



COPPER STRUCTURED CABLING DESIGN GUIDE

Issue 10



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1. INTRODUCTION

Welcome to Issue 10 of Belden's "*Copper Structured Cabling Design Guide*". The purpose of this document is to provide a concise summary of standards-based requirements and recommendations for the design and testing of balanced twisted-pair cabling in a commercial building environment.

Subjects covered include:

- Horizontal and backbone design layouts
- Cabling system performance and available topologies
- Power separation and environmental guidelines
- Cabling components for required and optional telecommunications spaces within buildings

Belden offers both shielded and unshielded cabling systems for end-to-end connectivity, which are separately summarized in two Annexes.

This Guide concludes with a standards summary that identifies the most significant publications for balanced twisted-pair cabling infrastructure in various types of premises.

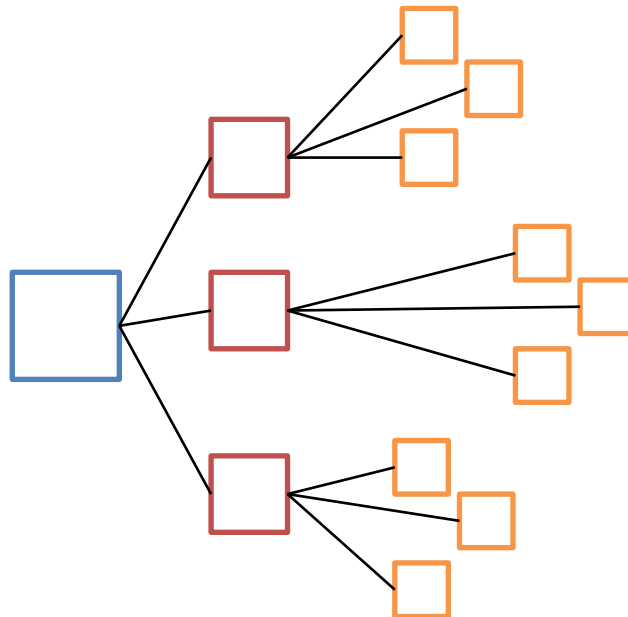
We hope you find the contents useful.

2. DESIGN FUNDAMENTALS

THE HIERARCHICAL STAR MODEL

Structured cabling design uses a hierarchical star model in which cables extend from a single location to multiple destinations in a one-to-many configuration.

Figure 1: Example of a two-tier generic hierarchical star model



Examples include:

- Cables routed from one Telecommunications Room on a floor to multiple Work Area outlets on the same floor.
- Cables routed from one Equipment Room in a building to multiple Telecommunications Rooms distributed throughout the building.
- Cables routed from one building on a campus to multiple other buildings on the same site.

DESIGN COMPONENTS

There are five fundamental design components common to all structured cabling designs.

Spaces

Telecommunications spaces are used as starting, interim, and endpoint locations for the cabling runs within buildings. Examples include Equipment Rooms, Telecommunications Rooms, Telecommunications Enclosures, and Work Areas.

Pathways

Telecommunications pathways are used to guide, isolate, and protect cables as they are routed from one space to another. Pathway orientation can be horizontal (e.g., ceiling-level cable trays) or vertical (e.g., floor-penetrating conduits).

Cables

Commercial building cabling standards for copper structured cabling systems call for the use of 100-ohm balanced twisted-pair cables, either shielded or unshielded. Four-pair cables are the most common type, with multi-pair (e.g., 25-pair, 100-pair) cables permitted for some applications.

Connectors

The pairs in each cable are terminated at both ends onto connectors that are packaged into various formats, such as a rack-mounted patch panel in a Telecommunications Room or a wall-mounted outlet in a Work Area.

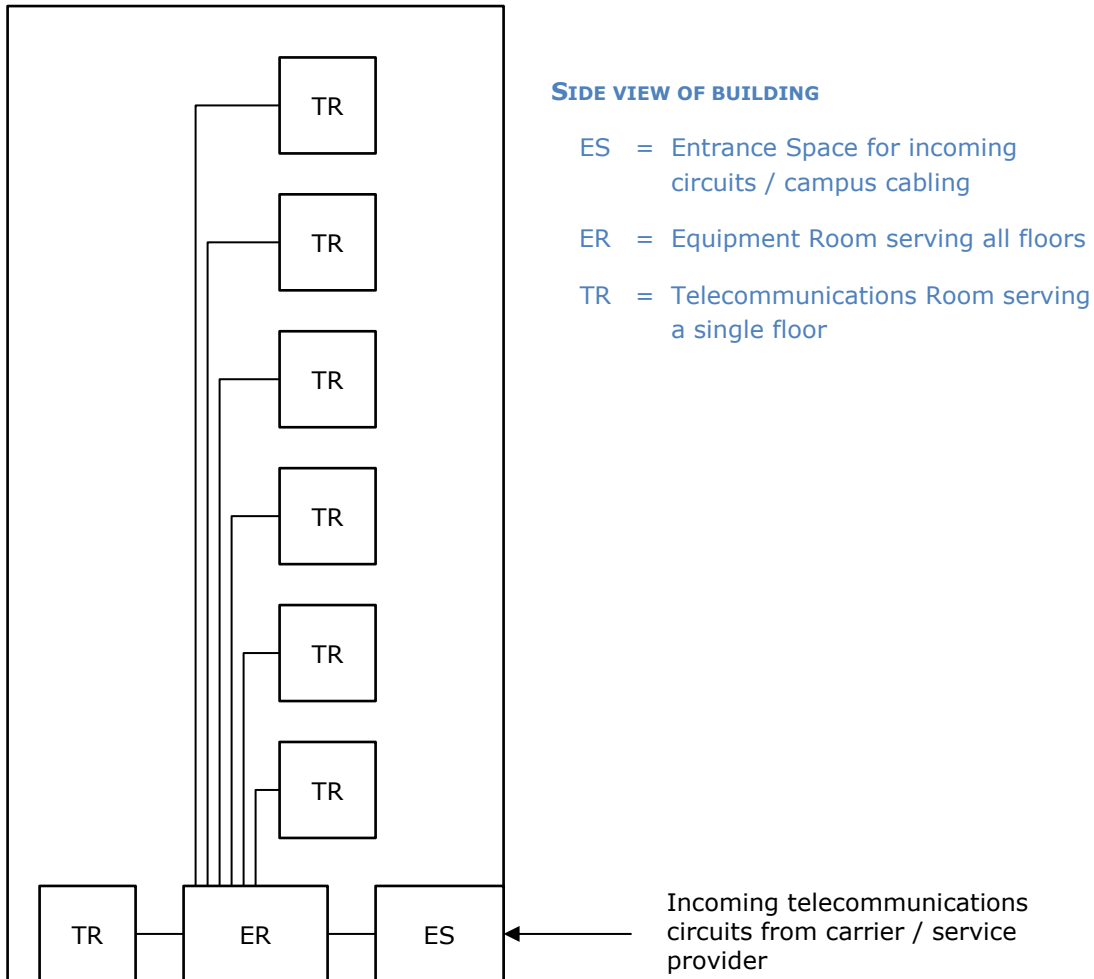
Cords

A cord can be used to link one connector to another (e.g., from one patch panel to another in an Equipment Room) or to link a connector to a network device (e.g., from a Work Area outlet to a desktop phone or computer). Terms such as patch cord, equipment cord, and Work Area cord are often used to identify how or where a cord is used.

BACKBONE DESIGN LAYOUTS

The generic backbone design layout uses the multi-floor commercial building as its model, with a vertical backbone cabling infrastructure as shown in Figure 2.

Figure 2: Generic backbone design layout



NOTE 1: In Figure 2, the Equipment Room shown on the ground floor can be located on any of the other floors.

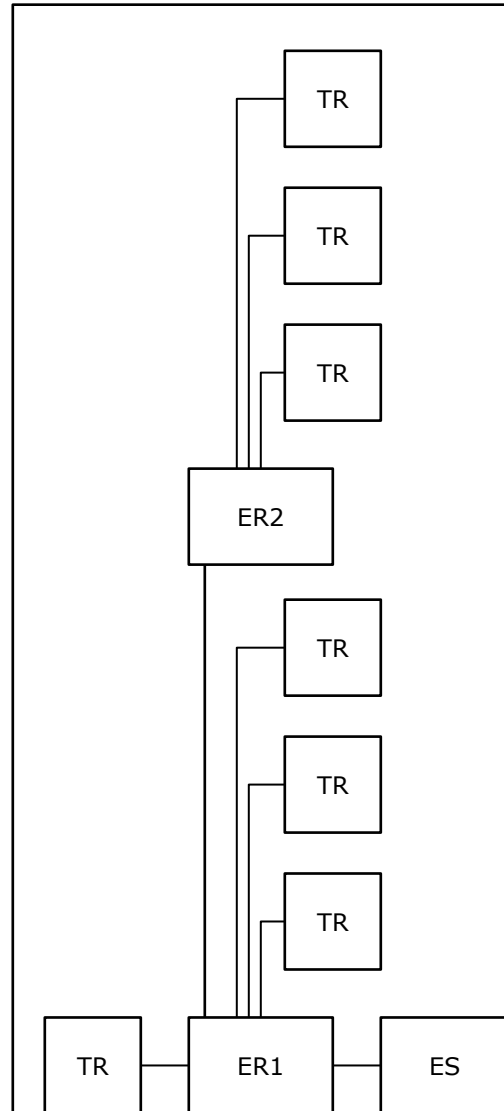
NOTE 2: In Figure 2, the Telecommunications Room and the Entrance Space adjacent to the Equipment Room do not have to be separate spaces. They can be dedicated areas within the Equipment Room.

If the building is very tall, the generic backbone layout allows for one or more additional Equipment Rooms to serve as intermediate distribution spaces, as shown in Figure 3. This avoids the need to terminate the backbone cables for all of the Telecommunications Rooms in a single space.

Figure 3: Generic backbone design layout with multiple Equipment Rooms

SIDE VIEW OF BUILDING

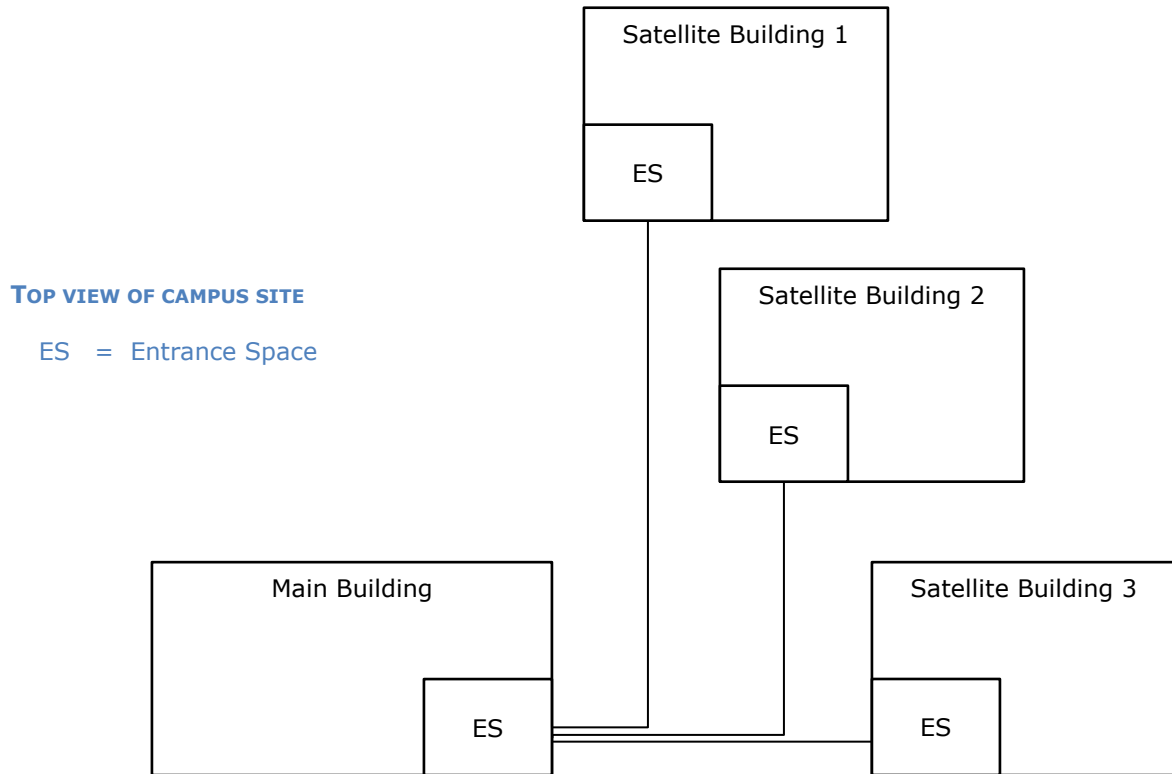
- ES = Entrance Space
- ER = Equipment Room
- TR = Telecommunications Room



NOTE: The backbone design layouts shown in Figures 2 and 3 can also be implemented horizontally in single floor buildings with large surface areas, such as retail shopping malls or airport terminal buildings.

Generic backbone design for a multi-building campus is an extension of the single-building layout, with one building designated as the Main Building for backbone cabling purposes. Each of the other buildings on campus is a Satellite Building directly connected to the Main Building, as shown in Figure 4.

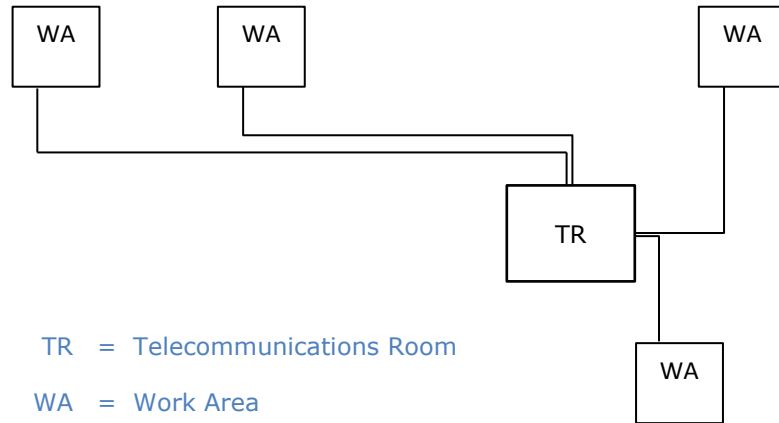
Figure 4: Generic campus backbone design layout



HORIZONTAL DESIGN LAYOUTS

The generic horizontal design layout uses a single floor as its model, with a horizontal cabling infrastructure serving multiple Work Areas from a single Telecommunications Room, as shown in Figure 5.

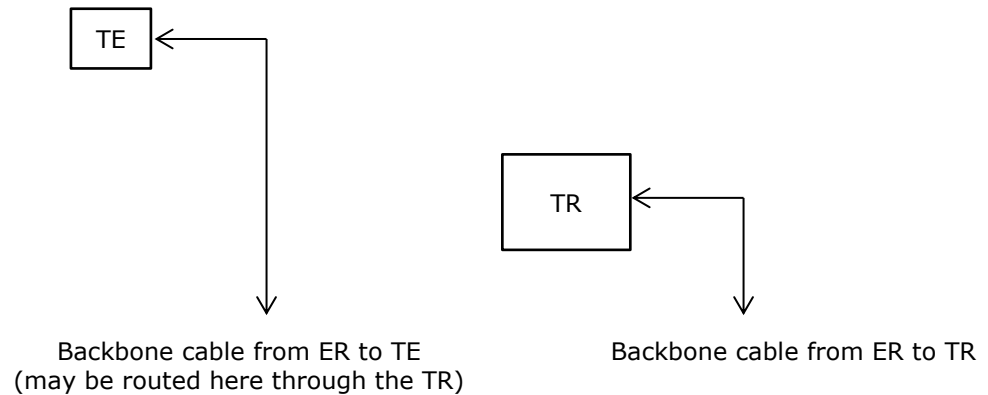
Figure 5: Generic horizontal design layout



Telecommunications Enclosure

In cases where a portion of the floor area requires additional space for telecommunications components, one or more smaller versions of the Telecommunications Room called the Telecommunications Enclosure can be added to the design layout, as shown in Figure 6.

Figure 6: Horizontal design layout with Telecommunications Enclosure



ER = Equipment Room

TE = Telecommunications Enclosure

TR = Telecommunications Room

NOTE: The Telecommunications Enclosure is an optional addition to—not a replacement for—the Telecommunications Room.

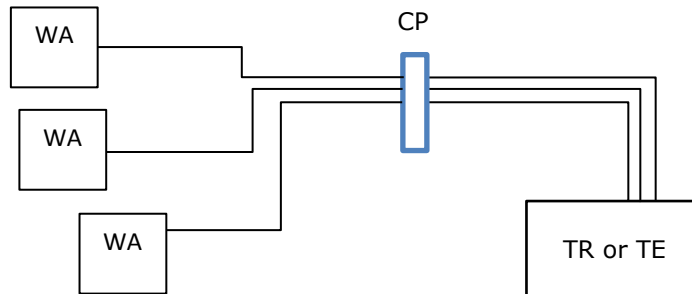
Consolidation Point

Another option for the generic horizontal design layout is the Consolidation Point, which allows for additional flexibility when cabling runs need to be replaced (e.g., due to modular furniture configuration changes in an office).

The Consolidation Point serves as an additional connector between the Telecommunications Room or Telecommunications Enclosure and the Work Area outlet in the modular furniture.

When the furniture needs to be moved, only the cable from the outlet to the Consolidation Point has to be replaced—the cable from the Consolidation Point to the Telecommunications Room or Telecommunications Enclosure can remain undisturbed, as shown in Figure 7.

Figure 7: Horizontal design layout with Consolidation Point



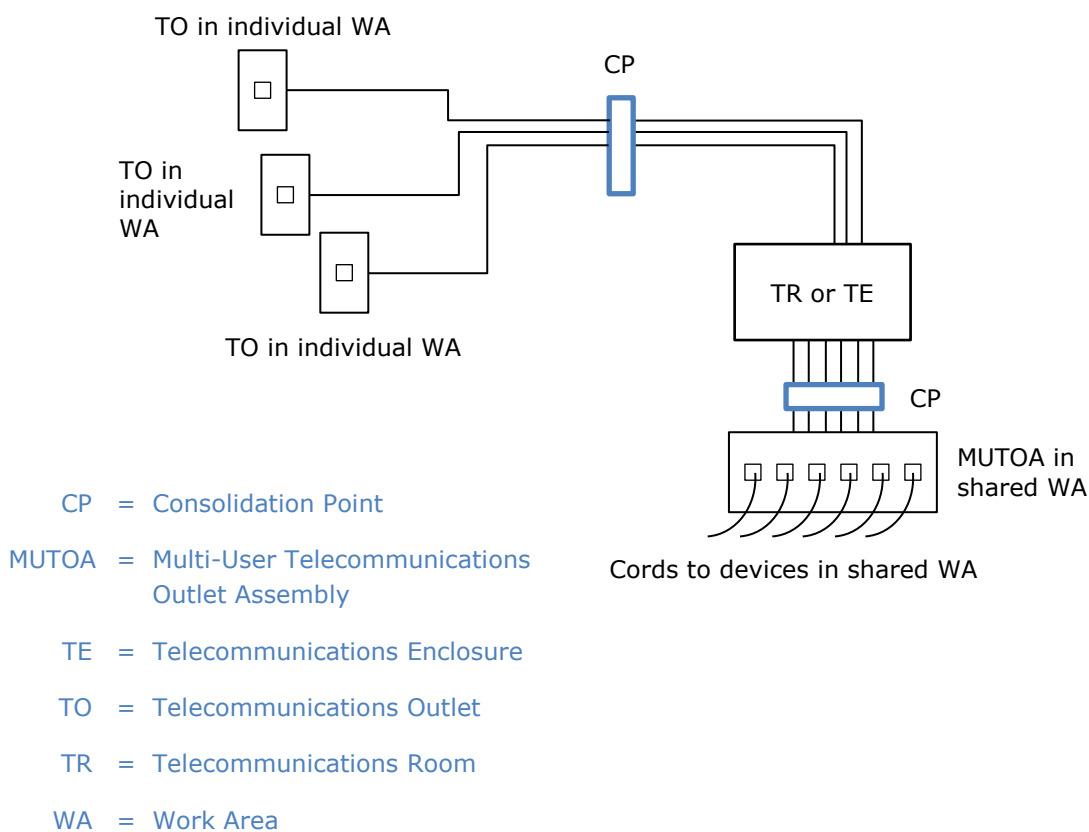
- CP = Consolidation Point
- TE = Telecommunications Enclosure
- TR = Telecommunications Room
- WA = Work Area

Multi-User Telecommunications Outlet Assembly

The Work Area connector serving the space assigned to a single individual within a commercial building is commonly referred to as a Telecommunications Outlet.

In spaces designed for multiple users (e.g., meeting or training rooms) a larger version of the Telecommunications Outlet called a Multi-User Telecommunications Outlet Assembly can be used in place of multiple separate Telecommunications Outlets, as shown in Figure 8.

Figure 8: Horizontal design layout with MUTOA



3. PLANNING CONSIDERATIONS

CABLING SYSTEM PERFORMANCE

The performance requirements for a cabling system are directly linked to the maximum network data rate expected over the planned life of the installation.

Data rates for Ethernet networks are typically used for reference due to the near-universal adoption of Ethernet as the networking technology of choice.

Table 1 lists the performance categories for copper cabling systems, their maximum Ethernet data rates, and the corresponding maximum allowable end-to-end channel lengths.

Table 1: Copper cabling performance categories

Category	Maximum Ethernet Data Rate	Maximum Channel Length
5e	1000 Mb/s (1 Gb/s)	100 m (328 ft)
6	1000 Mb/s (1 Gb/s) 10 Gb/s	100 m (328 ft) 37 m – 55 m (121 ft – 180 ft)*
6A	10 Gb/s	100 m (328 ft)
8 (under development)	40 Gb/s	30 m (98 ft)

* This range is an estimated value that must be verified through field testing of each Category 6 cabling run intended to support a 10 Gb/s data rate.

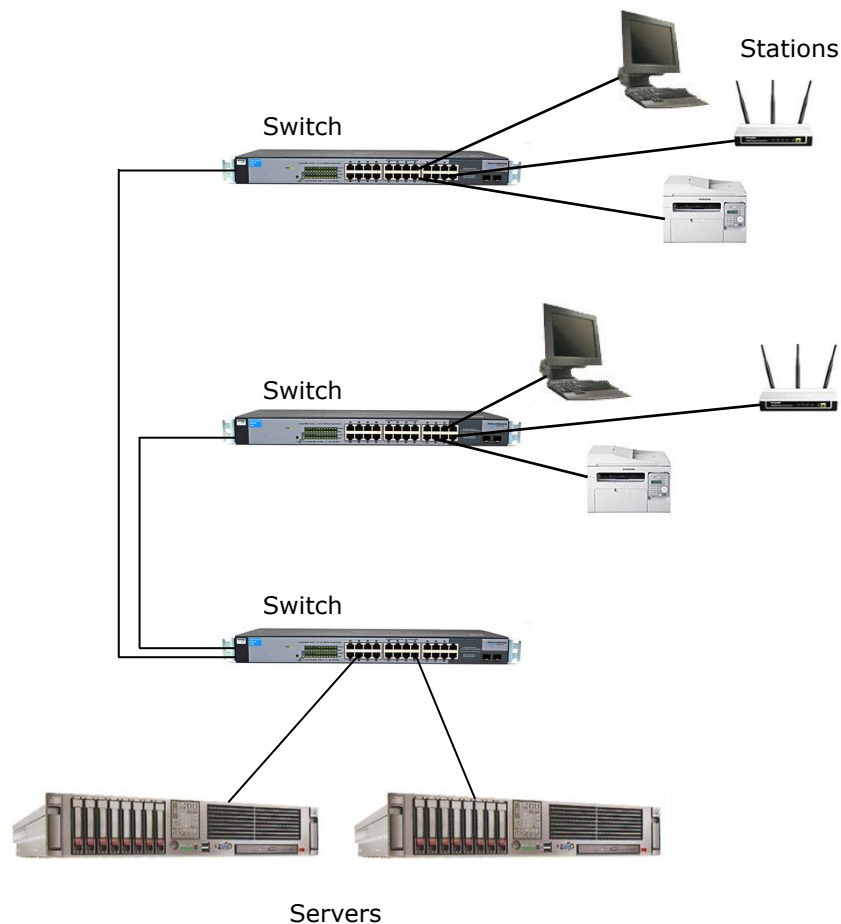
TOPOLOGIES

A basic Ethernet connection consists of a switch port at one end of the cabling run and a network interface port in a device at the other end (e.g., desktop computer, server, printer, wireless access point, surveillance camera). Common terms for such devices include stations, terminals, and end nodes.

A switch port in one switch can also be connected to a similar port in another switch as a means of expanding the network. Terms such as uplink, aggregation, and internetworking are often used to describe switch-to-switch connectivity.

Figure 9 illustrates both the horizontal and backbone network topologies, using a hierarchical model that corresponds to the cabling system layout.

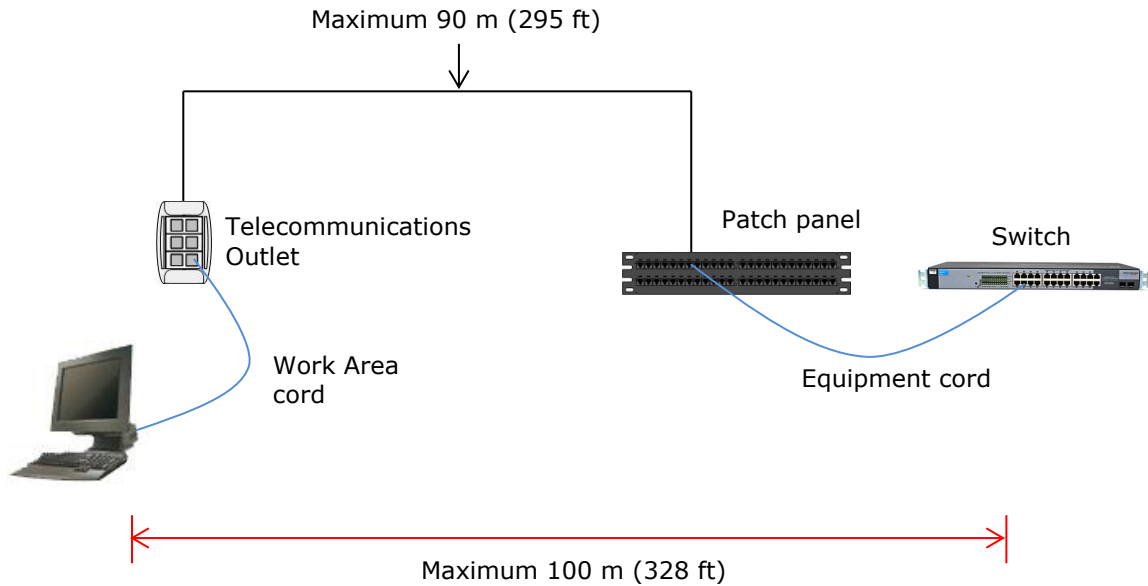
Figure 9: Ethernet network topology example



Two-Connector Topology Using an Interconnect

The basic end-to-end cabling design layout uses two connectors between the ports at either end of the link, as shown in Figure 10.

Figure 10: Two-connector topology using an interconnect



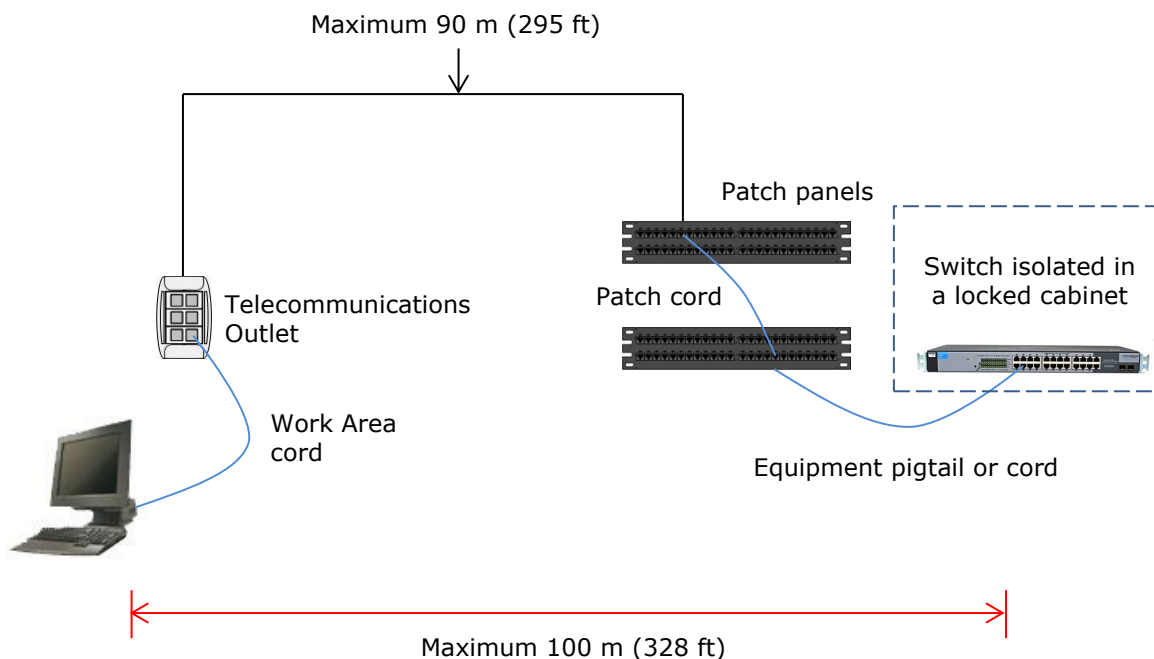
NOTE 1: A single set of connectors used to link cables directly to equipment cords is referred to as an interconnect configuration.

NOTE 2: The combined maximum length of the Work Area cord PLUS the equipment cord is 10 m (33 ft).

Three-Connector Topology Using a Cross-Connect

Additional flexibility and security can be obtained by using separate sets of connectors to terminate cables and equipment pigtails or cords, referred to as a cross-connect configuration. This allows for the permanent cabling and isolation of the switches, with each port always accessible through its associated patch panel instead of directly at the switch, as shown in Figure 11.

Figure 11: Three-connector topology using a cross-connect



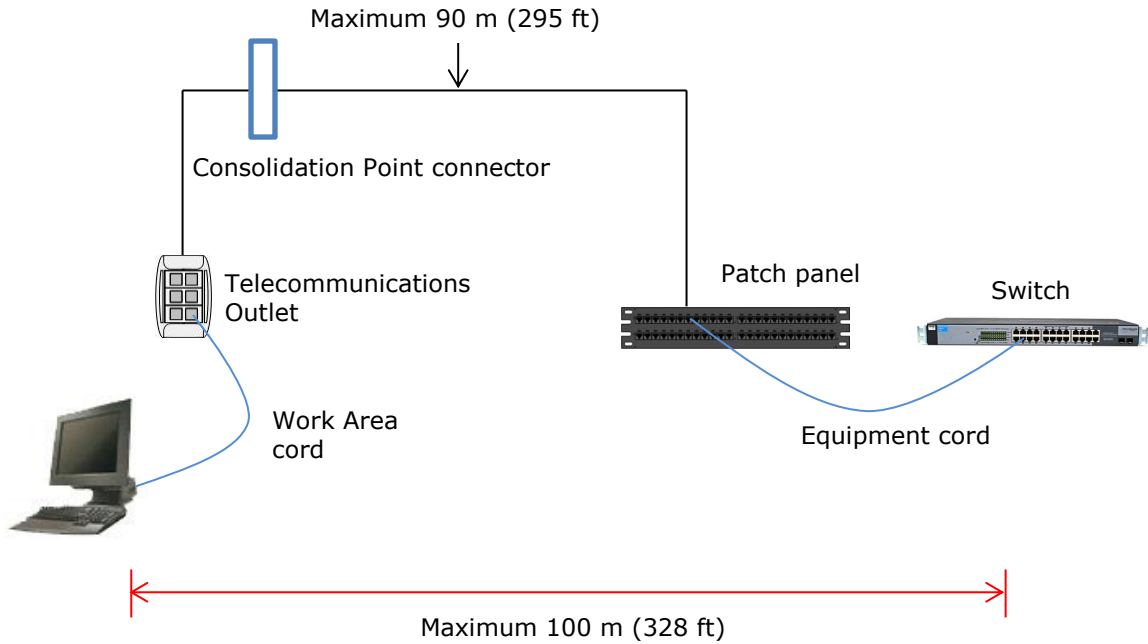
NOTE 1: The equipment cords can be pigtails (cords with modular plugs at one end) terminated like cables onto standard connectors or patch cords (modular plugs at both ends) connected to coupler-type connectors.

NOTE 2: The combined maximum length of the Work Area cord PLUS the equipment pigtail or cord PLUS the cross-connect patch cord is 10 m (33 ft).

Three-Connector Topology Using an Interconnect and a Consolidation Point

Another three-connector topology introduces a Consolidation Point connector to the two-connector topology described previously. This design enables the partial replacement of the cable without disturbing the entire run, as shown in Figure 12.

Figure 12: Three-connector topology using an interconnect and a Consolidation Point

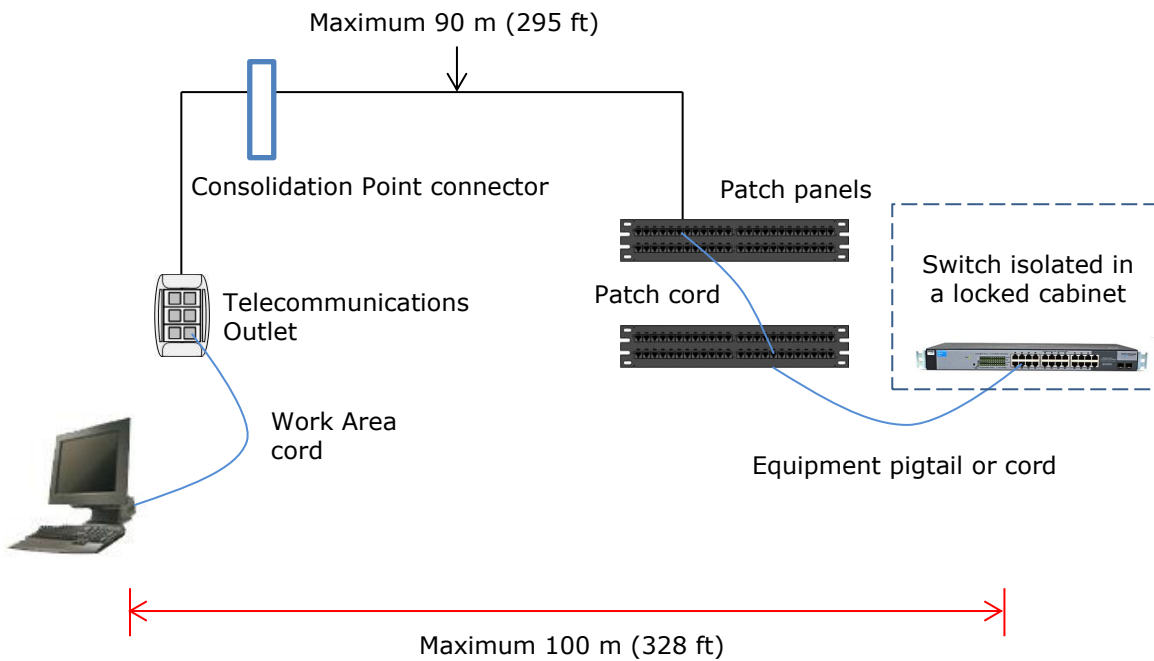


NOTE: The combined maximum length of the Work Area cord PLUS the equipment cord is 10 m (33 ft).

Four-Connector Topology Using a Cross-Connect and a Consolidation Point

This design uses the maximum allowable number of connections for an end-to-end cabling channel, which is four. Both the switch side and the station side are given maximum flexibility with the inclusion of a cross-connect and a Consolidation Point, as shown in Figure 13.

Figure 13: Four-connector topology using a cross-connect and a Consolidation Point



NOTE: The combined maximum length of the Work Area cord PLUS the equipment pigtail or cord PLUS the cross-connect patch cord is 10 m (33 ft).

Work Area Cord Length Limits When Using MUTOAs

If a MUTOA is used in place of multiple Telecommunications Outlets in a shared Work Area space, it is usually necessary to allocate a longer maximum length for the cords than the 10 m (33 ft) value given previously. This allows for the connection of devices to the MUTOA from anywhere in the shared space.

The formula for calculating the maximum allowable combined length of a Work Area cord, patch cord (if using a cross-connect), and equipment pigtail or cord when using a MUTOA is as follows:

$$\text{Maximum combined length of all cords} = \frac{(102 - \text{length of cable in meters})}{(1 + D)}$$

Where D is a de-rating value equal to:

- 0.2 for 24 AWG conductor cords
- 0.5 for 26 AWG conductor cords

EXAMPLE:

What is the maximum allowable Work Area cord length for a channel that includes a MUTOA, 80 m of cable and a 3 m length of 24 AWG solid conductor equipment cord?

$$\begin{aligned} \text{Maximum combined length of all cords} &= \frac{(102 - 80)}{(1 + 0.2)} \\ &= \frac{22}{1.2} \\ &= 18 \text{ m} \end{aligned}$$

$$\begin{aligned} \text{Maximum allowable Work Area cord length} &= 18 \text{ m} - 3 \text{ m equipment cord} \\ &= 15 \text{ m} \end{aligned}$$

SEPARATION FROM POWER CABLES AND FLUORESCENT LIGHTING

Electrical codes typically specify minimum safety-related separation distances for power cables, whether they are exposed, within raceways, or terminated within shared spaces such as rooms or outlet boxes.

Telecommunications standards also specify minimum separation distances between network and power cables to minimize the risk of electromagnetic interference (EMI) causing signal degradation or loss.

ANSI/TIA-569-C titled "*Commercial Building Standard for Telecommunications Pathways and Spaces*" contains minimum separation recommendations for office cabling with values that vary according to:

- The number of power cables nearby
- Their voltage and current ratings
- Whether the circuits are single-phase or three-phase
- Whether the individual power conductors in a circuit are loose (i.e., exposed) or grouped together and covered with a jacket
- Whether jacketed power cables contain any metallic armoring or shielding elements

If a continuous metallic pathway completely covering the cables (e.g., conduit) is used for either network cables or power cables, there does not need to be a minimum separation between the two types of cables.

Similarly, if power cables and network cables cross at a right angle to each other, there does not need to be a minimum separation apart from the need for a barrier to separate the network and power cables in accordance with electrical code requirements.

If separate solid metallic or wire mesh cable trays are used for both network and power cables, all minimum separation distances listed can be reduced by 50 percent.

For the following cases, the separation distance between network and power cables is 600 mm (24 in) or more:

- 91 or more unshielded power cables, 120 or 230 volts, 20 amps, single-phase
- 29 or more unshielded power cables, 120 or 230 volts, 32 amps, single-phase
- 15 or more unshielded power cables, 120 or 230 volts, 63 amps, single-phase
- 4 or more unshielded power cables, 120 or 230 volts, 100 amps, single-phase
- 2 or more armored/shielded or unshielded power cables, 480 volts, 100 amps, three-phase

NOTE: For other distances, refer to "*Table 6 – Recommended separation from power cabling for balanced twisted-pair cabling*" in ANSI/TIA-569-C.

The minimum separation distance between network cables and fluorescent lighting such as lamps and fixtures is 125 mm (5 in).

TEMPERATURE AND HUMIDITY REQUIREMENTS

Telecommunications spaces within commercial buildings must provide environmental conditions suitable for the continuous operation of network equipment.

ANSI/TIA-569-C, titled "*Commercial Building Standard for Telecommunications Pathways and Spaces*" and its Addendum 1, titled "*Revised Temperature and Humidity Requirements for Telecommunications Spaces*" specify the allowable values for temperature, relative humidity, and dew point.

Telecommunications spaces within commercial buildings that are covered by these publications include:

- Entrance Spaces
- Access or Service Provider Rooms/Spaces
- Equipment Rooms
- Telecommunications Rooms and Telecommunications Enclosures

These spaces are rated Class B environments (formerly, Class 3) by the American Society of Heating, Refrigerating and Air-conditioning Engineers or ASHRAE, which serves as the source¹ for the environmental specifications referenced by ANSI/TIA-569-C and its Addendum 1.

The specified values are as follows:

- Allowable temperature range (dry bulb):
5 °C – 35 °C (41 °F – 95 °F)
- Allowable relative humidity (RH) range:
8% – 80%
- Maximum allowable dew point:
28 °C (82 °F)

Note that equipment manufacturers may specify limits that are more restrictive or less restrictive than the values shown here.

¹ ASHRAE "*Thermal Guideline for Data Processing Environments*", 3rd Edition (2012)

4. DESIGN GUIDELINES

This section features standards-based recommendations and design options for copper structured cabling systems within the following spaces in commercial buildings:

- Work Area
- Consolidation Point
- Telecommunications Room
- Telecommunications Enclosure
- Equipment Room
- Entrance Space

Note that in many cases, optical fiber cabling is used for both in-building and campus network backbones. Please refer to Belden's *"Optical Fiber Structured Cabling Design Guide"*, which contains recommended design options for fiber-based connectivity.

WORK AREA

Work Areas serve individuals (e.g., private offices, cubicles) or groups (e.g., meeting rooms, reception areas) on a floor. Structured cabling components for Work Areas include Telecommunications Outlets, Multi-User Telecommunications Outlet Assemblies, and cords to connect Work Area devices such as desktop phones and computers to the outlets.

NOTE: Telecommunications Outlets commonly consist of separate faceplates or other types of housings that contain multiple spaces for inserts such as twisted-pair modular jacks, optical fiber adapters, or coaxial video connectors.

Work Area Specifications

1. For copper cabling, a minimum of two 4-pair, 100-ohm, unshielded or shielded twisted-pair cables shall be terminated within an individual Work Area. The choices are Category 6A, Category 6, or Category 5e in any combination.
2. The eight-position modular jack is used to terminate the 4-pair cable in one of the two configurations—T568A or T568B—as shown in Figure 14. To prevent wire map errors, the same T568A or T568B configuration shall be used for all eight position modular connectors throughout an installation at both ends of a channel.

Figure 14: T568A and T568B pin/pair assignments—front view of jack

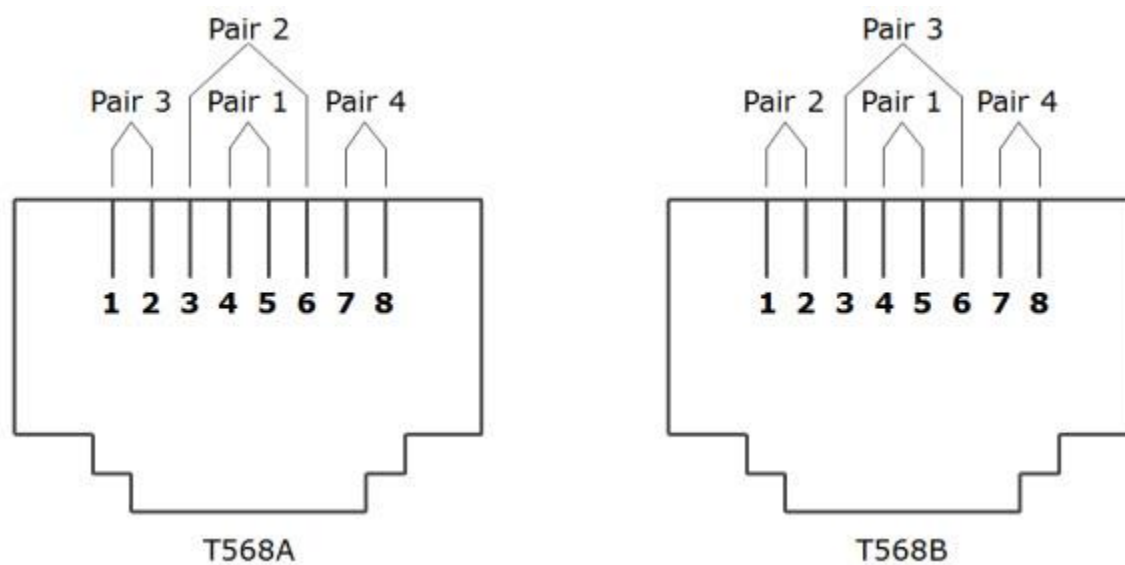


Table 2: T568A and T568B pinouts

Pin	T568A	T568B
1	White-Green	White-Orange
2	Green	Orange
3	White-Orange	White-Green
4	Blue	Blue
5	White-Blue	White-Blue
6	Orange	Green
7	White-Brown	White-Brown
8	Brown	Brown

3. If the Work Area device is equipped with a different type of connector than the eight-position modular jack, any necessary adapters must be installed external to the Telecommunications Outlet (to avoid converting it into a device-specific connection point).
4. For convenience, an electrical outlet should be available at the same height and no farther than 1 m (3.3 ft) from the Telecommunications Outlet.
5. A single Multi-User Telecommunications Outlet Assembly should serve no more than 12 Work Areas.
6. A Multi-User Telecommunications Outlet Assembly contains no active electronic equipment, only passive connectivity for horizontal cabling runs.

Examples of Work Area Components

Telecommunications Outlets – Faceplates and Adapters

Figure 15: KeyConnect single-gang 2-port faceplate



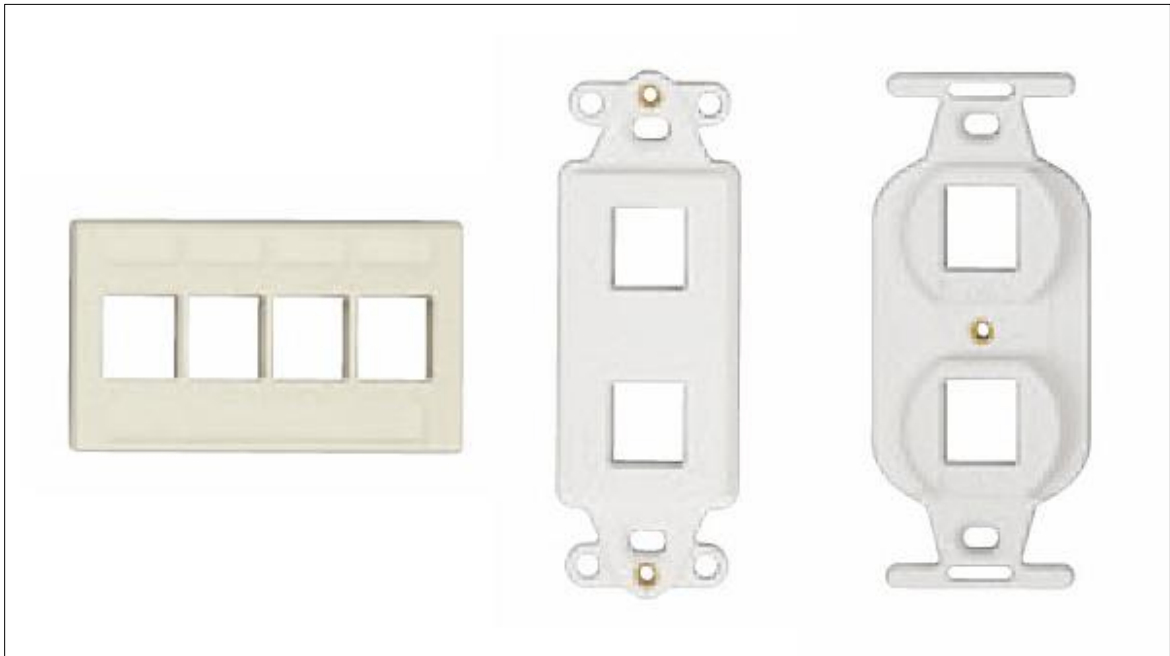
Figure 16: KeyConnect stainless steel 4-port faceplate for institutional applications



Figure 17: KeyConnect tamper-resistant 4-port faceplate with locking cover



Figure 18: KeyConnect modular furniture, Decora, and 106-style adapters



Multi-User Telecommunications Outlet Assemblies

Figure 19: KeyConnect double-gang 12-port faceplate



Figure 20: 12-port Multi-User Outlet Box equipped with modular jacks



Telecommunications Outlets
Links to Additional Information:

[Belden Copper Catalog \(84 pages\).pdf](#)

Product Bulletin:

[KeyConnect Workstation Outlet System \(6 pages\).pdf](#)

Product pages at belden.com:

[KeyConnect Faceplates](#)

[KeyConnect Adapters and Boxes](#)

[KeyConnect Tamper-Resistant Faceplates](#)

General resource pages at belden.com:

[Solutions Catalogs](#)

[Brochures](#)

[Product Bulletins](#)

[Installation Guides](#)

Twisted-Pair Modular Jacks for Faceplates, Adapters, and Multi-User Telecommunications Outlet Assemblies

Figure 21: KeyConnect unshielded modular jacks



Figure 22: KeyConnect shielded modular jacks



Modular Jacks

Links to Additional Information:

[Belden Copper Catalog \(84 pages\).pdf](#)

Product Bulletins:

[KeyConnect Workstation Outlet System \(6 pages\).pdf](#)

[Shielded Cabling Systems \(6 pages\)](#)

Product pages at belden.com:

[Category 5E KeyConnect and MDVO-Style Modular Jacks](#)

[Category 6+ KeyConnect and MDVO-Style Modular Jacks](#)

[Category 6A 10GX KeyConnect and MDVO-Style Modular Jacks](#)

[Category 6+ Shielded Patch Panels and Modular Jacks](#)

[Category 6A 10GX Shielded System](#)

General resource pages at belden.com:

[Solutions Catalogs](#)

[Brochures](#)

[Product Bulletins](#)

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Work Area Cords

Figure 23: Work Area unshielded modular cords



Figure 24: Work Area shielded modular cords



Modular Cords

Links to Additional Information:

[Belden Copper Catalog \(84 pages\).pdf](#)

Product Bulletin:

[10GX, CAT6+ and CAT5E Bonded-Pair Modular Cords \(4 pages\).pdf](#)

[Traceable Bonded-Pair Patch Cords \(2 pages\).pdf](#)

Product pages at belden.com:

[Category 5E Modular Cords](#)

[Category 6+ Modular Cords](#)

[Category 6A 10GX Modular Cords](#)

[Category 6+ Shielded Modular Cords](#)

[Category 6A 10GX Traceable Patch Cords](#)

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CONSOLIDATION POINT (OPTIONAL)

A Consolidation Point serves as an optional interconnection in the horizontal cable link between a Work Area outlet and its corresponding Telecommunications Room or Telecommunications Enclosure.

Consolidation Point Specifications

1. A cross-connect configuration is not permitted for the connectors at the Consolidation Point.
2. Only one Consolidation Point connection is permitted within any individual horizontal cable run. It should be located at least 15 m (49 ft) from the Telecommunications Room or Telecommunications Enclosure to minimize the possibility of signal degradation due to multiple connections within a short distance.
3. A single Consolidation Point space should serve no more than 12 Work Areas.
4. A Consolidation Point contains no active electronic equipment, only passive connectivity for horizontal cabling runs.
5. A Consolidation Point should be located in a permanent position that is fully accessible (e.g., in an enclosure attached to a building column, not to a moveable item of furniture).
6. Connections from a Consolidation Point directly into equipment ports are not permitted. All cables from the Consolidation Point shall terminate at Work Area outlets (Telecommunications Outlets or Multi-User Telecommunications Outlet Assemblies) at one end and connectors in Telecommunications Rooms or Telecommunications Enclosures at the other end.

Examples of Consolidation Point Components

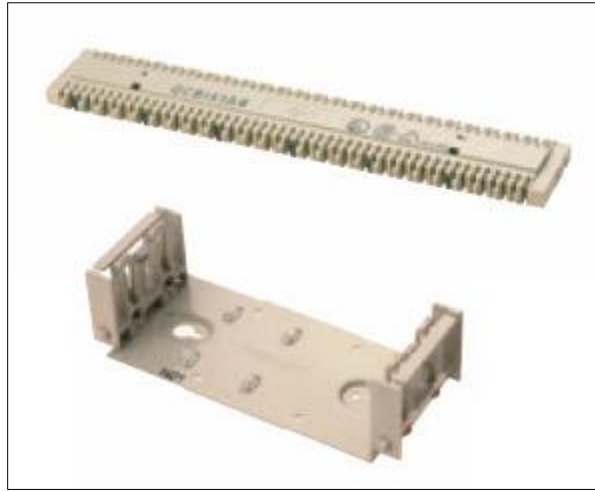
Figure 25: Category 6A insulation displacement contact connector (10 GX IDC)



Figure 26: Category 6 insulation displacement contact connector (GigaBIX)



Figure 27: Category 5e insulation displacement contact connector (BIX)



**Consolidation Point Components
Links to Additional Information:**

[Belden Copper Catalog \(84 pages\).pdf](#)

Product pages at belden.com:

[Category 6+ GigaBIX IDC System](#)

[Category 6A 10GX IDC System](#)

General resource pages at belden.com:

[Solutions Catalogs](#)

[Brochures](#)

[Product Bulletins](#)

[Installation Guides](#)

TELECOMMUNICATIONS ROOM

A Telecommunications Room serves as the floor-based centralized distribution and management space for horizontal cables going to Work Areas on the same floor as well as backbone cables coming from the building’s Equipment Room. It can also contain active electronic equipment such as network switches.

Telecommunications Room Specifications

1. The Telecommunications Room must be located as centrally as possible to the area it serves.
2. The space allocated to the Telecommunications Room function must be dedicated to that function—no other systems, pathways, or components can be installed in or pass through that space.
3. If multiple Telecommunications Rooms are required on the same floor, they should be connected with a pathway consisting of (or equivalent to) a Trade Size 3 (metric 78) conduit.
4. The minimum size of the Telecommunications Room is 3 m x 3 m (10 ft x 10 ft). A larger room may be required, depending on the number of outlets served from that room, as shown in Table 3.

Table 3: Telecommunications Room sizing

Number of Outlets Served	Minimum Floor Space* sq. m / sq. ft	Typical Dimensions* m / ft
Up to 200	15 / 150	3 x 5 / 10 x 15
201 – 800	36 / 400	6 x 6 / 20 x 20
801 – 1600	72 / 800	6 x 12 / 20 x 40
1601 – 2400	108 / 1200	9 x 12 / 30 x 40

* Conversions are approximate

5. An environmental system capable of continuously monitoring and maintaining temperature and humidity levels must be available for the Telecommunications Room. If possible, the air in the room should always remain at positive pressure with respect to air in the surrounding space.
6. The power infrastructure for the Telecommunications Room should include a dedicated electrical panel and the means to automatically connect to a backup power source upon failure of the primary supply.
7. A minimum of two 120 volt / 20 amp branch circuits must be available for network equipment powering in the Telecommunications Room. Each circuit shall terminate in a dedicated duplex electrical outlet.

Additional duplex outlets on one or more separate branch circuits for powering miscellaneous (i.e., non-network equipment) devices must be located 150 mm (6 in) above the floor, 1.8 m (6 ft) apart along all perimeter walls.

8. The horizontal cables going to Work Areas and backbone cables coming from Equipment Rooms may be routed to and terminated on any combination of:
 - Wall-mounted panels, racks, or enclosures
 - Free-standing open racks or enclosed cabinets

TELECOMMUNICATIONS ENCLOSURE (OPTIONAL)

A Telecommunications Enclosure serves as an optional secondary floor-based centralized management and distribution space for horizontal cables routed to Work Areas on the same floor as well as backbone cables coming from the building's Equipment Room. It can also contain active electronic equipment such as network switches.

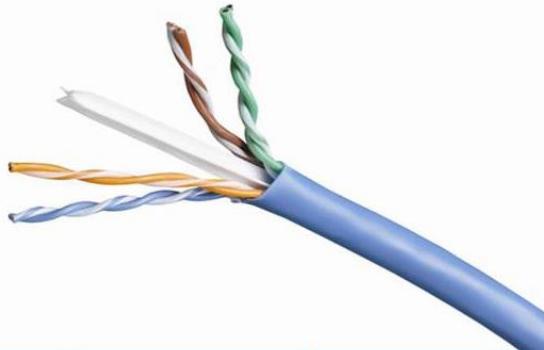
Telecommunications Enclosure Specifications

1. A Telecommunications Enclosure cannot be used in place of a Telecommunications Room—each floor must have at least one Telecommunications Room and may optionally have one or more Telecommunications Enclosures.
2. Telecommunications Enclosures are sized to accommodate current and future requirements and can be configured to blend in with the architectural design of their destinations. Due to their smaller size, they can be located in places where it would be impossible or impractical to construct a separate dedicated room (e.g., building lobby or atrium spaces, historical properties with restrictions on allowable renovations).
3. Sufficient space shall be provided within the enclosure to ensure compliance with cable bend radius requirements and to facilitate mounting of hardware.
4. The minimum environmental and power requirements for Telecommunications Enclosures are the same as those for Telecommunications Rooms, with the following exceptions:
 - A minimum of one (not two) 120 volt / 20 amp branch circuit, terminated in a dedicated duplex electrical outlet, must be available for network equipment powering in the Telecommunications Enclosure.
 - One additional duplex outlet on a separate branch circuit should also be provided for powering miscellaneous (i.e., non-network equipment) devices.

Examples of Telecommunications Room / Telecommunications Enclosure Components

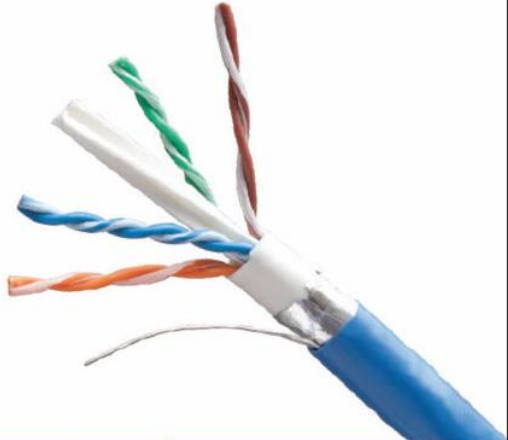
Horizontal Cables

Figure 28: Unshielded cable types



Unshielded cable (U/UTP)	CMP		CMR		LSZH	
	Nonbonded / Bonded-Pair		Nonbonded / Bonded-Pair		Nonbonded / Bonded-Pair	
Category 6A - 10GX	10GX13	10GX33	10GX12	10GX32	10GX24	10GX44
Category 6 - DataTwist 4800	4813	7852A	4812	7851A	4824	7851NH
Category 6 - DataTwist 3600	3613	3633	3612	3632	3624	3644
Category 6 - DataTwist 2400	2413	1874A	2412	1872A	2424	
Category 5e - DataTwist 1200	1213	1701A	1212	1700A	1224	1700NH

Figure 29: Shielded cable types



Shielded Cable (F/UTP)	CMP		CMR	
	Nonbonded / Bonded-Pair		Nonbonded / Bonded-Pair	
Category 6A - 10GX	10GX53F 10GX63F		10GX52F 10GX62F	
Category 6 - DataTwist 2400	2413F Not available		2412F Not available	
Category 5e - DataTwist 1200	1213F Not available		1212F Not available	

Horizontal Cables

Links to Additional Information:

[Belden Copper Catalog \(84 pages\).pdf](#)

Product Bulletins:

[Belden DataTwist 1200 Cables \(4 pages\).pdf](#)

[Belden DataTwist 2400 Cables \(4 pages\).pdf](#)

[Belden DataTwist 3600 Cables \(6 pages\).pdf](#)

[Belden 3600 Pre-Terminated Cabling System \(8 pages\).pdf](#)

[Belden DataTwist 4800 Cables \(6 pages\).pdf](#)

[Belden 10GX Cables \(6 pages\).pdf](#)

[Belden 10GX Pre-Terminated Cabling System \(8 pages\).pdf](#)

[Shielded Cabling Systems \(6 pages\).pdf](#)

[SFP+ Direct Attached Cables \(2 pages\).pdf](#)

Product pages at belden.com:

[Category 5E DataTwist 1200 UTP Cable](#)

[Category 6+ DataTwist 2400 UTP Cable](#)

[Category 6+ DataTwist 3600 UTP Cable](#)

[Category 6+ DataTwist 4800 UTP Cable](#)

[Category 6A 10GX System Cable](#)

[Category 6A 10GX Pre-Terminated Cabling System](#)

[Category 6+ DataTwist 2400 Shielded Cable](#)

[Category 6A 10GX Shielded Cable](#)

[Category 6A 10GX Shielded Pre-Terminated System](#)

[Category 6A SFP+ Direct Attached Cables](#)

General resource pages at belden.com:

[Solutions Catalogs](#)

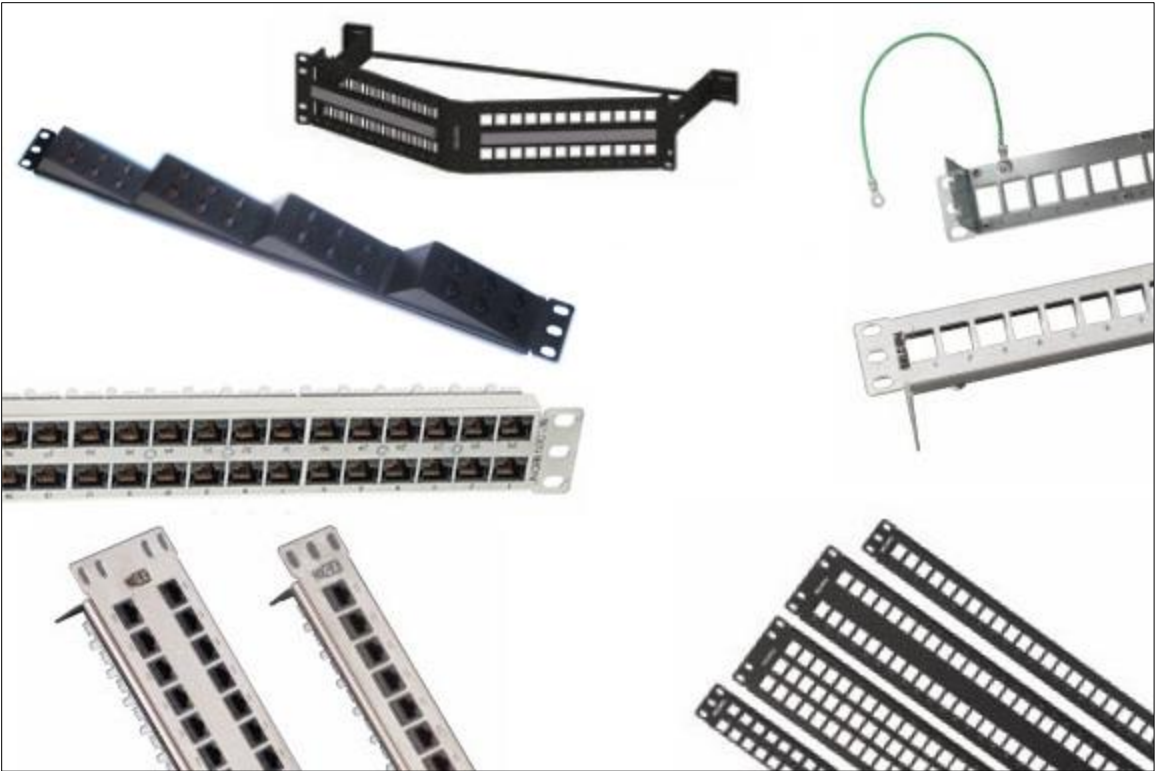
[Brochures](#)

[Product Bulletins](#)

[Installation Guides](#)

Patch Panels

Figure 30: Unshielded and shielded patch panels—preloaded with modules or empty



Patch Panels**Links to Additional Information:**

[Belden Copper Catalog \(84 pages\).pdf](#)

Product Bulletins:

[KeyConnect Patch Panels \(2 pages\).pdf](#)

[AngleFlex Patch Panels \(2 pages\).pdf](#)

Product pages at belden.com:

[Category 5E KeyConnect Patch Panels](#)

[Category 6+ KeyConnect Patch Panels](#)

[Category 6A 10GX Patch Panels](#)

[Category 6+ Shielded Patch Panels and Modular Jacks](#)

[Category 6A 10GX Shielded System](#)

General resource pages at belden.com:

[Solutions Catalogs](#)

[Brochures](#)

[Product Bulletins](#)

[Installation Guides](#)

Racks and Enclosures

Figure 31: Wall-mount and free-standing racks and enclosures



Racks and Enclosures**Links to Additional Information:**

[Belden Infrastructure Solutions Catalog \(84 pages\).pdf](#)

Product Bulletins:

[High-density Racking System \(4 pages\).pdf](#)

[Belden Performance Value Line \(4 pages\).pdf](#)

[Belden X Series Enclosures \(4 pages\).pdf](#)

[Adaptive Enclosure Heat Containment System \(4 pages\).pdf](#)

Product pages at belden.com:

[Infrastructure Solutions](#)

[Enclosures and Racks](#)

[Data Center Solutions Configurator](#)

General resource pages at belden.com:

[Solutions Catalogs](#)

[Brochures](#)

[Product Bulletins](#)

[Installation Guides](#)

EQUIPMENT ROOM

A single Equipment Room serves as the building's centralized distribution and management space for backbone cables going to the Telecommunications Rooms (and optionally, to the Telecommunications Enclosures) on every floor in the building.

Other types of cables that may be terminated in the Equipment Room include telecommunications circuits from access or service providers and campus cabling to one or more other buildings on the same site.

An Equipment Room can also contain active electronic equipment serving multiple floors or the entire building, such as switches, servers, routers, and mass storage units for a variety of applications. These include:

- Traditional data
- Voice / telephony
- Audio / video
- Premises security (e.g., surveillance, access control)
- Building management (e.g., lighting, climate control)

Equipment Room Specifications


1. The space serving as the Equipment Room for the building can also contain a Telecommunications Room serving horizontal cabling to the Work Areas located on the same floor as the Equipment Room.
2. To facilitate in-building backbone cabling runs, the Equipment Room should be vertically aligned with the Telecommunications Rooms on all of the other floors in the building.
3. The minimum sizing, environmental, and power requirements for Equipment Rooms are the same as those for Telecommunications Rooms, with the acknowledgement that an Equipment Room is usually a larger space. In buildings with high pair-count copper backbone cabling (e.g., 300 or more pairs to every floor in a 20-floor building), it may be necessary to use special-purpose free-standing frame systems in the Equipment Room in order to efficiently terminate and manage the large number of connections.

Examples of Equipment Room Components

Indoor Backbone Cables

Figure 32: Multi-pair indoor backbone cables—Category 5e and Category 3

Backbone Product	CMP	CMR
IBDN Plus Backbone Indoor Cable (25-pair Category 5e)	IBDN25P	IBDN25R
DataTwist 3 Backbone Indoor Cables (High Pair Count Category 3)	DPLN25 DPLN50 DPLN100 DPLN200 DPLN300	DIW12 DIW25 DIW50 DIW100 DIW200 DIW300



Indoor Backbone Cables
Links to Additional Information:

[Belden Copper Catalog \(84 pages\).pdf](#)

General resource pages at belden.com:

[Solutions Catalogs](#)

[Brochures](#)

[Product Bulletins](#)

[Installation Guides](#)

Wall-Mount Cross-Connect Systems

Figure 33: GigaBIX Cross-Connect System—patch cord or cross-connect wire (Category 6)

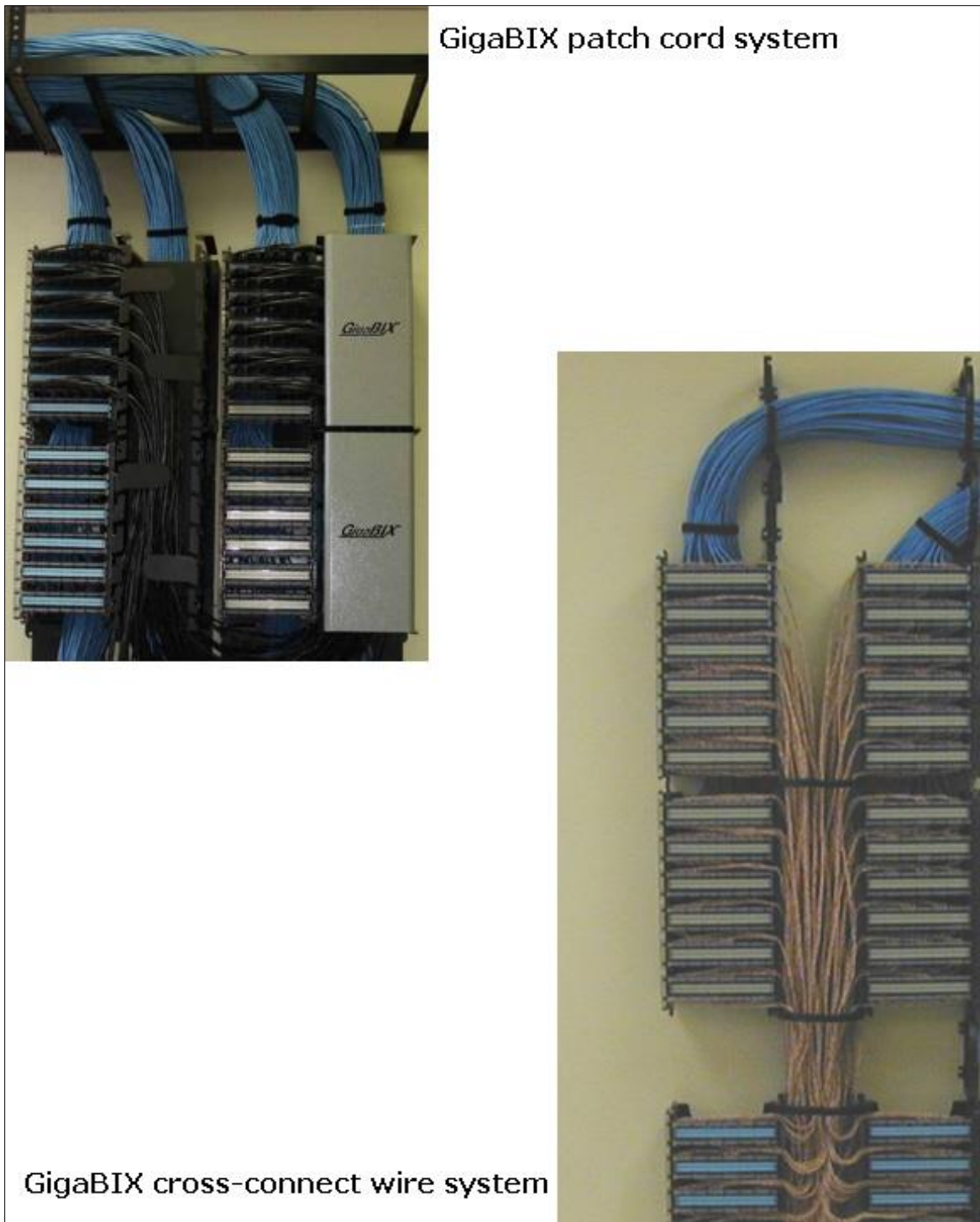
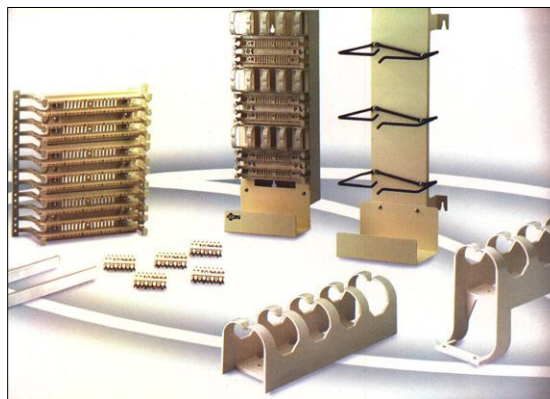


Figure 34: BIX Cross-Connect System—patch cord or cross-connect wire (Category 5e)



Figure 35: 110- Cross-Connect System—patch cord (Category 5e)



Wall-Mount Cross-Connect Systems
Links to Additional Information:

[Belden Copper Catalog \(84 pages\).pdf](#)

General resource pages at belden.com:

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[Brochures](#)

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ENTRANCE SPACE

Once an outdoor-rated cable physically enters a building through an entrance point in an exterior wall, it is subject to the same requirements (e.g., fire resistance) as in-building cable. In most cases, this requires a transition from one cable type to another, using either splicing or connectorization.

If the cable contains both copper conductors and other metallic elements (e.g., shielding, armor), it is mandatory to provide electrical protection and to bond the shield or armor to the grounding system for life safety and the protection of property.

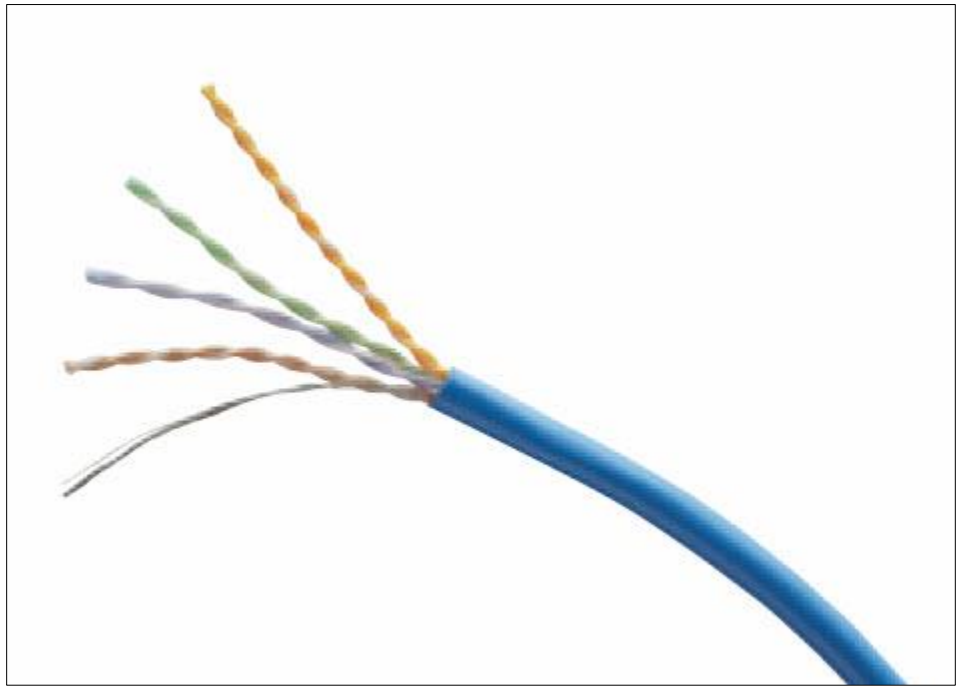
In the case of cable delivering telecommunications circuits from access or service providers, an additional physical demarcation point is required to identify the boundary between the provider and the building owner or tenant. Any time there is a problem with a circuit, the provider can test in the direction facing outwards from the demarcation point and the building owner or tenant can test in the direction facing inwards.

Entrance Space Specifications

1. All entrance services (i.e., transition, electrical protection, grounding, demarcation) can be provided in one or more stand-alone Entrance Spaces or a dedicated Entrance Space within the building's Equipment Room. If the useable floor space in the building exceeds 2000 sq. m (21,520 sq. ft), it is recommended to provide a separate enclosed Entrance Space.
2. An Entrance Space can also contain network equipment belonging to the building owner, a tenant, or a telecommunications circuit provider.
3. Entrance services should be as close as possible to both the cable entrance point and the building's main electrical distribution panel (in order to minimize the length of the bonding conductors from the cables to the grounding system).
4. The minimum environmental and power requirements for Entrance Spaces are the same as those for Telecommunications Rooms.

Example of Entrance Space Components

Figure 36: 4-pair gel-filled outside plant cables—Category 6 and Category 5e



Entrance Space Components
Links to Additional Information:

[Belden Copper Catalog \(84 pages\).pdf](#)

General resource pages at belden.com:

[Solutions Catalogs](#)

[Brochures](#)

[Product Bulletins](#)

[Installation Guides](#)

5. INSTALLATION AND TESTING GUIDELINES

INTRODUCTION

Guidelines for the installation of copper cabling systems and components are provided by standards, industry best practices, and manufacturers. Their common goal is to prevent faulty installation or poor maintenance of cables and connectors in order to avoid costly network outages and time-consuming troubleshooting.

Sources of installation guidelines include ANSI/TIA-568-C.0 (Generic Telecommunications Cabling for Customer Premises) Section 5, titled "Cabling Installation Requirements" and BICSI's Information Technology Systems Installation Methods Manual (ITSIMM), 6th Edition.

The following are examples of copper cable termination requirements, extracted from a published project specification document:

- Cables shall be installed and terminated in accordance with standards-based requirements and recommendations (e.g., TIA), industry best practices (e.g., BICSI Information Technology Systems Installation Methods Manual), and Belden's Installation Guides.
- The twisted pairs shall be guided, positioned and secured at the connector termination point using a bar mechanism that locks the pairs in place to prevent the untwisting of pairs when terminating the conductors.
- Cables shall be neatly bundled, dressed, and routed to their respective termination connectors. Each patch panel shall terminate one or more cable bundles separated and dressed back to the point of cable entrance into the equipment cabinet or rack.
- Each cable shall be clearly labeled on the cable jacket behind the patch panel at a location that can be viewed without the prior removal of any support element for the cable bundle.

Testing is an integral component of installation, maintenance, and troubleshooting for both cabling systems and the network devices they connect. When an active link fails, testing makes it possible to isolate or eliminate the cables and connectors between the devices as the source of the fault.

Three levels of testing are possible, as follows:

- Basic verification

Testing to verify that the components in a cabling link are properly connected and not damaged.

- Network qualification

Testing to verify that the cabling link provides error-free signal transport for a specific type of network (e.g., Gigabit or 10 Gigabit Ethernet).

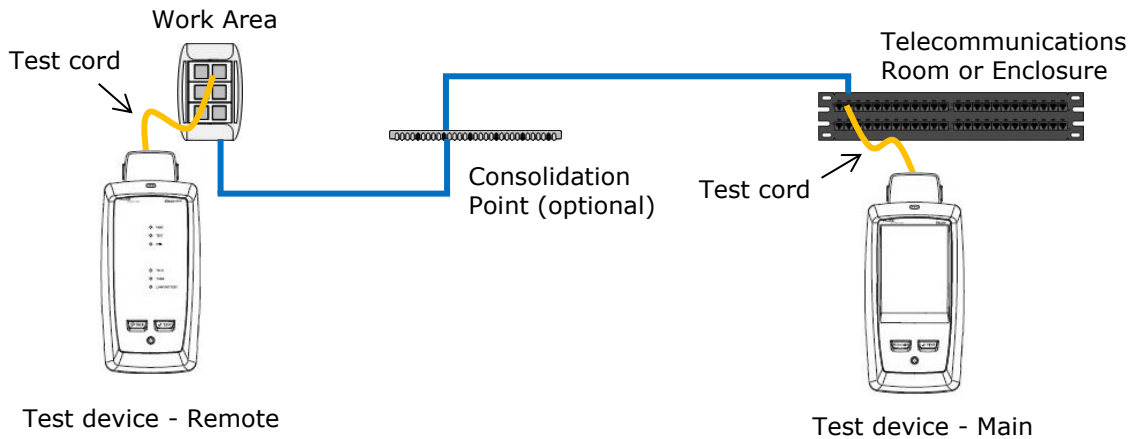
- Certification

Testing to verify that the cabling link passes all of the requirements as published in an industry-recognized cabling standard (e.g., ANSI/TIA-568-C, ISO/IEC 11801).

NOTE: Familiarity with the selected testing instruments and associated software is essential for correct test setups and subsequent interpretation of test results.

The most common configuration tested as part of the initial installation and acceptance of a cabling system is the Permanent Link. This configuration excludes the cords used to connect to network devices at both ends, as shown in Figure 37.

Figure 37: Permanent Link testing



* Test cords are excluded from measurement

The alternative testing configuration is the Channel, which is used to test all of the cabling components between connected devices, including the cords at both ends.

Figures 38 and 39 illustrate the Channel testing configuration with an interconnect and cross-connect, respectively.

NOTE: Belden’s certification guarantee applies to a channel. Permanent link testing is acceptable for certification provided that Belden cords are used for an end-to-end system.

Figure 38: Channel testing with an interconnect

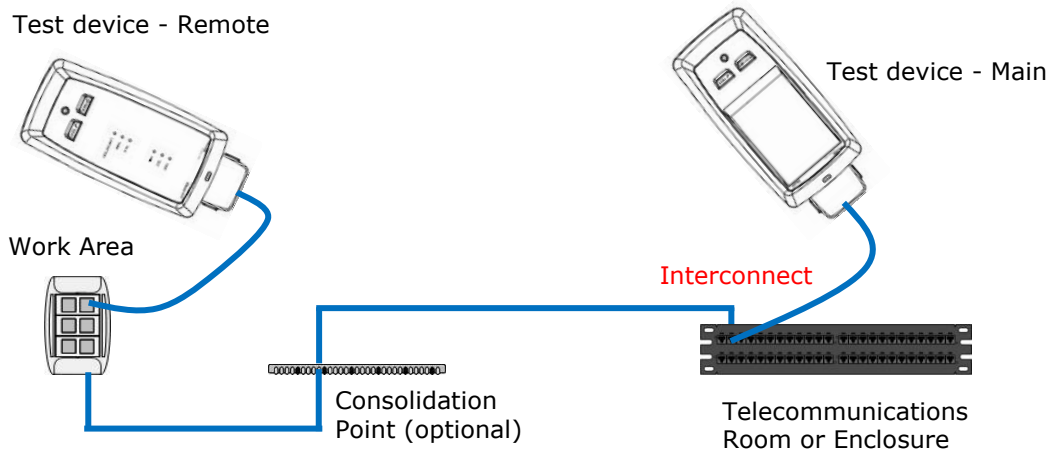
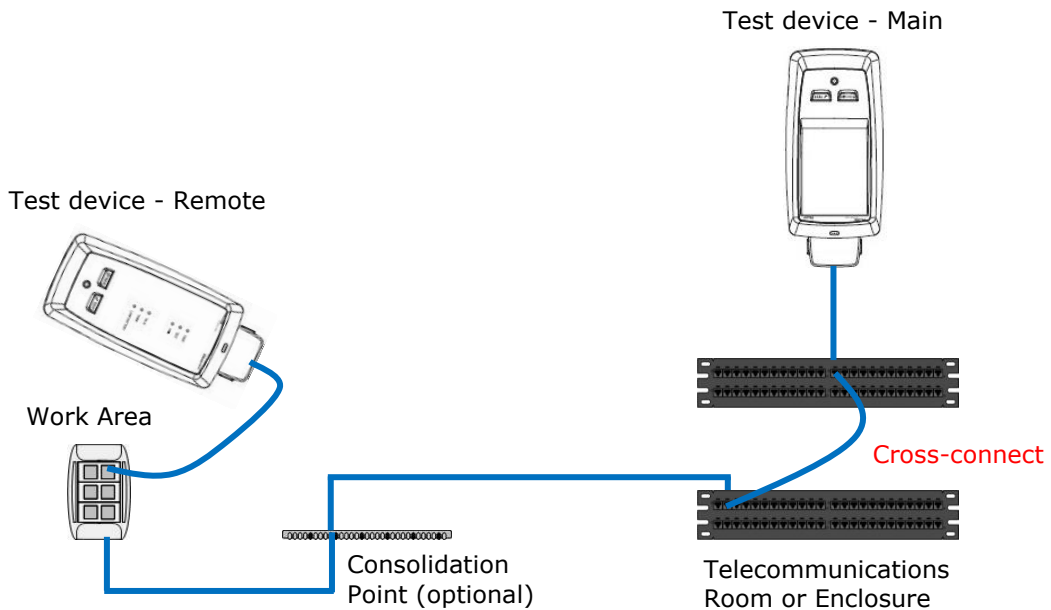


Figure 39: Channel testing with a cross-connect



There are 10 parameters that must be tested and reported in order to comply with ANSI/TIA-1152, titled "*Requirements for Field Test Instruments and Measurements for Balanced Twisted-Pair Cabling*".

1. Wire map/shield continuity (when testing shielded cabling)
2. Length, using the shortest pair (with fewest twists per unit of measure)
3. Propagation delay for each pair
4. Delay skew (delay between each of the three pairs and the shortest/reference pair, at 10 MHz)
5. Insertion loss
6. Return loss—must test from both ends
7. Near-End Crosstalk (NEXT)—must test from both ends
8. Power-Sum Near-End Crosstalk (PSNEXT)—must test from both ends
9. Attenuation-to-Crosstalk Ratio, Far end (ACRF)—must test from both ends
10. Power-Sum Attenuation-to-Crosstalk Ratio, Far end (PSACRF)—must test from both ends

EXTENT OF TESTING

The extent of testing shall be in accordance with the end-customer's testing requirements. Belden recommends 100% testing of permanent links for Insertion Loss, Return Loss, NEXT, PSNEXT, and PSACRF. These tests are performed at the same time as the Continuity Test using an automated tester such as the Fluke DTX-1800.

For Category 6A installations, a random sampling of short length and long length installed permanent links shall be tested for Power-Sum Alien Near-End Crosstalk (PSANEXT) and Power-Sum Alien Attenuation-to-Crosstalk Ratio, Far-end (PSAACRF). The links selected for testing shall follow the selection criteria specified in ANSI/TIA-568-C.2, *"Balanced Twisted-Pair Telecommunications Cabling and Components Standard"*.

With regards to the sampling size for alien crosstalk testing, the Belden Certified System Vendor (CSV) shall test in accordance with the end-customer's testing/sampling requirements, or a minimum of five (5) permanent links or 1% of installed permanent links—whichever is greater—up to a maximum of thirty (30) permanent links.

Links to Additional Information at belden.com:

[Belden Installation Guides page](#)

[Belden LabelFlex Labeling System page](#)

[Belden Conduit Capacity Calculator page](#)

Links to Additional Information at flukenetworks.com:

[Fluke Networks - Learn About Cable Installation page](#)

[Fluke Networks - Learn About Cable Testing page](#)

ANNEX A: DESIGN EXAMPLES

IBDN UNSHIELDED CABLING SYSTEMS

The design examples in this Annex are intended to provide guidance on product selection for Belden's unshielded twisted-pair structured cabling systems.

Three performance levels are featured:

- Category 6A
- Category 6
- Category 5e

DESIGN EXAMPLE 1 — CATEGORY 6A**Customer Requirement:**

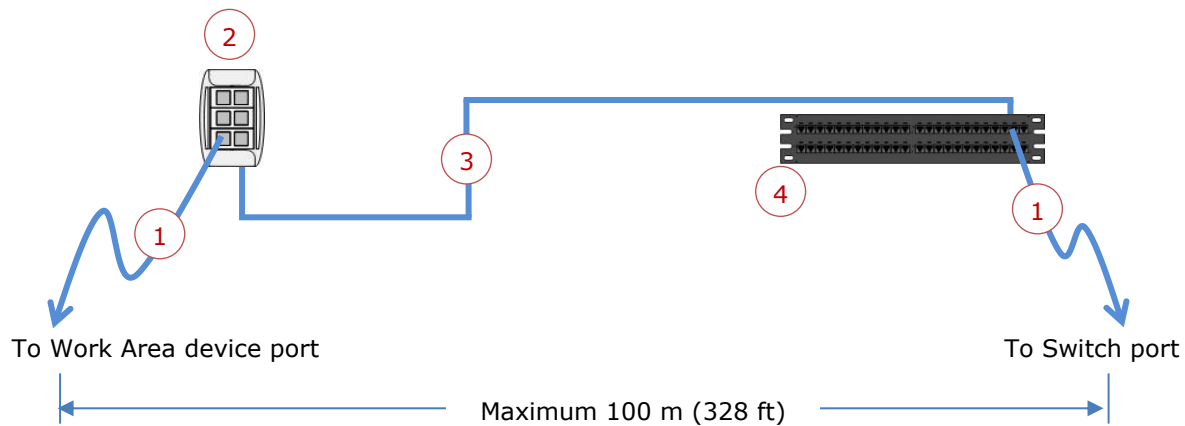
Category 6A end-to-end performance to enable Ethernet connections to any device at up to 10 Gb/s over a maximum 100 m (328 ft) channel length.

Category 6A bandwidth: 500 MHz

Belden IBDN 10GX System bandwidth: 625 MHz

Proposed Design:

Two-connector topology - Telecommunications Outlet or Multi-User Telecommunications Outlet Assembly in Work Area and interconnect patch panel layout in Telecommunications Room



- ① 10GX Modular Cords (Bonded-pair, 24 AWG solid conductors)
- ② KeyConnect, MediaFlex, Interface, or MDVO outlet hardware, equipped with 10GX Modular Jacks
- ③ 10GX UTP Cable (Nonbonded-pair or bonded-pair, 23 AWG)
- ④ 10GX Patch Panels (Empty or preloaded with 10GX Modular Jacks)

DESIGN EXAMPLE 2 — CATEGORY 6

Customer Requirement:

Category 6 end-to-end performance to enable Ethernet connections to any device at up to 1 Gb/s over a maximum of 100 m (328 ft) channel length. Some of the shorter channels—up to any length between 37 m (121 ft) and 55 m (180 ft) depending on bundling conditions—may be used for 10 Gb/s connections after successful field testing for qualification.

Category 6 bandwidth: 200 MHz, with transmission characteristics specified to 250 MHz.

Belden IBDN 4800 System bandwidth: 300 MHz

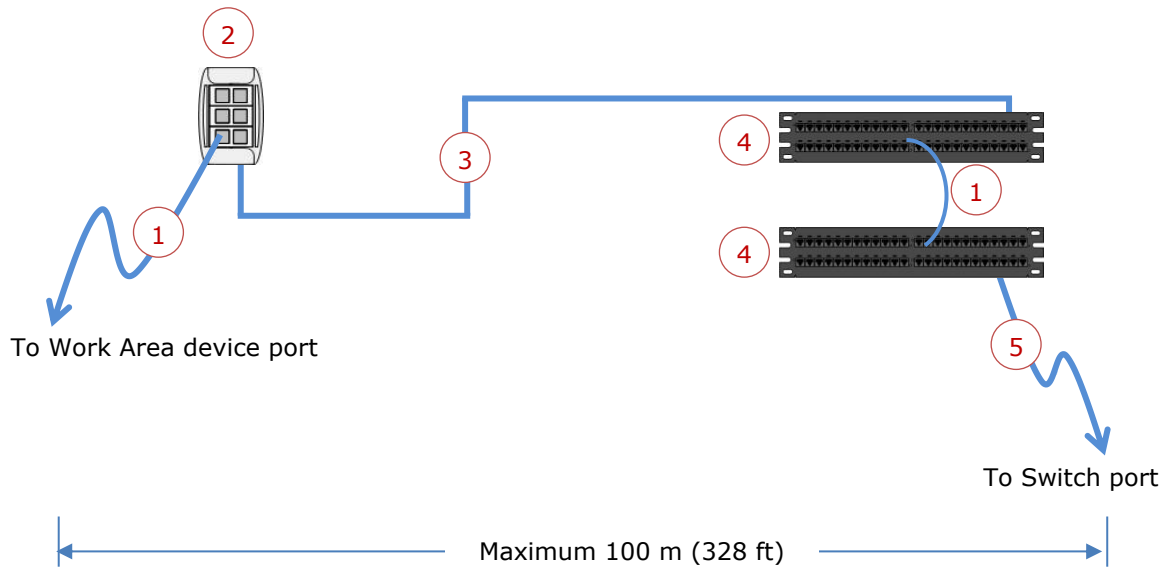
Belden IBDN 3600 System bandwidth: 280 MHz

Belden IBDN 2400 System bandwidth: 250 MHz

NOTE: Although each of these three IBDN Systems features one or more cables with unique characteristics, they all use the same connectors and cords.

Proposed Design:

Three-connector topology - Telecommunications Outlet or Multi-User Telecommunications Outlet Assembly in Work Area and cross-connect patch panel layout in Telecommunications Room



① CAT6+ Modular Cords, (Bonded-pair, 24 AWG solid conductors)

② KeyConnect, MediaFlex, Interface, or MDVO outlet hardware, equipped with CAT6+ Modular Jacks

DataTwist 4800 UTP Cable (Nonbonded-pair or bonded-pair, 23 AWG) ... or
 ③ DataTwist 3600 UTP Cable (Nonbonded-pair or bonded-pair, 23 AWG) ... or
 DataTwist 2400 UTP Cable (Nonbonded-pair or bonded-pair, 23 AWG)

④ CAT6+ Patch Panels (Empty or preloaded with CAT6+ Modular Jacks) ... or
 Belden IBDN GigaBIX Cross-Connect System

⑤ CAT6+ Pigtails (Nonbonded-pair, 23 AWG solid conductors)

DESIGN EXAMPLE 3 — CATEGORY 5E**Customer Requirement:**

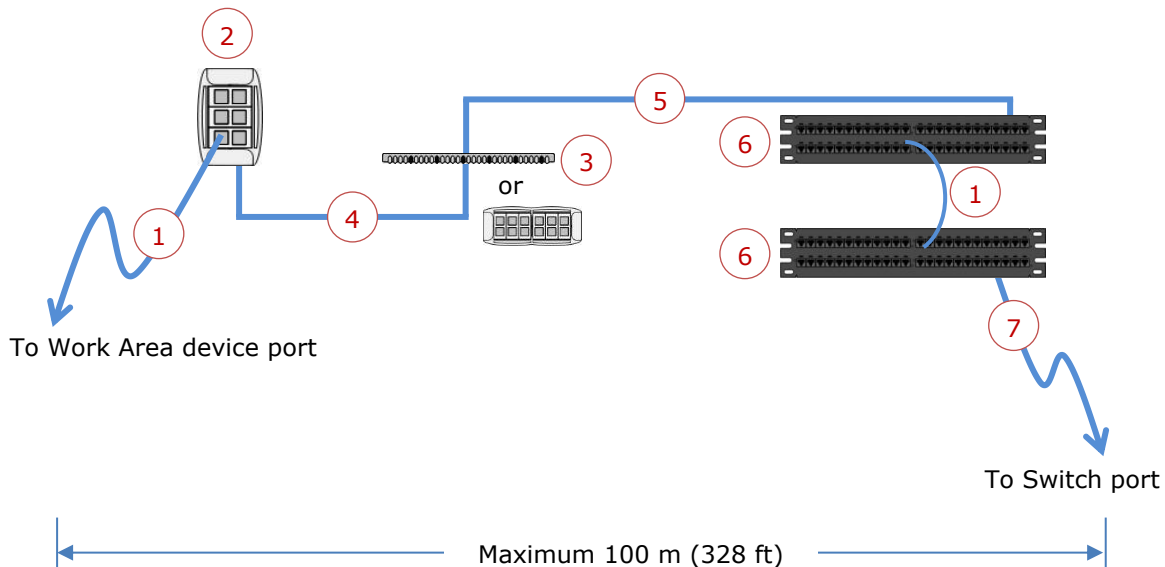
Category 5e end-to-end performance to enable Ethernet connections to any device at up to 1 Gb/s over a maximum 100 m (328 ft) channel length.

Category 5e bandwidth: 100 MHz

Belden IBDN 1200 System bandwidth: 160 MHz

Proposed Design:

Four-connector topology - Telecommunications Outlet or Multi-User Telecommunications Outlet Assembly in Work Area, Consolidation Point, and cross-connect patch panel layout in Telecommunications Room



① CAT5E Modular Cords (Bonded-pair, 24 AWG solid conductors)

② KeyConnect, MediaFlex, Interface, or MDVO outlet hardware, equipped with CAT5E Modular Jacks

③ BIX connectors or CAT5E Modular Jacks and outlet hardware

DataTwist 1200 UTP Cable (Bonded-pair, 24 AWG) ... or

④ CAT5E Pigtails (Nonbonded-pair, 24 AWG solid conductors)

NOTE: If modular jacks are used in place of BIX connectors, pigtails must be used in place of horizontal cable.

⑤ DataTwist 1200 UTP Cable (Bonded-pair, 24 AWG)

CAT5E Patch Panels (Empty or preloaded with CAT5E Modular Jacks) ... or

⑥ Belden IBDN BIX Cross-Connect System ... or

Belden 110 Cross-Connect System

⑦ CAT5E Pigtails (Nonbonded-pair, 24 AWG solid conductors)

ANNEX B: DESIGN EXAMPLES

IBDN SHIELDED CABLING SYSTEMS

The design examples in this Annex are intended to provide guidance on product selection for Belden's shielded twisted-pair structured cabling systems.

Three performance levels are featured:

- Category 6A
- Category 6
- Category 5e

DESIGN EXAMPLE 1 — CATEGORY 6A**Customer Requirement:**

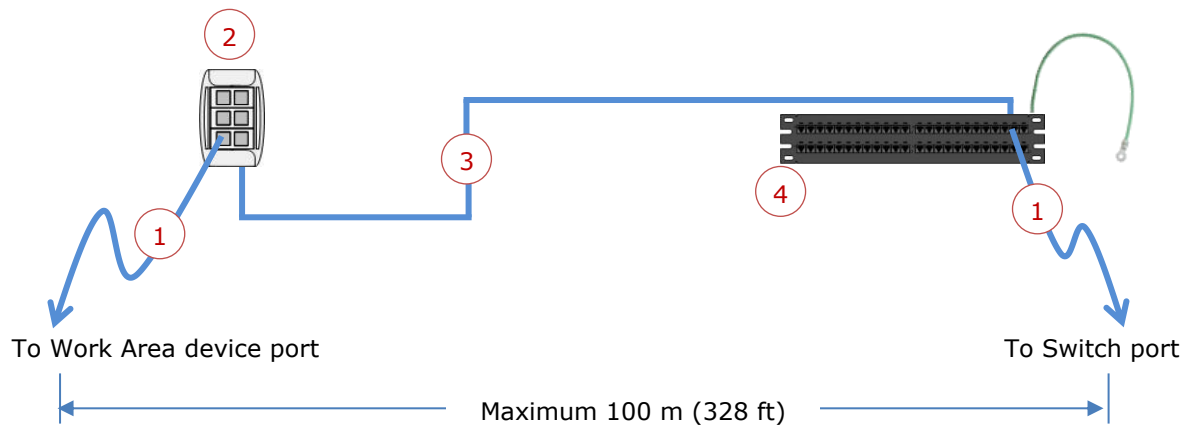
Category 6A end-to-end performance to enable Ethernet connections to any device at up to 10 Gb/s over a maximum 100 m (328 ft) channel length.

Category 6A bandwidth: 500 MHz

Belden IBDN 10GX Shielded System bandwidth: 625 MHz

Proposed Design:

Two-connector topology - Telecommunications Outlet or Multi-User Telecommunications Outlet Assembly in Work Area and interconnect patch panel layout in Telecommunications Room



- ① 10GX Shielded Modular Cords (Bonded-pair, 24 AWG solid conductors)

- ② KeyConnect or MediaFlex outlet hardware, equipped with 10GX Shielded Modular Jacks

- ③ 10GX Shielded Cable (F/UTP, nonbonded-pair or bonded-pair, 23 AWG)

- ④ 10GX Shielded Patch Panels (Empty) and 10GX Shielded Modular Jacks

DESIGN EXAMPLE 2 — CATEGORY 6

Customer Requirement:

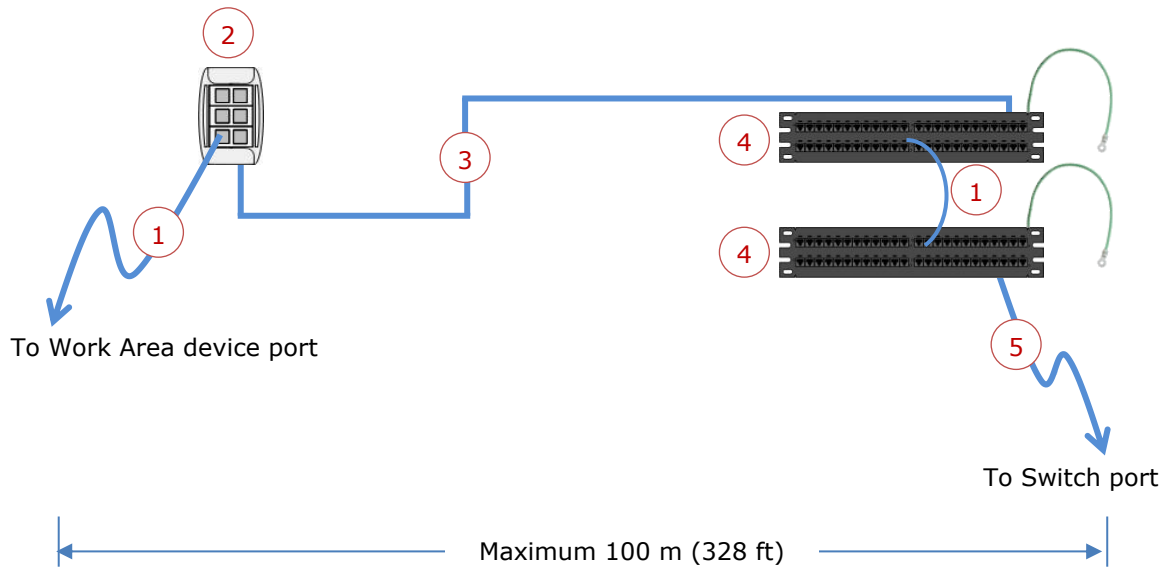
Category 6 end-to-end performance to enable Ethernet connections to any device at up to 1 Gb/s over a maximum of 100 m (328 ft) channel length. Some of the shorter channels—up to 55 (180 ft) in length—may be used for 10 Gb/s connections after successful field testing for qualification.

Category 6 bandwidth: 200 MHz, with transmission characteristics specified to 250 MHz.

Belden IBDN 2400 Shielded System bandwidth: 250 MHz

Proposed Design:

Three-connector topology - Telecommunications Outlet or Multi-User Telecommunications Outlet Assembly in Work Area and cross-connect patch panel layout in Telecommunications Room



- ① CAT6+ Shielded Modular Cords, (Nonbonded-pair, 24 AWG solid conductors)

- ② KeyConnect or MediaFlex outlet hardware, equipped with CAT6+ Shielded KeyConnect Modular Jacks

- ③ DataTwist 2400 Shielded Cable (Nonbonded-pair, 23 AWG)

- ④ CAT6+ Shielded Patch Panels (Empty) and CAT6+ Shielded KeyConnect Modular Jacks

- ⑤ CAT6+ Shielded Pigtails (Nonbonded-pair, 24 AWG solid conductors)

DESIGN EXAMPLE 3 — CATEGORY 5E**Customer Requirement:**

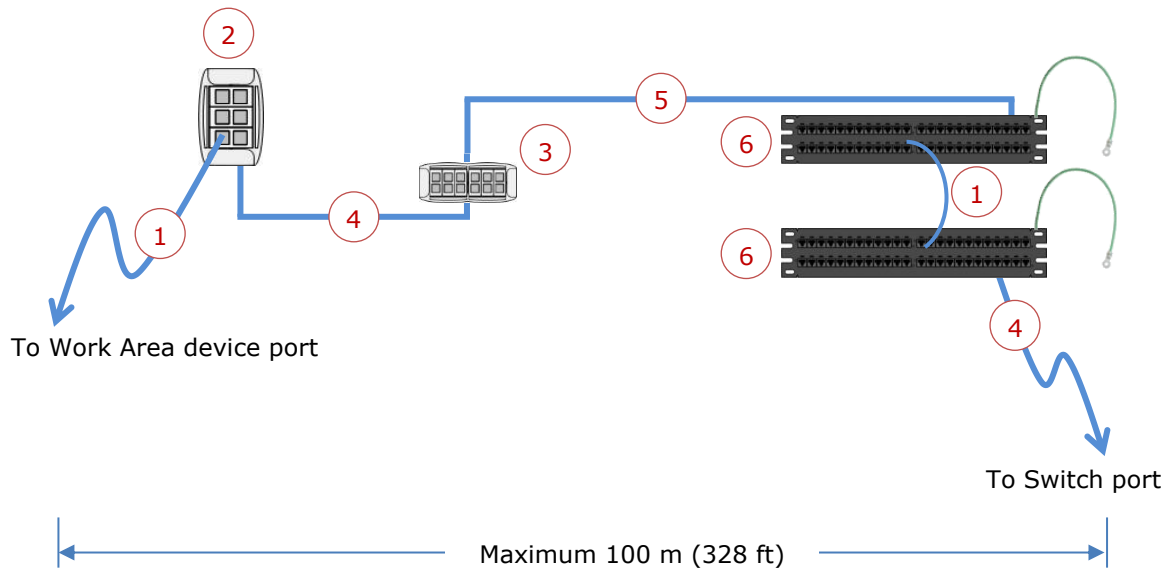
Category 5e end-to-end performance to enable Ethernet connections to any device at up to 1 Gb/s over a maximum 100 m (328 ft) channel length.

Category 5e bandwidth: 100 MHz

Belden IBDN 1200 Shielded System bandwidth: 160 MHz

Proposed Design:

Four-connector topology - Telecommunications Outlet or Multi-User Telecommunications Outlet Assembly in Work Area, Consolidation Point, and cross-connect patch panel layout in Telecommunications Room



- ① CAT5E Shielded Modular Cords (Nonbonded-pair, 24 AWG solid conductors)

- ② KeyConnect or MediaFlex outlet hardware, equipped with CAT5E Shielded KeyConnect Modular Jacks

- ③ CAT5E Shielded KeyConnect Modular Jacks and outlet hardware

- ④ CAT5E Shielded Pigtails (Nonbonded-pair, 24 AWG solid conductors)

- ⑤ DataTwist 1200 Shielded Cable (Nonbonded-pair, 24 AWG)

- ⑥ CAT5E Shielded Patch Panels (Empty) and CAT5E Shielded KeyConnect Modular Jacks

ANNEX C: HDBASET CABLING CONSIDERATIONS

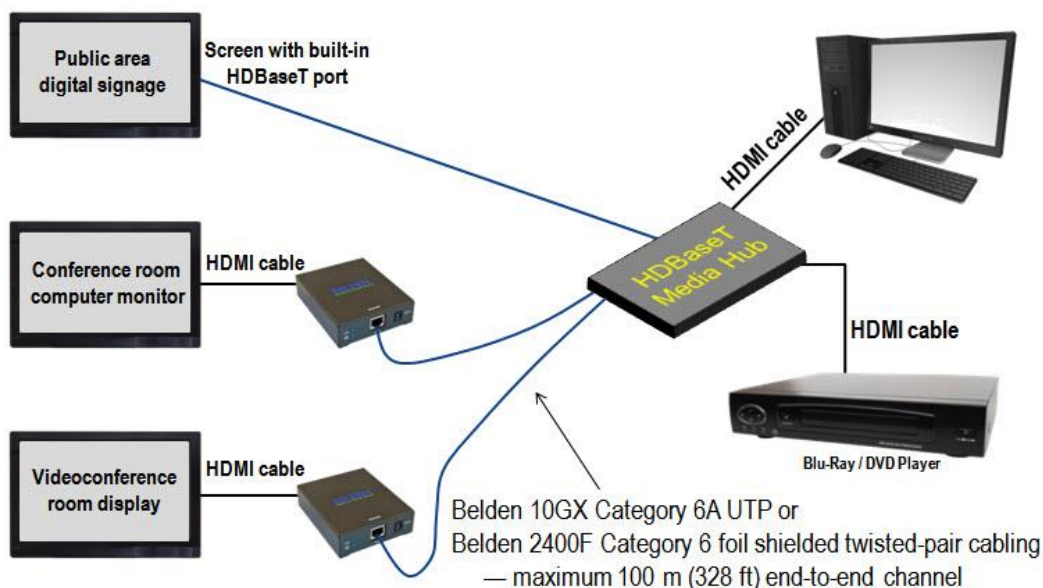
The High-Definition Multimedia Interface (HDMI) is a point-to-point digital audio/video (AV) connection standard introduced in 2002. HDMI cables and connectors are used to interconnect devices such as televisions, Blu-ray/DVD players, audio systems, computer monitors, gaming devices, and laptops.

The HDMI standard does not define a maximum cable length, and most constructions are no longer than 5 m to 15 m (16 ft to 49 ft), with signal attenuation serving as the limiting factor. Field termination of HDMI cables is impractical due to the complexity of the various connectors (5 types defined, up to 29 pins).

HDBaseT is a networking technology introduced in 2010 by the HDBaseT Alliance (www.hdbaset.org). Its purpose is to enable HDMI signals to be transported up to 100 m (328 ft) in an uncompressed format using familiar balanced twisted-pair network cables and modular (RJ-45) connectors.

Using HDBaseT, commercial facilities can deploy HDMI devices such as large screen digital signage or computer monitors with the same flexibility and cabling infrastructure as desktop computers and telephones, as shown in Figure 40.

Figure 40: Example of an HDBaseT network



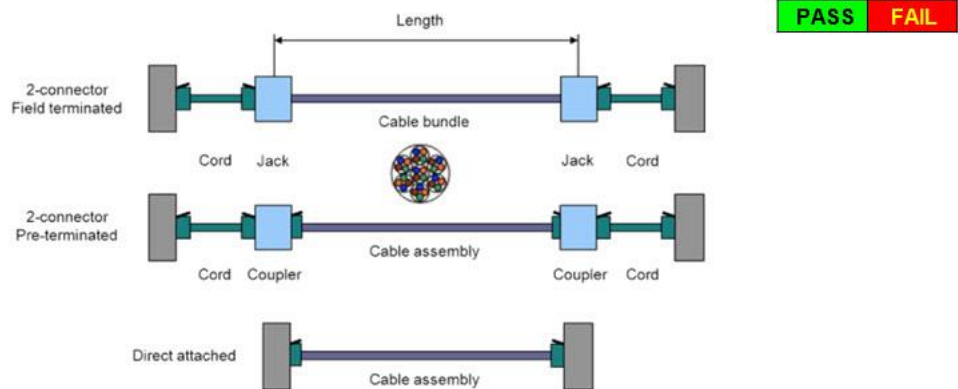
NOTE: Although the term “BaseT” is included in the name, it must be emphasized that HDBaseT is not an Ethernet standard developed by the IEEE. An HDBaseT network can transport Ethernet frames along with HDMI audio/video signals, but at a maximum rate of 100 Mb/s.

Cabling considerations for HDBaseT are based on differences in tested performance between individual cable runs (typical in homes) versus multiple cables grouped in bundles (typical in commercial buildings).

The HDBaseT Alliance allows for the use of Category 5e or higher cabling (shielded or unshielded) up to 100 m (328 ft) end-to-end, in conformance with structured cabling guidelines. However, test results indicate that bundling the cables can reduce the functional length of an HDBaseT channel to as little as 10 m (33 ft) using unshielded Category 5e cabling, as shown in Figure 41.

Figure 41: HDBaseT test results using bundled cables

Cabling System	Configuration	10 m	15 m	20 m	35 m	40 m	80 m	85 m	105 m
Category 5e UTP	2-connector Field terminated	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL
	2-connector Field terminated	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Category 6 UTP	2-connector Field terminated	PASS	PASS	PASS	FAIL	FAIL	FAIL	FAIL	FAIL
	2-connector Pre-terminated	PASS	PASS	PASS	PASS	FAIL	FAIL	FAIL	FAIL
	Direct attached	PASS	PASS	PASS	PASS	FAIL	FAIL	FAIL	FAIL
Category 6A UTP	2-connector Pre-terminated	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
	Direct attached	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS



Source: "HDBaseT Signals over Bundled Cables" White Paper, available for download in the "Audio/Video" section at <http://www.belden.com/resourcecenter/documents/white-papers.cfm>

The testing illustrated in Figure 41 can be summarized as follows:

- Shorter cable lengths deliver stronger signals to the inputs of the HDBaseT receivers and can tolerate more alien crosstalk (undesirable noise) between cables in a bundle.
- Category 5e unshielded twisted-pair (UTP) cables can only support distances up to 10 meters without link failure in a bundled configuration.
- Category 6 cables can support distances of 30 to 40 meters without link failure in a bundled configuration.
- Category 6A UTP cables or foil shielded twisted-pair cables (Category 6 recommended) can support distances up to 105 meters without link failure for any configuration.

NOTE: Shielded cables rely on the physical integrity of the shield and a low impedance path to ground to provide alien crosstalk isolation. If the shield is damaged, non-continuous, or not connected to ground at both ends, alien crosstalk interference between bundled shielded cables can be worse than measured values for unshielded cable bundles.

Based on these outcomes, Belden offers the following recommendations for optimal HDBaseT performance.

- Category 6A UTP cabling systems are the first choice for AV networks that will use HDBaseT technology, immediately or in the future.
 - Belden IBDN 10GX Field-Terminated and Pre-Terminated Cabling Systems
- Category 6 F/UTP shielded cabling systems may be considered as an alternate choice. Shielded Category 6 is favored over shielded Category 5e because of lower attenuation (stronger signal to the receiver) and better overall transmission performance of Category 6 at higher frequencies.
 - Belden IBDN 2400 Field-Terminated Shielded Cabling System
- If a shielded cabling system is selected, it is critical to maintain shield integrity at all connection points and to provide a uniform, low resistance path to ground for all network equipment and cabling within the premises, as specified in ANSI/TIA-607-B *“Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises”*, issued September 2011.

REFERENCES

The Telecommunications Industry Association (TIA) is the prime source of the standards for structured cabling systems referenced in this document.

This section presents three groupings of standards current at the time of publication. To view the most up-to-date listings, please visit: <http://www.tiaonline.org/standards/buy-tia-standards>

Figure 42: TIA common infrastructure standards

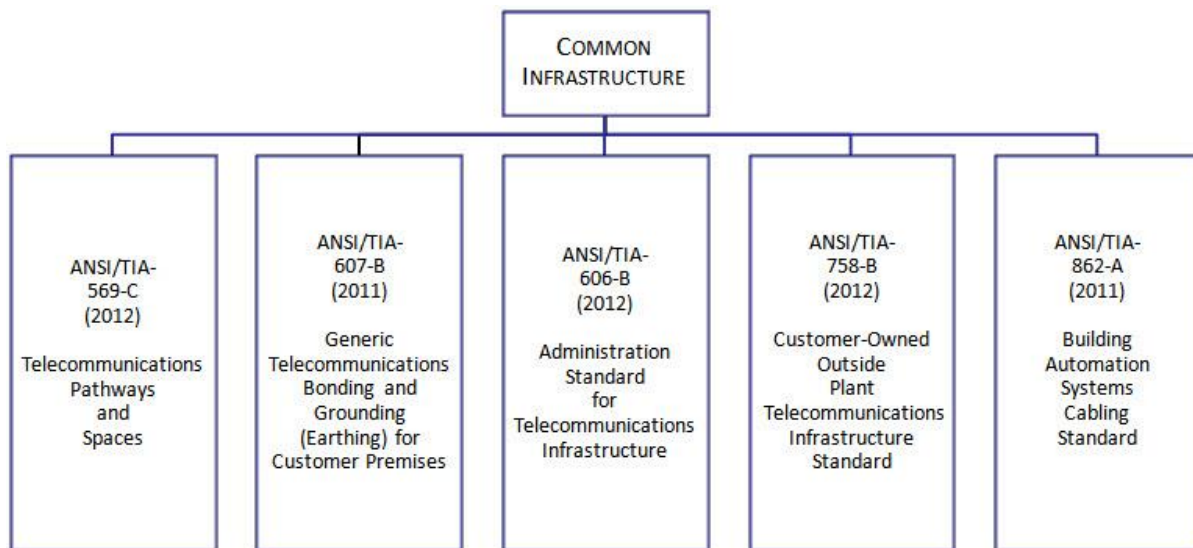


Figure 43: TIA standards by premise type

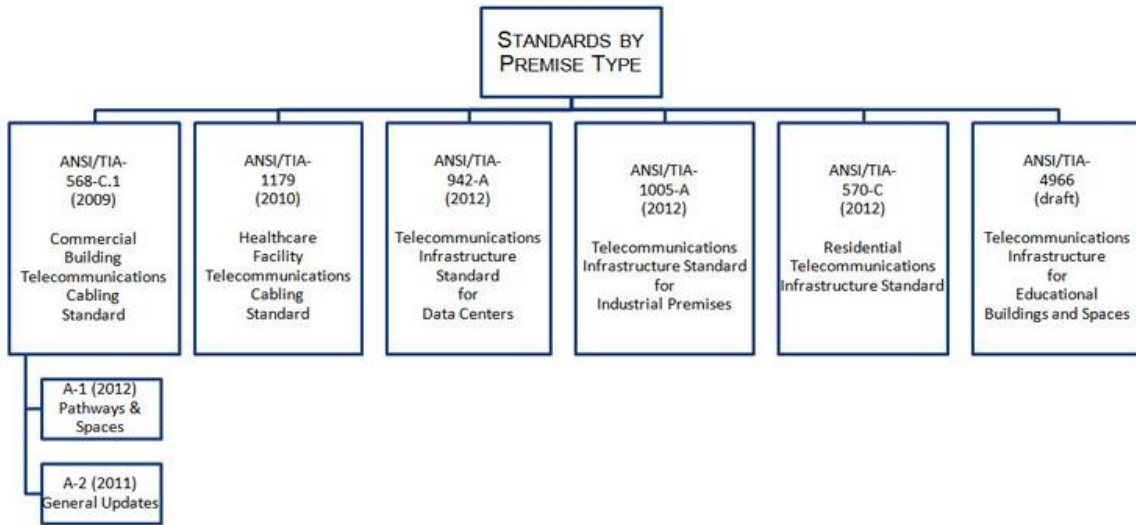


Figure 44: TIA twisted-pair cabling standards

