systems that require calibration or adjustment can be serviced in the shop instead of in the field.

11.4.3 Preliminary Testing and Calibration

11.4.3.1 Requirements

Each critical point shall be tested. For example, for intrusion detection and video camera call-up and recording:

- Video cameras shall be tested for resolution, light sensitivity, focus, and where applicable, pan, tilt, and zoom (PTZ) control.
- The graphical user interface system response shall be tested for functionality.
- Intercom systems shall be tested for proper operation as well as sound quality. This is followed by a burn-in period.

11.4.3.2 Recommendations

Systems and subsystems should be thoroughly tested and all adjustments and calibrations completed prior to the start of final acceptance testing. This includes the testing of each individual device or component for proper operation and system response. Some examples are testing each access control device for door prop alarms, forced door alarms, and valid and invalid card reads.

11.4.4 Burn-in Period

11.4.4.1 Recommendations

Prior to scheduling the final acceptance test, the commissioning technician should power up and operate each of the systems during a burn-in period. During this burn-in period, each system should be powered and operate for an entire day. A burn-in period could be 2–14 consecutive days or based on client requirements. Any faults, errors, and noncompliance issues should be corrected prior to beginning the final acceptance testing. The acceptance test should be performed after the successful completion of the burn-in period. Any components that are replaced also should be subject to a burn-in period.

11.4.5 Acceptance Testing

11.4.5.1 Overview

All points, (e.g., access control points, intrusion detection points, video cameras, intercom systems) require testing and observation to ensure they operate as required in the construction documents.

11.4.5.2 Requirements

Acceptance testing is to be complete and test documentation approved by the client prior to the project completion.

In order to account for all lighting conditions, video cameras shall be examined during the day and at night.

11.4.5.3 Recommendations

Acceptance testing should be performed after the completion of a successful and complete system burn-in period. As with preliminary testing, acceptance testing should include testing individual devices for proper operation and proper system responses.

Acceptance testing may also include a “defeat the system” test to demonstrate there are no potential shortcomings within the hardware and software system that would compromise the integrity of the system under normal operating conditions.

11.4.6 Retesting Equipment and Systems

The commissioning technician will need to correct any deficiencies identified by the client. Upon completion of all corrections, the equipment shall be retested to demonstrate proper operation, integration, and performance. The contractor should provide all the labor and materials required for any necessary retesting. Verification of proper system operation and performance should be completed during the preliminary testing stage to avoid retesting. Construction documents should identify the party responsible for the client's costs to supervise and observe any retesting of failed system components.

11.5 Additional Commissioning Tasks

The hardware and software installation shall be inspected both visually and electrically. The items most commonly subject to verification during commissioning ensure that:

- The system has been installed in accordance with the specifications and drawings and follows the manufacturer's recommendations.
- Record drawings are completed and provided to the architect and engineer for use during testing.
- All test reports are given to the architect and engineer for review.
- Headend equipment and intermediate equipment are installed as indicated in the project documents. If this was a direct sell to the end user without documentation, at a minimum, lockable cabinets should be installed within communications equipment rooms (ERs). They shall be kept separate from the other devices housed in the ER.
- All cabinets are clean inside.
- System software licenses have been provided for the specified number of equipment and personnel.
- An equipment matrix has been developed, and all information has been properly programmed.
- Directories for each panel, listing the card reader interface slot locations, names, and utilized channels, are provided.
- All low-voltage cables are installed in conduit, boxes, and locked enclosures when required and meet all applicable codes.
- All enclosures, panels, and field equipment are properly labeled.
- All cable and termination points are properly labeled. Tag numbers on record drawings also should be provided.
- All hardware is properly installed and meets the manufacturer requirements for installation.
- All power supplies are hardwired. Plugs should not be used unless indicated in the drawings or specifications.
- Checking all electrical circuits of the various devices for proper wiring polarity, grounding (earthing), and activation. A designer should ensure that proper battery backup is installed to provide operation for a specified period of time during power outages. Test the system with a simulated power failure to verify operation of power backup and establish that all fail-safe criteria are being met.
- Systems that might perform differently under various weather conditions should be tested to the fullest extent possible under all conditions.

A "defeat the system" test may be required by a client to verify system hardware and software integrity prior to acceptance of the system.

If any failures in the electrical or mechanical operation of the system are noted, a retest is needed. A corrective action plan should be created and a retest performed, with passing results once obtained added to the documented file.

During the system's operation, all event logs should be regularly analyzed, and repeat events should be decreased or eliminated. System performance should be retested periodically to ensure that all functions comply with the original specifications.

Installation companies should be aware that equipment warranty periods are an opportunity to make required adjustments to systems and components. Additionally, operation and maintenance manuals, as well as the record drawings, should be updated to reflect any modifications made during the warranty period.

A final warranty walk-through should be undertaken in the last quarter of the warranty period to correct any deficiencies and make required adjustments to the system.

11.5.1 Cleaning

11.5.1.1 Overview

A major task in commissioning systems is the cleaning and removal of dust, dirt, and temporary covers.

11.5.1.2 Requirements

All devices and enclosures, including those used in outdoor applications, shall be inspected to ensure the finish has not been damaged during the installation. The cleanliness of the system shall be maintained by the contractor until the date of completion and final acceptance by the client for all of the work.

11.5.1.3 Recommendations

All foreign debris should be removed from the equipment and enclosures. The cleanliness of outdoor mounted video surveillance camera domes is extremely important and should be regularly maintained.

11.5.2 Labeling Components

11.5.2.1 Overview

Labeling the equipment and cables is a vital part of system commissioning. Labeling will support the relationship between components and as-built or record drawings and prove their value in future repair, troubleshooting, or MACs of a system.

11.5.2.2 Requirements

Components require labeling with identification numbers or letters that accurately correspond to the drawings. Cables shall be marked with machine-printed permanent labels at each end. Cables and terminations should be marked in accordance with applicable standards (e.g., ANSI/TIA-606-C, ISO/IEC 14763-2).

Labels and identification plates affixed to rack- or wall-mounted equipment shall be located where readability is not impaired. Electrical circuits feeding equipment shall be clearly identified at electrical receptacles, junction boxes, and distribution panels.

11.5.2.3 Recommendations

Enclosures and other large components typically should have engraved plastic or metal identification plates.

11.5.3 Training

Typically, the system training is the responsibility of the system's integrator or installation contractor. Further information on training can be found in Appendix B.

This page intentionally left blank

Appendix A Commissioning Fundamentals (Informative)

This appendix is not part of the requirements of this standard, but it is included to provide additional information related to this standard.

A.1 Overview

Commissioning is often one of the most neglected aspects of system installation. A system that is properly tested and commissioned will provide the designer, installer, and client with a system that functions correctly, meets the client's requirements, and can help foster a continuing professional business relationship between the designer and client for future work.

Commissioning a building system should clearly identify real and potential issues with the building system and the affiliated subsystems during all phases of the project.

A.2 Terminology

Definitions and acronyms that apply specifically to commissioning follow below and only apply to the commissioning section of this standard:

BoD	basis of design
BOM	building´s operational manual
CxA	commissioning agent
CxP	commissioning plan
CxT	commissioning team
DT	design team
O&M	operation and maintenance
OPR	owner´s project requirements
MAC	moves, adds and changes
PM	project manager
RFI	request for information

basis of design (BoD) Documents that are generated by the design team, where it is given specific response to meeting the owner's project requirements in each of the fields of application. They must comply with the laws, codes, regulations, rules and standards.

commissioning (Cx) A quality assurance process that confirms that building´s systems have been designed, constructed or installed correctly, tested and consistently started, documented and operated in strict accordance with the requirements stated by the owner for a contracted execution building project.

commissioning agent (CxA) Agent may consist of one or more individuals with proven experience in accordance with the provisions of the basis of design and is jointly liable with the owner to monitor the technical processes of each of the work areas involved.

Note: Some municipalities / regions / states/countries accept the commissioning agent as a legal AHJ

commissioning plan (CxP) Document prepared by the commissioning agent and approved by the owner, that provides a structure, schedule and coordination plan for the commissioning process from the design phase to the warranty period. The commissioning plan must satisfy owner project requirements, and establish the roles and responsibilities of commissioning´s team members.

commissioning team (CxT)	Composed of representatives of the owner, project manager, operation and maintenance, design team (architecture and engineering), general contractor and subcontractor, testing, tuning and balancing personnel, manufacturers, commissioning agent, civil protection and all others involved with the commissioning plan.
compliance data sheets	Documents issued by the manufacturer with the technical details and specifications of systems or components, which must be approved by the design team for releasing purchase by the contractor.
construction documents / executive project	Set of documents issued by the design team based on the owner's project requirements, used for contractors to carry out their economic proposal and run the installation or systems.
continuous commissioning	A systematic commissioning process that continues throughout the building´s life cycle.
contractor and subcontractors	The company or group of companies responsible for the Building Construction with all its facilities, components and systems.
deficiency	Condition of a component, piece of equipment or system that is not in conformity with the owner's project requirements.
design team (DT)	All technical consultants who bring their intellect in the conceptual development of the building, such as architects, engineers, etc. in all disciplines and other technical involved areas.
factory tests	Tests that are made to the equipment at the factory by the manufacturer's personnel. Testing may be done in the presence of owner's representative, as deemed necessary.
functional test	Tests that assess the operation of the equipment and systems installed by the contractor, and may assess: startup and commissioning, compliance values, tolerances, manufacturer's specifications, codes, and rules and standards. The testing performed is typically defined in the owner's project requirements, basis of design as well as the construction documents.
incident log	The collection of any addition, modification or change in the status of the project in stages until the formal start of its operation, and must include the cause, responsible and resolution.
integral system testing	Performance testing and operation of systems to ensure they work in a coordinated manner and properly according to manufacturers' specifications, codes, rules and standards. The testing performed is typically defined in the owner's project requirements, basis of design as well as the construction documents.
operational building manual (OBM)	Documentation that includes all system operating processes and includes all building information from the owner's project requirements up to its implementation.
owner	Refers to but is not limited to the person, company or government entity that legally owns a property without limitation.
pre functional tests	Verification procedures for ensuring that equipment, components and accessories of a system were installed according to the manufacturers' specifications, codes, rules and standards.
pre functional verification check list	A list of visual inspection and component material, and testing to ensure proper installation of the equipment (e.g., belt tension, oil levels, set tags, calibrated sensors). Pre functional word refers to pre-functional tests. These should include checklists by the manufacturer.

seasonal commissioning A systematic commissioning process that is performed in different seasons (e.g., summer, winter) depending on building´s latitude, longitude, altitude.

seasonal / periodic tests Those tests that assess the performance and operation of systems to ensure they work in a coordinated manner and properly according to manufacturers' specifications, codes, rules and standards. They confirm the status of its components prior to the expiration of their guarantees.

submittals Technical documents to be approved by the design team and commissioning agent. They must comply with owner's project requirements.

testing requirements Documents with system specifications, modes, functions, conditions, etc., to be tested. These are not detailed testing procedures.

A.3 Personnel and Responsibilities

The following commissioning process responsibilities scheme may change depending on applicable law, codes, and standards for the site.

A.3.1 Project Owner

Is responsible for:

- Hiring and paying commissioning agent (CxA) and design team.
- Promptly informing all participants involved in the design, construction and operation to start a commissioning process at once.
- Working together with the CxA and the design team to issue requirements for the OPRs and documents in the process, e.g., building´s classification programs –LEED, UTI, ECoC, BREEAM
- Establishing a representative in the CxT with authority for decision-making.
- Authorizing moves, additions and changes (MACs) in the OPRs based on the results of the commissioning process.
- Receiving and accepting reports of periodic visits and registration of incidents during the work. Participating in the training process.
- Receiving and authorizing the building once the final report of the commissioning process is completed.

NOTE: Because of the size of some projects, the owner hires the services of a project manager (PM) to act as the owner's representative. The PM must notify the design team and the CxA of any MACs that affect or change the OPRs

A.3.2 Design Team (DT)

Is responsible for:

- Developing and delivering the BoD according to the OPRs.
- Developing and providing documentation of each system design included in the design contract according to the OPRs and the corresponding executive project/construction documents.
- Developing and delivering coordination drawings of the facility´s systems.
- Developing and delivering the moves, additions and changes (MACs) in the design/construction documents based on the results of the commissioning process and the scope of the contract.
- Establishing a representative in the CxT.
- Working together with the CxA and Owner to issue requirements for OPRs. Must participate in Cx meetings, including those held during functional testing process.
- Reviewing and approving the submittals and responding to RFIs concerning the technical specifications and manufacturers' manuals for the construction stage of each system to be designed.
- Working with the CxA to set parameters, ranges, tolerances and performance measurement systems.
- Informing and notifying the owner and CxA of the results of the evaluation (technical and resources) of any MACs that affect or change the OPRs.
- Plan must follow the commissioning best practices and requirements for the completion on time and Budget.
- Must attend to all Cx team meetings.

A.3.3 Commissioning Agent

The commissioning agent is the person who has the knowledge, skills and experience to plan, perform and execute a plan of commissioning in one or more of the systems susceptible commissioning in a building. The commissioning agent is responsible for:

- Working together with the owner and DT team to issue requirements for OPRs and the MACs that must be approved by the owner.
- Working with the design team to develop the feasibility studies and the project schedule.
- Developing the commissioning plan (CxP) and attached documents.
- BoD review to ensure compliance with the OPR. Reviewing the plans and specifications for the planning and design phases.
- Planning, organizing and ensuring the Cx processes, attends and coordinates Cx team meetings.
- Ensuring Cx process activities are clearly specified throughout all processes.
- Identifying and integrating the commissioning process activities within the project schedule.
- Reviewing, in conjunction with the design team, contractor and subcontractors manuals and manufacturers' compliance with the BoD to integrate the BOM.
- Documenting and tracking all deviations from the OPRs and keeping track of incidents with the resolutions-incident log.
- Preparing the Cx process progress reports and the closing report of the commissioning process of each stage with recommended actions as well as the final report of commissioning to the Owner.
- Ensuring the final design executive project/construction documents of each specialty can be commissioned.
- Coordinating the review and approval by the design team of the technical specifications and compliance of each system.
- Conducting periodic visits to the work site to ensure quality by issuing the corresponding report, which can be supplemented with documents to ensure compliance with the design. The visit reports should include a checklist and track incidents arising during the work, with the solutions to them and the allocation of those responsible for carrying them out.
- Issuing formats for pre-functional and functional tests described in this document, which must be approved and used by the commissioning team.
- Validating the information in the pre-functional tests once the contractor and subcontractors have completed them.
- Organizing, coordinating and witnessing the functional tests and performance final tests of systems.
- Checking that required technical training for operation and maintenance personnel is conducted by contractors, subcontractors and equipment manufacturers.
- Checking that required user training on the operation of the systems is carried out.
- Integrating the operations manual of the building (OEM) gathering information by the contractors and with the commissioning team, coordinating the operation and maintenance of all systems.
- Issuing the final report of the commissioning process for acceptance by the owner.
- Preparing the plan of continuous commissioning at the request of the owner.
- The plan must follow the commissioning best practices and requirements for completion on time and within budget.
- Must attend to all Cx team meetings.

NOTE The commissioning agent (CxA) is not responsible or liable for the concept design, design criteria, compliance with codes or national and international standards, the general program of work, the cost estimation and management / administration the work.

A.3.3.1 Recommended Requirements For Commissioning Agent

A.3.3.1.1 General

- The CxA must have a management structure that allows it to maintain the capability to perform the functions with technical quality.
- The CxA must be legally constituted.
- The CxA must have a quality management system and updated documentation.
- The CxA must have a code of ethics or conduct and enforce it with the appropriate staff.
- The CxA must avoid conflicts of interest with persons or organizations with which they have direct business relations in the work for which it has been contracted.

A.3.3.1.2 Personal

- The CxA must ensure that personnel assigned to provide temporary or eventual commissioning services has the academic standards for the class and category of interest; staff must possess professional license and / or certificate based on competency standards, as appropriate.
- The CxA must comply with the job description for each class or category, including the requirements for education, training, skills, expertise and experience.
- The CxA must comply with health and safety regulations.

A.3.4 Contractor and Subcontractor

Is responsible for:

- Installing systems based on the final design and scope of its contract.
- Proposing, performing and recording all moves, additions and changes (MACs) in the installation of the systems of their responsibility in coordination with the design team and the scope of its contract.
- Submitting to review and approval by the design team, the technical specifications of compliance, diagram detail and shop drawings of each building system (submittals).
- Updating equipment according to the approved technical specifications.
- Addressing the report's findings of incidents and regular visits to work based on the conditions set out in the commissioning plan (CxP).
- Conducting tests with qualified personnel according to the formats established in the CxP; it must provide necessary equipment or instruments with current calibration according to the CxP´s specifications.
- Carrying out the training plan for the owner´s operation and maintenance (O&M) staff and system´s users installed under the scope of its contract. (e.g., voice, data, video systems).
- Updating the building operational manual (BOM) in coordination with the CxA and O&M personnel.
- Preparing the O&M plan of installed equipment in coordination with the CxA and O&M personnel.
- Witnessing, in conjunction with the CxA, seasonal Cx to conform to the O&M plan.
- The plan must follow the commissioning best practices and requirements for completion on time and within budget.
- Must attend to all Cx team meetings.

A.3.5 Operation and Maintenance Staff (O&M)

Is responsible for:

- Setting the O&M needs of each system under their responsibility so they will be included in OPRs.
- Witnessing testing procedures based on the formats established in the CxP.
- Assisting and providing an acceptance document of the training received by the contractor(s).
- Receiving and revising the building operations manual (BOM).
- Revising, supplementing and approving the operation and maintenance plan for all installed equipment in coordination with CxA.
- Performing the systems´ seasonal recommended testing to all systems. Where appropriate, carrying out the continuous commissioning plan.
- Supervising, monitoring and executing the operation and maintenance of the systems according to plans received. Monitoring and evaluating the performance of systems delivered by contractor(s).
- Its plan must follow the commissioning best practices and requirements for the completion on time and within budget.
- Must attend to all Cx team meetings.

A.4 Commissioning Process Stages

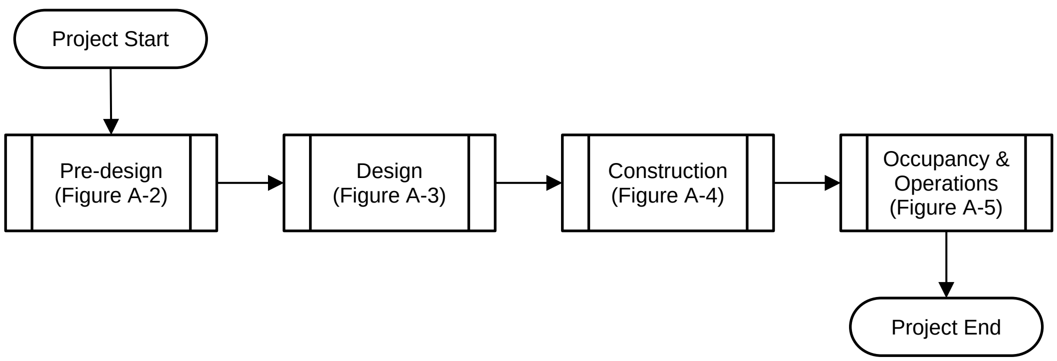


Figure A-1
General Commissioning Phases Flow Chart

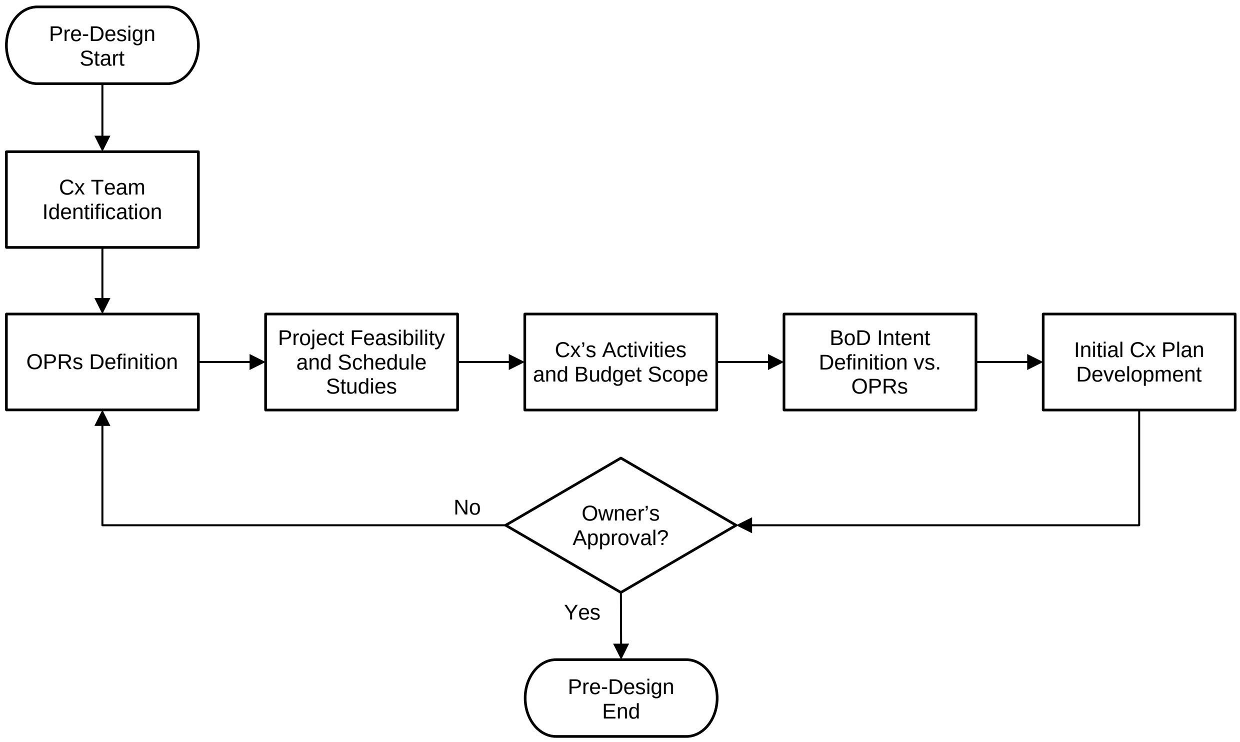


Figure A-2
Pre-Design Commissioning Phase Flow Chart

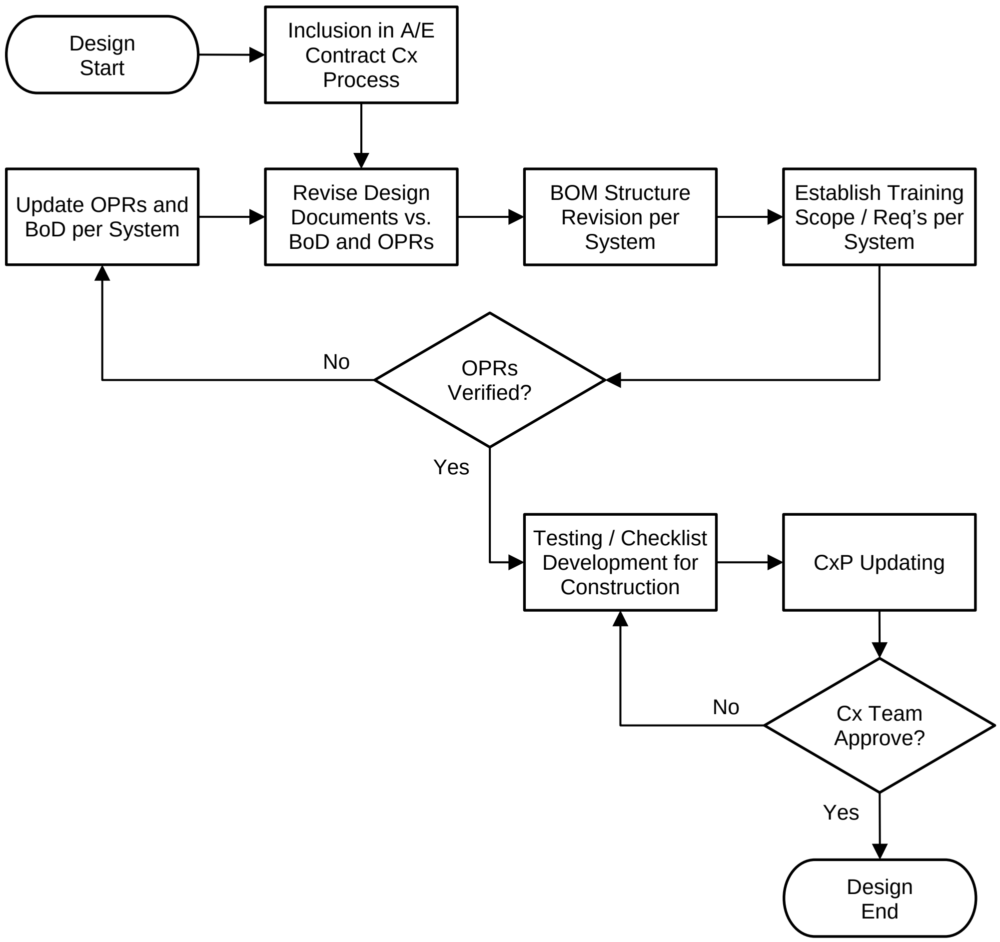


Figure A-3
Design Commissioning Phase Flow Chart

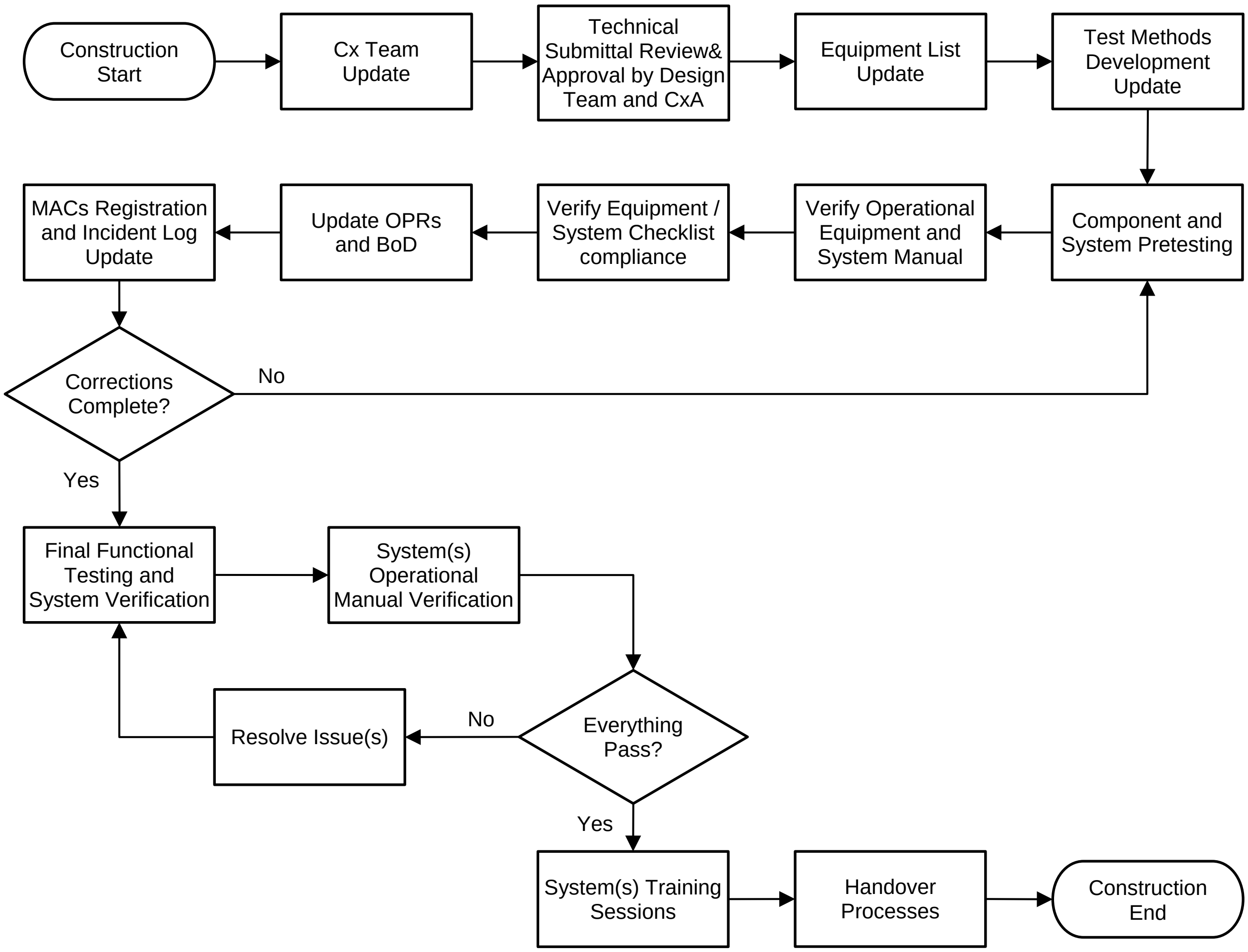


Figure A-4
Construction Commissioning Phase Flow Chart

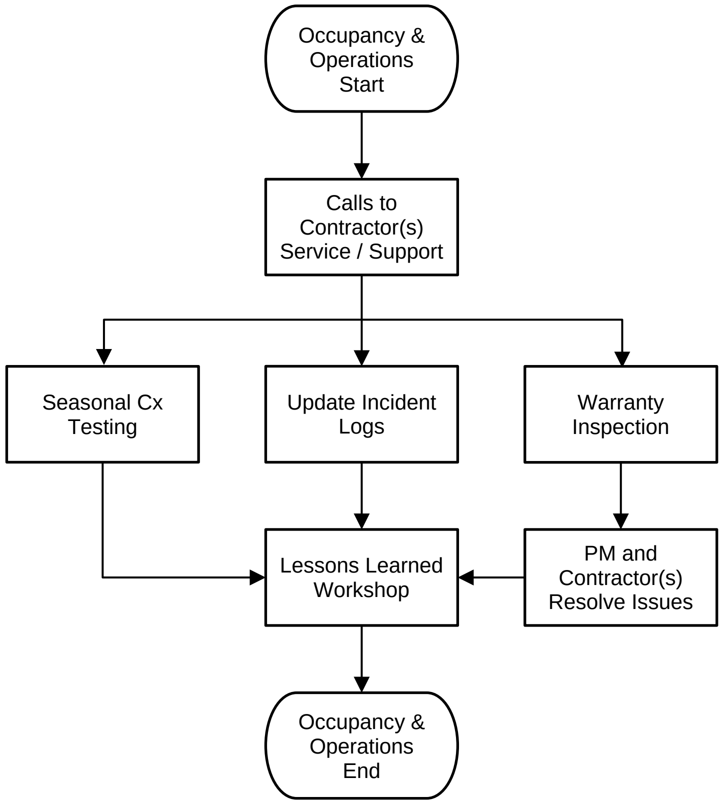


Figure A-5
Occupancy and Operations Commissioning Phase Flow Chart

A.5 Commissioning Process Documentation

Table A-1 Commissioning Documentation Matrix

Stage	*Document*	*Required by*	*Issued by*	*Revised / Approved*	*Used by*
Pre - Design	Owner´s Project Requirements (OPRs)	Users, O&M, Owner, CxA	Owner, CxA	Owner	CxA, CxT
	Cx Feasibility Study	Owner, CxA	CxA	Owner	CxA, CxT
	Commissioning Plan (CxP)	Owner, DT, CxA	CxA	Owner, DT	Owner, CxA, CxT
	Incidents Registration(log)	CxA	CxA	N/A	CxA, CxT
	Cx Pre-design Stage Process Report	CxA	CxA	Owner	Owner
Design	OPRs update	Users, O&M, Owner, DT	CxA or DT	Owner	CxA, CxT
	Bases of Design (BoD)	DT	DT	CxA	CxA, CxT
	Design Revision and Observations	CxA	CxA	Owner	DT
	Cx´s for Construction specs	Owner, DT, CxA	CxA, System(s) Designer	Owner, CxA	Contractor(s), CxA, DT
	Building Operational Manual (BOM) Index revision	DT, CxA, O&M Contractor(s)	CxA, System(s) Designer	Owner, CxA	DT, Contractor
	Training Needs Alignment / O&M	O&M, User, CxA, DT	Owner or CxA	Owner	DT
	Construction Pre- Functional Tests scheme and checklist	DT, CxA	CxA	CxA, DT	Contractor(s)
	Incidents Registration(log)	CxA	CxA	N/A	CxA, DT
	Cx Plan Update	Owner, DT, CxA, Contractor(s)	CxA	Owner, DT, CxA, Contractor	Owner, DT, CxA, Contractor
	Design Cx Report Stage	CxA	CxA	Owner	Owner, DT
Construction	OPRs Update	Owner, User, DT, CxA, Contractor(s)	Owner, CxA	Owner	CxA, DT, Contractor(s)
	BoD Update	DT	DT	CxA	CxA, Contractor
	Cx Plan update	Owner, DT, CxA Contractor	CxA	Owner, DT, CxA, Contractor(s)	Owner, DT, CxA, Contractor(s)
	Technical Components, Equipment, Systems (Submittals) Revision and Approval Process	Contractor(s)	Contractor(s)	DT, CxA	Contractor(s)
	Equipment list(s) Update	Contractor(s)	Contractor(s)	DT, CxA	Contractor(s)
	Systems Cross Coordination Drawings	DT, Contractor(s)	Contractor(s)	DT, CxA	CxA, Contractor(s)
	Construction Cx Checklist(s)	DT, CxA, Contractors	CxA	DT, CxA	Contractor(s)
	Supervision Reports	Contractor(s)	CxA	Owner, CxA	CxA, Contractors
	Cx Testing Process	DT, CxA, Manufacturer(s)	CxA	DT, CxA	Contractors

Table continues on the next page

Stage	Document	Required by	Issued by	Revised / Approved	Used by
Construction	Pre-functional Testing Reports	Contractors	CxA	Owner, CxA	Contractor(s)
	Cx Meeting and Documentation	CxA	CxA	All	All
	Training Plan	CxA, O&M Contractor(s)	Contractor(s) Manufacturer(s)	Owner, CxA	O&M, User(s) Contractor(s)
	BOM As-Built	CxA, O&M, Contractor(s), Manufacturer(s)	Contractor(s)	Owner, CxA	O&M, User(s)
	Maintenance Plan	O&M, CxA Contractor(s)	Contractor(s)	Owner, CxA	O&M, User(s)
	Incident Registration (log)	CxA	CxA	N/ A	CxA, DT, Contractor(s)
	Cx report Construction stage	CxA	CxA	Owner	Owner
Occupancy / Operations	OPRs update	Owner, O&M, Users, CxA	DT	Owner, CxA	CxA, DT, Contractor(s)
	Building Operations Manual (BOM) Update	CxA, O&M, Contractor(s)	Contractor(s)	Owner, CxA, O&M	O&M
	O&M Program Update	O&M, CxA, Contractor(s),	O&M	Owner, CxA	O&M, End Users
	Seasonal Testing Process	O&M, CxA, Contractor(s),	Contractor(s)	CxA, O&M	Contractor(s)
	Final Test Reports	O&M, CxA	Contractor(s)	CxA, O&M	O&M, Contractor(s)
	Incidents Registration (Log)	CxA	CxA		Owner, CxA, DT, Contractor(s)
	Cx Process Reports	Owner	CxA	Owner	Owner
	Continuous Cx Plan	CxA, O&M, User(s)	CxA	Owner	Owner, O&M

A.5.2 Owner Project Requirements (OPRs)

This document details the functional requirements of a project and the expectation of how it will be used and operated. It is the base from which all decisions of design, construction, acceptance and operation should be made. It is a living document and can change throughout the entire process of commissioning and must include at least:

- Owner´s directives
- User´s requirements
- Occupation schedules
- Quality of materials and construction
- Indoor environment quality
- Automation control systems
- Performance criteria
- Environmental and sustainability goals
- Energy efficiency goals
- Comparison of performance requirements
- Adaptability to change
- Health and hygiene

List continues on the next page

- Acoustics and vibration
- Security
- Risk analysis (natural disaster/delinquency /terrorism)
- Estheticians
- Classification program (e.g., LEED, BREEAM, Uptime, EU CoC,)
- Standards, codes and regulations
- Operation and maintenance criteria
- Environmental conditions

A.5.3 Feasibility Commissioning Study

This document should analyze the scope, benefits and costs for commissioning all systems, including verification that all the activities described in this document, are assigned an amount and should define its deliverables.

A.5.4 Project Schedule

This document is developed by the owner and his advisers, provides execution times and must integrate the concepts of commissioning in it.

A.5.5 Commissioning Plan

This document identifies the processes and procedures for successful commissioning and individual responsibilities of the participants, the program of activities, documentation requirements, communication protocols and reporting assessment procedures. The plan must contain, but is not limited to, the following:

- Description of activities during the phases of this document
- Formats for process documentation
- Document verification procedures for design
- Procedures to follow when the verification results in non-compliance with OPR
- Schedule of activities according to the project schedule
- Roles and responsibilities
- Commissioning team.
- Reports and testing procedures described in this document
- Procedure required for training
- Proposed schedule of seasonal tests

NOTE: If the above points are properly completed, the plan will be the core of the final commissioning report.

A.5.6 Incident Registration Log

The purpose of this registry is to document all the events that generate a deviation from the OPRs in order to prevent further mistakes in the project.

This format should establish a procedure for documenting design or installation issues that do not comply with the OPRs, maintain control of the unresolved issues, and generate a report of the important issues to be addressed in commissioning team meetings. It must contain at least:

- Incident identification
- Brief description of the incident
- Identification date
- Name of the team member to solve
- Expected settlement date
- Solution
- Incident and involvement in system performance, time, and cost. Incident classification:
  - Minor incident: It only affects the system where the incident originated without changing operating conditions and performance.
  - Greater incident: Affects the operating conditions and system performance where the incident originated or other systems.
- Actions to prevent recurrence of incidents.

A.5.7 Basis of Design (BoD)

Generated by the design team, the BoD are the documents that specify each of the systems and installations, as well as meeting the OPRs. It is a narrative with initial project data, the considerations that were taken from the OPRs, the basic criteria and evaluated technologies to meet the same OPRs, and must include at least:

- Owner guidelines
- Systems applicable options
- Criteria for system selection
- Performance criteria for building and systems
- Estimated calculation / dimensioning
- Environmental conditions
- Make and model references
- Assumed operation criteria
- Regulations, codes, standards and reference guides
- System descriptions
- Must show how each criteria in the OPR is implemented in the design
- Should be developed in simple language for people not trained in engineering
- Modes (normal, emergency, fail and maintenance) and sequences of operation of the systems

A.5.8 Comments on Design Reviews

The purpose of these reviews is:

- To ensure compliance with quality criteria established in the OPR.
- To give feedback in a positive, proactive and concise manner, avoiding value judgments.
- To ensure the design basis is consistent with the RPD.
- To find areas of opportunities to optimize the design.
- To ensure the review is carried out for the coordination of all trades to avoid obstructions, collisions between paths and service spaces.
- To include random review calculation reports, specifications and drawings of each system.

The random check must be made to 20 percent of the documents of each system. If significant differences are found, another 20 percent should be reviewed. Continuing divergence should require that 100 percent of the documentation of each system be checked, and a full correction of the documentation for each system should be requested.

These documents must translate comments into the designs for each of the systems and installations. They must be made at strategic moments in the design stage and should be performed at least twice; at 50 percent and 95 percent of completion.

It is the obligation of the design team to respond to these comment reviews before finishing the design stage.

A.5.9 Construction Specifications for Commissioning

Construction specifications for commissioning establish minimum activities during the Cx construction phase that must be performed for each system, the purpose of which are included in the scope for contractors. They must contain:

- Expected runtimes
- Responsibilities
- Lists of measurement instrumentation; properly calibrated
- Documentation requested
- Contractors minimum equipment and material for inspection, testing, startup, operation and maintenance of systems

A.5.10 Building Operations Manual (BOM)

The design stage BOM should be generated to form the structure and minimum requirements of what will be the full BOM. In subsequent stages (construction and occupation), it will be supplemented according to the MAC during the project.

It must contain at least:

- OPRs
- BoD
- Commissioning plan
- Executives projects and construction documents by system
- Incident registration:
  - Major incidents
  - MAC
- Operation and maintenance manuals generated by contractors
- Training
- Final commissioning report

A.5.11 Guidelines for O&M Training According to Specifications

This document should be integrated based on the requirements set by the designer and manufacturers' manuals. The O&M staff must revise it and propose any MACs.

A.5.12 List of Test Equipment and Functional Checklist

The design team must generate a checklist which becomes a guide for the installer that contains specific information for equipment and assemblies required by the OPRs and should include the following:

- Equipment Verification
- Pre-installation Review
- Installation Review

The contractor(s) generates the lists, and the commissioning agent verifies them. This activity it is also known as "pre-functional tests." Verification by the CxA should be performed at 20 percent of the listed equipment and assemblies. If significant differences are found, review another 20 percent. Continuing divergence should require a 100 percent review.

A.5.13 Compliance Technical Data Sheets (Submittals)

Before purchasing equipment and accessories a technical submittal for all equipment must be issued by the contractor, including the details of what you plan to buy, for review. If approved by the design team, under the supervising commissioning agent, the purchase will be authorized. This review should obtain one of the following results:

- Approved (Ap) – The contractor may purchase them
- Approved with comments (AC) – You can order, but must respond to comments
- Review and redeliver (RE) – Cannot make the purchase and must correct the data sheet or the specification that was submitted in the design.

A.5.14 O&M Manual Operation and Maintenance of Systems

As part of the Cx process the submission of detailed documentation for the Operation and Maintenance (O&M) of each of the systems in the building is required, so each contractor must deliver O&M manuals of the systems installed, containing at least:

- Contractor
- Table of Contents
- Basis of design
- Calculation spreadsheet per system AS BUILT
- Construction documents AS BUILT
- Materials specifications
- Approved Submittals

List continues on the next page

- Incident registration
- O&M Procedures, both normal operation as planned and unplanned interruption
- Maintenance schedule
- O&M manufacturer´s manual for installed equipment
- Equipment and systems warranties
- Test templates issued and signed by CxA
- Manufacturer and suppliers contact data
- Installation drawings AS BUILT
- Equipment list AS BUILT
- Diagrams and shop drawings AS BUILT
- Operational sequences (normal, fail, emergency and maintenance)
- Digital record of all documentation

A.5.15 List of Equipment

The design team must deliver the package of project/construction documents, including drawing(s), pictures and tables as necessary, listing the equipment to at least the specificity as described below:

- Identification
- Location in building
- Characteristics
- Physical dimensions
- Brand
- Model
- Technical operational features

NOTE: Once the technical specifications mentioned are approved, if there are changes in some part of the specification, the contractor must update those equipment drawings according to how it was built or installed.

A.5.16 Coordination of Systems Building Plans

Plans should be carried out by level of coordination of the different facilities/systems in which they can identify potential path or location conflicts or interference between them. Each of the systems/facilities must be indicated in a different color. Once potential conflicts are determined, the design team provides cutouts or sections to determine the heights of each of the possible solutions. Such plans must be made in a computer-aided design (CAD) program or in a building information modeling (BIM) suite and printed for use as required. It must be carried out by the design team and confirmed by on-site construction management or the project management team.

A.5.17 Test Procedures

Test procedures should be documented procedures for both pre-functional and functional tests of equipment and systems to ensure that all requirements are met.

NOTE: Testing is a quality assurance process and is a tool to ensure the work is properly done by the contractor.

The CxA must generate templates for pre-functional and functional tests for recording data in a clear and simple language, sorted by specialty, and specific for each type of equipment. These must be completed by the contractor performing the work mentioned therein. The will be reviewed by the CxA, following a sampling of 20 percent. If inconsistencies are found, another 20 percent should be reviewed. If the inconsistency persists, the CxA must review 100 percent of the documentation. The decision of repetition is the responsibility of the owner.

NOTE: It is important that templates and tests aid in detecting the source issue causing the errors rather than provide methods to decrease the incident of errors to an acceptable level for the system.

Test templates must contain at least:

- Project name, test number, date and time of testing
- Indication whether an original or a repeat of the first test
- Equipment identification of the proven system
- Identification of the measuring equipment and calibration status
- Conditions under which the test is performed
- System performance, equipment or assembly
  - Indicate whether the result meets expectations of the design
  - Signature of the person who developed the test and the team members who supported and witnessed the test along with the date.

A.5.18 Agendas and Minutes of Commissioning Meetings

Agendas must be filed at the beginning of each meeting of the CxT. The agenda must include all topics to review. The minutes must be written and signed, and include agreements reached along with the list of attendees and the date thereof.

A.5.19 Training Plan

A training plan for operation and maintenance of systems and equipment must be developed and coordinated by CxA with the contractor(s) and the O&M owner's representative that meets the needs and expectations of the owner. Training requirements should be established from the construction documents issued between the design team and the contractor, supported by the vendor or manufacturer, giving a schedule of training sessions. Upon successful completion of the training sessions, the project manager and owner representative will deliver to the contractor a document of training acceptance.

A.5.20 Maintenance Plan

The contractor must provide at the end of training a maintenance plan which contains for each system recommendations and good practices to be carried out during the lifetime of the systems. This should include a list of parts and recommended spare parts and a schedule for the predictive maintenance and the tendency of systems and equipment that compose it to fail.

A.5.21 Seasonal Testing Procedures

Seasonal testing procedures for each system must be developed. These procedures must be carried out under various seasonal conditions over a maximum period of 10 months, or before the expiration of the warranty, whichever comes first. The procedures developed must include the actual expected performance, along with possible solutions to potential problems that may arise. These should be made using functional tests.

A.5.22 Commissioning Process Report

The commissioning process report must be drafted by the CxA and include activities and the aforementioned documents and closing reports of each stage. This document terminates the process of commissioning and is to be delivered to the owner.

A.5.23 Continuous Commissioning Plan

The continuous commissioning plan is a separate document and optional CxP document. It includes everything done in the process of commissioning and described in this document, setting times, responsible and requirements for development; along with activities to follow up on. Basically it follows the same process, with all activities and documents mentioned and must be approved by the owner.

This page intentionally left blank

Appendix B System Training (Informative)

This appendix is not part of the requirements of this standard, but it is included to provide additional information related to this standard.

B.1 Overview

An individual system is a valuable part of the overall solution being provided, with all other integrated systems dependent on proper utilization and operation of each individual system. Therefore, the users should know how to use the entire system properly.

Most system software packages are currently designed around the different roles and job requirements of end users. For instance, some workstation software is written exclusively for the occasional operator who may have the responsibility to occasionally add a user and monitor the alarms that come into the system.

In some cases, software is written exclusively for the administrator who owns the system and is responsible for its operation and all of the integrated systems. A group of users is responsible for maintaining the system. Their work with the software is limited, but they need to be familiar with the hardware. Each group would receive the most value from training that is focused on their everyday tasks.

Manufacturers offer many choices for user training. Because each software application is unique, each training course should be customized to the user's unique needs. This customization should go beyond the content to include class location options. The classes may be held either on the installed system at the end user's location or on test or demonstration equipment at the manufacturer's location.

If the end user has 50 or more users for training, a train-the-trainer program may be more cost effective. This person would get the training, the certificate, and the handout materials from the manufacturer to conduct classes on location. A designer should check with the manufacturer to learn if a train-the-trainer program is offered.

B.2 Sessions

At least two separate instruction sessions should be provided for training the client's operating staff.

The first session is conducted during acceptance testing to provide the initial training needed to operate and maintain the system. The first training session should include:

- General familiarization and operating instructions for each specialty system.
- Routine maintenance procedures.
- User level programming of software and systems.

Instruction on complicated systems and components should be provided by factory-trained technicians.

The second training session should be conducted after the final acceptance to fill in gaps and answer questions that develop once the staff has become familiar with the system. Each training session should provide all the necessary training materials, including:

- An overview of the implementation and commissioning program.
- A description of how the training is to be conducted.
- The date, time, and location of the training.
- The names and company affiliations of instructors.
- A summary of the content.
- Recommended reference material.

The training sessions should be recorded and archived for repeat training and reference for additional staff. Training should be required as part of the construction documents and included in the project cost.

B.3 Position or Task Training

The system users may be divided by different roles or job requirements, such as:

- System administrators
- System operators
- Managers
- IT staff
- Maintenance personnel

B.3.1 System Administrators

This training generally focuses on the personnel responsible for the system's initial setup and programming. This class teaches the system administrators how to use all the system functions.

These functions may include:

- System parameter programming
- Operator permissions
- Naming conventions for controllers and doors
- Credential holder profile
- Access level assignment
- Identification badge design and production
- Alarm implementation
- Report retrieval
- System backup
- Database archiving

B.3.2 System Operators

This training course generally focuses on the occasional users or the personnel responsible for day-to-day operations. This class teaches the system operator to monitor the various functions, including:

- Credential holder profile
- Access level assignment
- Identification badge design and production
- Events—alarm notifications or credential transactions
- Valid or invalid access monitoring
- Alarm response
- Alarm clearance
- Reports
- Manual door opening and closing

B.3.3 Managers

This training course generally focuses on personnel who are overseers of the system administrators. The manager would need to know how to delete a user or change the operator or password.

This class also teaches:

- Login basics
- System parameter programming
- Operator permissions
- Credential holder profile
- Access level assignment
- Reports

B.3.4 Information Technology (IT) Staff

This training course generally focuses on IT department personnel who need to know how systems connect to the LAN or wide area network. The bandwidth and other items, including data requirements, are discussed as well as:

- Network topologies
- Communication to each control panel
- Encryption strategies and capabilities

B.3.5 Maintenance Personnel

This training course generally focuses on how the system works and covers:

- Hardware troubleshooting
- System topology
- Networking basics
- Diagnostics
- Simple programming
- Device configurations
- Software troubleshooting

B.4 Training Schedules

Scheduling the training is almost as important as the training content. If the training is scheduled too far in advance, the attendees may forget the content because they would not have the opportunity to practice on the system and reinforce the knowledge gained during the class. Last-minute training also should be avoided.

The preferred point in the timeline to do system training is one to two weeks before the system is commissioned and turned over to the customer. The training should be performed on a working system. The training equipment or the installed system can be used in the training.

There is an advantage to training on a live system. Many decisions pertaining to the names and descriptions of door/readers could be determined during training to ensure they make sense to the customer. Simultaneously implemented programming and training reduces the number of hours needed for initial programming and may reduce the number of labor hours charged to the customer. This works best with smaller systems (e.g., 32 readers or less).

Too many control panels and readers may not allow a sufficient time to complete all of the programming during a training session.

If the training courses focus on role-based training, the order of the courses should be carefully considered. The administrator screens should be programmed before the operator screens to facilitate the programming flow. Cross training between the various roles is recommended.

This page intentionally left blank

Appendix C Data Center Integrated Management (DCIM) (Informative)

This appendix is not part of the requirements of this standard, but it is included to provide additional information related to this standard.

C.1 Introduction

Data center infrastructure management (DCIM) is a software application or a suite of software applications that are configured to gather, monitor and aggregate data from multiple subsystems within a facility. In its true sense, DCIM is not a management tool, because it does not directly control data center devices and components. It is used as a data collection and reporting tool. The result of the aggregated data is utilized for automated or manual adjustments to physical infrastructure in order to increase efficiency, provide fault tolerance, provide workflow management and implement changes resulting from expansion or consolidation of the facility. DCIM can source data from directly connected components, such as electrical components (e.g., UPS, power distribution units [PDUs], remote power panels [RPPs]) or environmental (e.g., computer room air conditioners [CRACs], computer room air handlers [CRAHs], temperature probes, humidity probes, wireless environmental reporting devices). Automated adjustments are performed by subsystems such as a building automation system (BAS) or building management system (BMS) and are initiated by those systems.

DCIM can also source and share data with other facility systems such as BAS, BMS and electrical power management system (EPMS). Each of the human machine interfaces (HMIs) within the other facility systems can also utilize the aggregated data collected by DCIM in order to determine facility based adjustments to be made by the BAS and BMS.

The DCIM suite of applications can be both localized and cloud based, depending upon the specific application service. This allows great flexibility as well as functionality by users from varying business groups within an organization. For instance, a data center manager would typically use a localized application in order to assess effects of changes within the environment when considering the purchase of new IT hardware. A facility manager might want to establish an energy cost reduction policy. Through the monitoring and assessment combined of power and cooling attributes within the data center via the DCIM, adjustments can be made via the BMS to control these items more effectively and efficiently. An energy procurement manager would use a cloud based application in order to assess energy cost projections across their organization's fleet of data centers. These projections might be based upon stored utilization data that can establish trend metrics in order to forecast future usage.

C.2 Components

C.2.1 Appliances

The DCIM may include:

- A centralized server or virtual appliance
- client console or web client
- HTTP or HTTPS connection to access the end-user interface
- Standard TCP protocol connections for end-user notifications

Figure C-1 shows an example of DCIM architecture. The DCIM architecture should permit managing devices on either the company/organization network or a separate dedicated network. The DCIM should also allow management devices that can reside on both the public LAN and the private LAN. Management and monitoring functions may be implemented as either firmware or software configuration within the appliances. Other more complex functions such as workflow management, change management, and analytics may be performed either by servers within the data center or in the cloud on a server in a service provider’s data center. The application requirements should include end user scalability, allowing for future expansion and enhancements.

C.2.2 Subsystems

DCIM can provide reporting and establish metrics for decision making through information acquired from components that are directly connected to the network, or from facility subsystems that have a primary purpose to control building functions. When we refer to direct connected components, it is assumed these components reside on the same network as the DCIM tool without any need for media or protocol conversion. These components might consist of SNMP enabled power and cooling devices that are located within a data center. But, to obtain the required information to make good decisions, operational data may need to be gathered from devices that are not connected to the LAN or are outside of the building. These devices might consist of power substations and electrical switchgear that are monitored by an EPMS with a protocol such as Modbus. They may also include chillers, cooling towers, and pumps that are managed by a BAS/BMS with a protocol such as BACnet. They may also consist of equipment with no LAN connections that are monitored using a proprietary protocol.

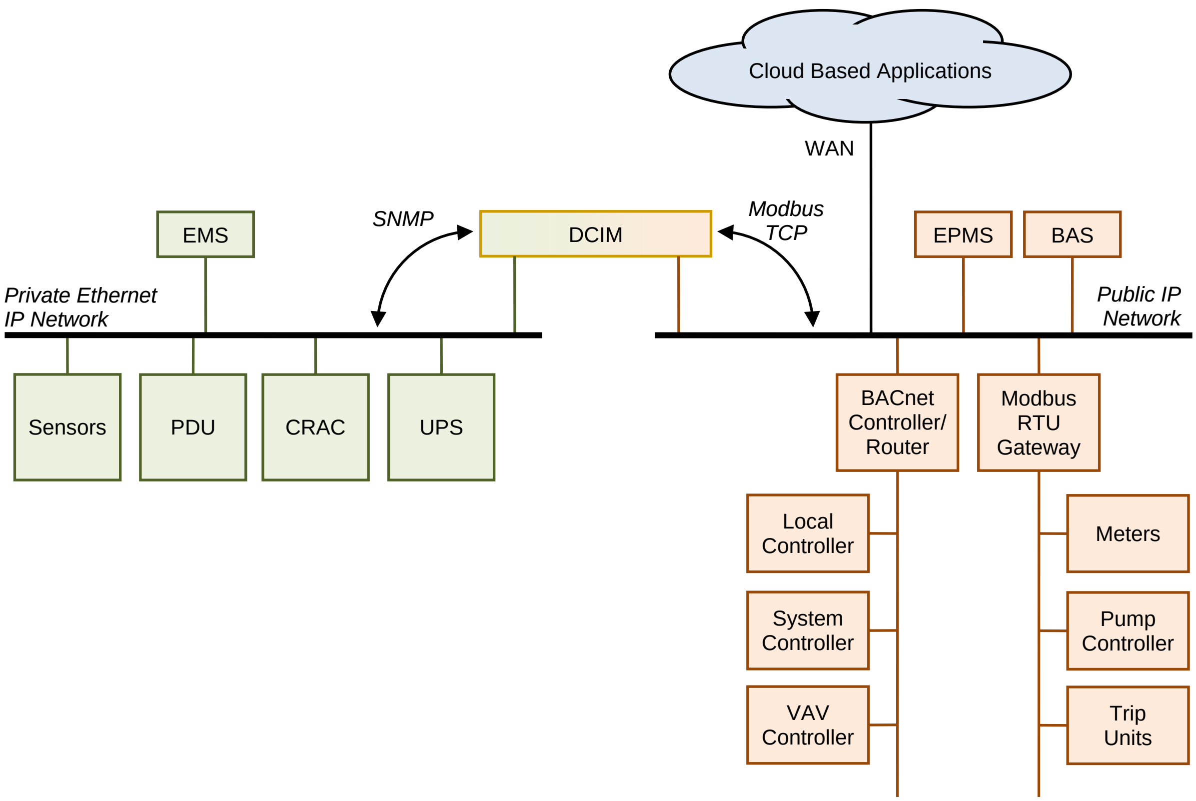


Figure C-1
Example DCIM Architecture

C.2.3 Modules

In base form, DCIM may consist of a base application for providing a unified view of critical components and their operation. It can also be configured for specific environments through the use of add-on software modules. Specific purpose modules may be geared to healthcare, colocation, financial, educational, industrial, and other vertical markets. In addition to the specific purpose modules, add-ons for workflow management, capacity management, planning, and asset tracking can be incorporated into the DCIM suite.

C.2.3.1 Building Automation Subsystem

A BAS is a control system comprised of hardware (e.g., controllers, cabling, input/output devices) and a software application or suite of software applications that automate the electrical and mechanical subsystems. A BAS may integrate with another BAS of a different system to coordinate their operation in a productive and efficient manner, or may be managed by a BMS. A BAS may communicate with BMS subsets, allowing for automated operational changes in order to achieve the goal of an established parameter or set of parameters.

C.2.3.2 Building Management Subsystem

A BMS is a management system that monitors, with the integration of one or more BAS, facility functions such as airflow, temperature, and water flow. A BMS may also provide the control functionality of the individual BAS systems. Although these functions are automated through their specific BAS, the BMS can be used to make adjustments. Adjustments through a BMS are typically performed manually through a HMI.

C.2.3.3 Energy Management Subsystem

An energy management system (EMS) is basically a BAS, but has evolved with a focus not only on the coordination and intercommunication of various subsystems for the purpose of system control, but has a main focus on how to obtain the maximum efficiency at all times based upon real time data. An EMS will control systems, but typically does not make changes or adjustments for increased efficiency based upon the data that is being shared.

C.2.3.4 Electrical Power Management Subsystem

An EPMS is designed to monitor and report power quality, power utilization, peak demand and peak forecasting. The EPMS incorporates a power monitoring strategy to capture specific, pre-established parameters at the time of an electrical disturbance including a waveform at a specific point in time. The disturbance is time stamped and stored locally on a metering device, but is periodically or continuously uploaded to a software package that is specific to the EPMS subset. This software package will share data with the DCIM in order to help make evaluations or corrections to the electrical system based upon risk, mission criticality and cost.

C.2.3.5 Enterprise Management Subsystem

DCIM can incorporate plug-ins that support network, operational and enterprise systems. These systems can provide measurements, such as processor load versus electrical load, that can be beneficial in determining optimal operations, such as if server hardware is providing optimal value for its energy consumption. Alarm thresholds can be set not only for events such as utilization or security violations, but also for thermal events, redundancy breaches, power availability and other physical conditions. Alarms and notification are typically communicated to the DCIM via a summary alarm; alarms (e.g., power or cooling failure) may also be independently communicated as specified by owner or operational requirements.

C.3 Communication Protocols, Media and Hardware

Protocols are not limited for DCIM, but most systems use TCP/IP. Subsystems may also incorporate standardized automation control protocols, [e.g., ISO 16484-5 (BACnet), ISO/IEC 14908-1 (LONTalk)], open use protocols (e.g., Modbus), or proprietary protocols specific to the system or manufacturer. LAN hardware and associated media is needed to provide an Ethernet gateway for communication between the DCIM and the subsystems as well as providing the communication link between the DCIM and the remote client accessing it. The components needed may include switches, routers, hubs, telecommunications standards-compliant balanced twisted pair cable, optical fiber media, IP addresses, firewalls, and client workstations/servers, though other components may be required for a particular solution.

DCIM servers access managed devices and are managed by client workstations using LAN connections. The virtual DCIM appliance is delivered as an open virtualization archive (OVA) and is supported on VMware. The virtual appliance is expected to function properly on any virtualization platform that supports the OVA format, or has an appropriate converter utility. The virtual appliance must be fault tolerant utilizing a 1 CPU configuration only, which eliminates dependencies upon multiple physical machines.

C.4 Reporting

Reporting metrics such as PUE and DCIE are totally dependent upon the collection, aggregation and processing of lower level subsystems, devices and sensors. If the DCIM is unable to obtain information from all subsystems, devices and sensors, the PUE (Power Usage Effectiveness) and DCIE (Data Center Infrastructure Efficiency) measurement can never be correct. Although real time reporting is most accurate at a given point in time, the need for continuous monitoring can be reduced if the DCIM can effectively calculate, model and simulate effects of changes in the environment. Therefore the communication polling frequency can be reduced, thus taxing the network to a lesser degree and the amount of metering devices can be reduced. In this respect, a more capable DCIM can provide an advantage to a retrofit facility with limited network and metering capabilities. DCIM plug-ins and add on modules can communicate with Enterprise Management Systems to collect operational data from active hardware such as servers, switches and storage devices. This data can be used along with data from facility subsystems to calculate IT dependencies on power, cooling and space allocation at the rack and device level. Manual entries are also accommodated in order to create simulations or "what if" scenarios for planning IT upgrades, moves, adds and changes.

C.5 Recommendations and Conclusion

DCIM should consist of an open communication architecture. This architecture exhibits the distinct ability to interface with any third party software or device over standard IP and industrial communication protocols. Alerts are required for critical threshold breaches as well as trending in order to forecast potential risk. Finally, DCIM should be scalable, enabling the user to monitor conditions on directly connected devices within a small data center or indirectly connected devices through subsystems within an enterprise environment. DCIM should have the ability to perform calculations based upon aggregated data from a proportionate number of devices and meters, but exhibiting the ability to make assumptions based upon whether the number of devices and meters are lesser or greater.

Appendix D Related Documents (Informative)

This appendix is not part of the requirements of this standard, but it is included to provide additional information related to this standard.

The following standards and documents are related to, or have been referenced within recommendations of this standard, and provide additional information which may be of use to the reader.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)

- ASHRAE Guideline 13, *Specifying Building Automation Systems*
- ANSI/ASHRAE/IES Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*

American Society of Mechanical Engineers (ASME)

- ASME A17.1-2007, *Safety Code for Elevators and Escalators*

ASIS International

- *Protection of Assets Manual*

BICSI

- ANSI/BICSI 002, *Data Center Design and Implementation Best Practices*
- *Information Technology Systems Installation Methods Manual, 7th edition*
- *Outside Plant Design Reference Manual, 6th edition*
- *Telecommunications Distribution Methods Manual, 13th edition*

Constructions Specifications Institute (CSI)

- *The Project Resource Manual: CSI Manual of Practice, 5th edition*

Electronic Components Industry Association (ECIA)

- ECA/EIA 310-E, *Cabinets, Racks, Panels, and Associated Equipment*

European Committee for Electrotechnical Standardization (CENELEC)

- EN 12464-1, *Light and lighting—Lighting of work places—Indoor work places*
- EN 12464-2, *Light and lighting—Lighting of work places—Outdoor work places*
- EN 50173-3, *Information technology—Generic cabling systems—Part 3: Industrial premises*
- EN 50173-4, *Information technology—Generic cabling systems—Part 4: Residential premises*
- EN 50173-5, *Information technology—Generic cabling systems—Part 5: Data centres*

Institute of Electrical and Electronics Engineers (IEEE)

- IEEE 802.3bz, *Standard for Ethernet Amendment: Media Access Control Parameters, Physical Layers and Management Parameters for 2.5 Gb/s and 5 Gb/s Operation*
- IEEE 802.11, *IEEE 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*
- IEEE 802.15.1, *IEEE Standard for Information technology-- Local and metropolitan area networks--Specific requirements-- Part 15.1a: Wireless Medium Access Control (MAC) and Physical Layer (PHY) specifications for Wireless Personal Area Networks (WPAN)*

List continues on the next page

- IEEE 1100 (The IEEE Emerald Book), *Recommended Practice for Powering and Grounding Electronic Equipment*
- ANSI/IEEE C2, *National Electrical Safety Code (NESC)*
- IEEE C62.41.1, *IEEE Guide on the Surges Environment in Low-Voltage (1000 V and Less) AC Power Circuits*
- IEEE C62.41.2, *IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits*

International Code Council

- *International Fire Code®*
- *International Energy Conservation Code®*

International Organization for Standardization (ISO)

- ISO/IEC 14543-3-1, *Information technology -- Home electronic systems (HES) architecture -- Part 3-1: Communication layers -- Application layer for network based control of HES Class 1*
- ISO/IEC 27001, *Information technology — Security techniques — Information security management systems — Requirements*

International Electrotechnical Commission (IEC)

- IEC 60529, *Degrees of protection provided by enclosures (IP Code)*
- IEC 60849, *Sound systems for emergency purposes*
- IEC 61280-4-1 edition 2.0, *Fibre-optic communication subsystem test procedures – Part 4-1: Installed cable plant – Multimode attenuation measurement*

National Electrical Manufacturers Association (NEMA)

- NEMA 250, *Enclosures for Electrical Equipment (1000 Volts Maximum)*

National Fire Protection Association (NFPA)

- NFPA 3, *Recommended Practice on Commissioning and Integrated Testing of Fire Protection and Life Safety Systems*
- NFPA 4, *Standard for Integrated Fire Protection and Life Safety System Testing*
- NFPA 90A, *Standard for the Installation of Air Conditioning and Ventilating Systems*
- NFPA 241, *Safeguarding Construction, Alteration, and Demolition Operations*
- NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems*

Telecommunication Industry Association (TIA)

- TIA TSB-184-A, *Guidelines for Supporting Power Delivery Over Balanced Twisted-Pair Cabling*
- ANSI/TIA-598-D, *Optical Fiber Cable Color Coding*
- ANSI/TIA-570-C, *Residential Telecommunication Infrastructure Standard*
- ANSI/TIA-942-B, *Telecommunications Infrastructure Standard For Data Centers*

Underwriters Laboratories Inc. (UL):

- UL File E349672, Project 11CA44391: *Validated test procedures for Category 5e/Class D and higher cabling for a Single Connector Modified Permanent Link for Direct Attach with and without a consolidation point*

Other Standards and Documents

- *Americans with Disabilities Act*, United States Department of Justice
- CEC-400-2015-037-CMF, *Building Energy Efficiency Standards For Residential and Nonresidential Buildings,* California Energy Commission