Ethernet Twisted Pair Cabling Plant, Power and Grounding Guidelines

Technical Paper

Solutions Engineering Group

Version 1

Mitel

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TRADEMARKS

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The Importance of Network Cabling

Although often hidden, the cable plant provides the connection between the end user and the data service (the IP phone and the Call Control server). Because data is sent at a high speed, there are cabling requirements that need to be met in order to get the best performance.

Once sent, real time data such as voice or video conferencing packets cannot be recovered, and so it is important to ensure that the cable plant is capable of handling the data without loss. This must be verified before installation. A network that introduces packet loss might not cause issues with PCs attached because PCs resend information if it is lost. The effect for the PC user is simply a slow file transfer. The effect on an IP phone user or a video conference user is interrupted audio or video.

Twisted Pair Cabling Categories

Unshielded Twisted Pair (UTP) LAN cabling comes in various Categories as defined under the specification ANSI/EIA/TIA-568-B 2001.

The various Categories of UTP cabling are:

- Category 3: Primarily used for analog telephony and lower-speed data applications. It's rated for a maximum data transmission speed of 10 Mbps (10Base-T). CAT 3 should not be used for new installations.
- Category 5: CAT 5 cable supports data transmission speeds of 100 Mb/s, which is required to support Fast Ethernet or 100Base-T.
- Category 5e: CAT 5e is an enhanced version of CAT 5 cabling and it supports data transmission speeds of 1000 Mb/s (1000Base-T). 1000Base-T or Gigabit Ethernet has in many cases replaced 100Base-T.
- Category 6: CAT 6 cable supports data transmission speeds of 10 Gb/s.

For new VoIP installations it is recommended to use a minimum of CAT-5 cabling, for future proofing the Administrator should consider using CAT 5e or CAT 6 cabling.

Consider other possible uses for the cables and future expansion requirements. It is easier to specify a slightly higher-grade cable at initial installation than it is to retrofit later. All connectors and interconnect blocks should also conform to the same requirements. If the cable used is CAT 6, but the connectors are CAT 5, then performance will not exceed CAT 5.

> **Note:** Refer to "CAT 3 Wiring Practices" in Appendix A for guidelines and restrictions when CAT 3 is encountered in an existing installation.

Straight and Crossover Cables

Two types of cable connections are used to connect between network equipment devices and also from the network equipment to the end equipment:

- Straight connection, used to connect end users to the network (for example, an IP phone to a switch)
- Crossover connection, used to connect between network equipment (for example, between switches)

The connections between devices contain pairs of wires to transmit data and to receive data. The transmit and receive pairs must swap over to make a connection work, otherwise, transmit connects to transmit, and no data passes. The switch ports in the network normally provide this crossover. This means that the connection between end device and switch can use a straight connection.

However, when switches within a network connect to each other there are two crossovers, thus nullifying the effect. A crossover cable is needed for these connections. Alternatively, some switches provide an additional port with the crossover removed, allowing a straight cable to be used. Both physical ports on such a connection cannot be used simultaneously, otherwise, data corruption occurs. In the following figure, the port labeled 5X would be used to connect to an end device OR the port labeled 5 would be used to connect to an X port of another switch.

Figure 1 Straight and Crossover Port Example

Some switches provide auto crossover detection and remapping of the transmit pairs and the receive pairs. With auto crossover detection and remapping, straight cables can be used for all connections.

Identification of Straight and Crossover Cables

Since a network usually includes a mix of straight and crossover cables, they need to be identified to make maintenance and troubleshooting easier. The installer can identify each type with a permanent marker, or label on the cable.

A better choice is to standardize on using just one particular colour for crossover cables. Many installers use bright yellow or bright red for crossover cables; however some military and government agencies reserve bright red for classified data cables. An example of a network cable colour coding scheme is discussed in the following section.

Test the cables to identify which cable is which type. Another method of identifying the cable type is to look at the colour of the wires inside the RJ-45 plug. If the colour order is the same in both plugs, then the cable is a straight connection. If they are different, then it is a crossover cable. Be careful, since other telecom functions, such as PRI, also use RJ-45 connections. In the following

figure, for the straight cable, the orange and green pairs are in the same position. For the crossover cable, the orange and green pairs swap positions between the connectors.

A more foolproof method of identifying a straight or crossover cable is to use a cable tester; some cable testers also provide the capability of verifying the cable for correct termination and performance. A good cable tester will pay for itself many times over.

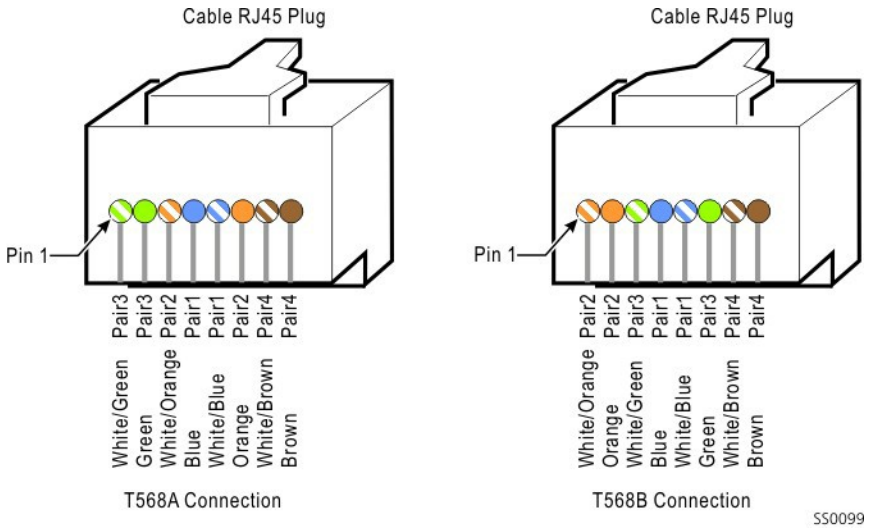

Figure 2 Using Wire Colour Order to Identify Connection Cables

The cables shown are those expected in new installations, namely, a T568A connection to a T568A for a straight cable, and a T568B connection to a T568A for a crossover cable. It is also possible to get straight cables that have a T568B connection to a T568B, but these are more likely in older installations.

International standards recommend that new installations conform to the T568A wiring format. However, a number of current installations may have wiring to T568B. As long as a common format is used throughout the installation, and there are no unexpected swaps, then electrically, the colour is less important (for example, all wall jacks to T568A or T568B, but not a mix).

Twisted Pair Cabling Installation Guidelines

This section provides general guidelines related to selection, handling and installation of twisted pair cabling.

Identifying Network Cables - Consider Using a Colour Coding Scheme

At one time twisted pair cables were like Ford Model Ts, they came in only one colour - a very exciting drab grey colour. This made identifying cables problematic because cables could only be identified with small plastic labels or with markings from permanent pens.

Today cable vendors offer cables in all kinds of colours. There is no accepted industry standard for identifying twisted pair LAN cabling with colour coding. If there is an existing corporate standard for cable colour coding, it is recommended that new cabling installations comply with the standard. In the absence of an existing corporate standard, it is recommended that the administrator create a standard and ensure that the standard is adhered to.

While purchasing a wide range of colours for network cabling may add somewhat to the upfront cabling expenses, the pay back will be realized quickly through reduced cabling installation, maintenance and troubleshooting costs.

The following table provides an example colour coding scheme:

Table 1 Colour Coding Scheme for LAN Cables

Function	Colour
Crossover cable	Yellow
L2 Interconnect	Blue
Customer Data	Black
Voice/Video Data	Green
DMZ	Red
Router Connections	Orange
Management for OAM	White
Management for Security	Purple
Printers	Brown
Others/Miscellaneous	Grey

Selecting Cabling with the Appropriate Sheath

The sheathing on Unshielded Twisted Pair (UTP) cabling can be designated for non-plenum usage or it can be designated for plenum usage.

UTP cabling that is non-plenum rated is usually sheathed with a PVC jacket, should this type of cabling sheath burn, it will release toxic gasses. If the cable is not going to be routed in an air handling space, then non-plenum rated cabling is usually appropriate.

Plenum-rated cabling is more expensive than non-plenum rated cabling, however the sheathing material is considered safer than non-plenum rated sheaths when exposed to fire.

As a general rule, anytime a cable is routed through any air handling space (ducts, suspended ceilings, and elevated server room floors) plenum-rated cabling must be used.

Check your local laws to ensure that the correct cabling type is being used.

Follow the Standards and Conventions

Each corporation or installation site should have some cabling standards in place that address:

- Which Category of cabling to use for both horizontal and vertical runs
- How to identify the cables - i.e. colour coding

The following recommendations should be taken under consideration:

- Follow the ANSI/EIA/TIA-568-B standards for structured wiring
- Keep accurate cable plant documentation and how the cables connect to L2 switches, router and IP end points so that employee location information can be more easily maintained so that during an emergency, authorities will be able to locate the employee's location - 911 and 999 services
- Keep all cable lengths within ANSI/EIA/TIA-568-B specifications, refer to the section of this document called Cabling Guidelines
- Route cables so that they are away from electromagnetic interference such as building mains wiring, heating and ventilation equipment, motors and fluorescent lighting fixtures
- Ensure that the complete cabling plant gets tested and certified for operation at the intended operational speeds

Maximum Twisted Pair Cabling Lengths

Cable lengths for Ethernet twisted pair cabling are specified up to 100 m when the correct cable type is used. This includes the internal building wiring as well as patch leads at either end. The limitation on this distance is quite strict and operation is not guaranteed beyond a total length of 100 m. More details can be found in ANSI/EIA/TIA-568-B 200, section 4.

Internal building, or horizontal cable runs, should not exceed 90 m, to allow for an additional 5 m of cable at both ends for connection to the end devices from the wall jack. Additional connections in the cable run add attenuation. Use the guidelines in the following table for installation.

> **Note:** If connecting an ethernet device at distances of more the 100 metres, the Mitel StreamLine solution might be an appropriate solution. The Streamline is a long haul ethernet switch that can provide ethernet connectivity with PoE over distances of up to 360 metres. For details refer to the Streamline documentation on Mitel On Line.

Table 2 Maximum Cable Lengths

Cable Run	Maximum Recommended Distance (Metres)
Horizontal or intra-building run	Less than 90 m
Wall jack to end equipment (IP phone)	Less than 3 m
Layer 2 switch to MDF (direct connection)	Less than 3 m
Layer 2 switch to PoE hub	Less than 2 m
PoE hub to MDF	Less than 2 m

These recommended cabling distances are shown in the following figure.

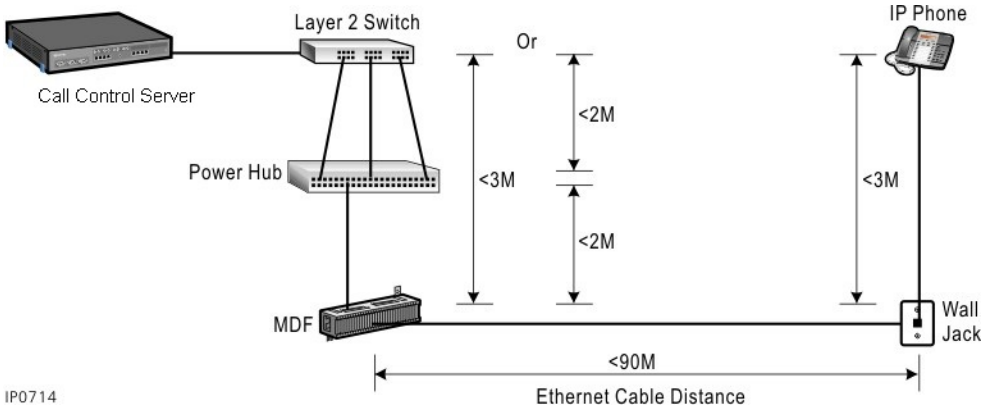

Figure 3 Recommended Distances for Cable Runs

Desktop and Equipment Room Cabling, Power and Grounding Guidelines

IP telephony transmits voice communications over a data network using Voice over Internet Protocol (VoIP). Electrical interference in the environment can reduce the quality of the voice and data signals that are transmitted over Ethernet cable. Desktop computers, printers, servers, lighting, and other office devices place a high demand on the electrical infrastructure and increase the risk of electrical interference.

You can minimize electrical interference and improve network efficiency by following the cabling guidelines detailed in the following sections. Both the desktop and the equipment room are discussed.

> **Note:** Special testing equipment is available from Mitel Product Support. This equipment can verify Ethernet cable performance and detect cable faults.

Guidelines for the Desktop

Refer to the following figure and the corresponding cabling guidelines to minimize electrical interference at the desktop.

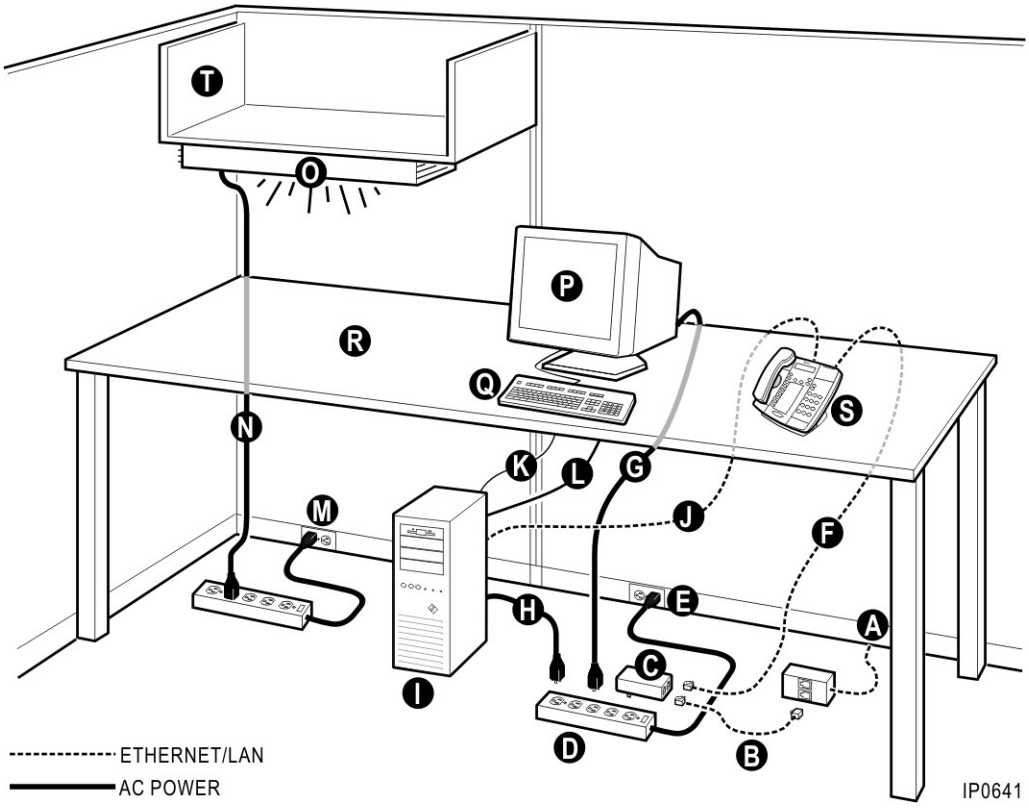

Figure 4 Desktop Cabling Guidelines

Table 3 Desktop Cabling Guidelines

Connection		Guidelines
A	Ethernet connection to network	Use CAT 5 or CAT 5e Ethernet cables and certified network connection blocks (TIA/EIA 568A). Adhere to the cable lengths listed in Table 4.
B	Network to power adapter Ethernet patch cable (for local power configuration only)	• Use CAT 5 or CAT 5e cables (certified to TIA/EIA 568A) • Maximum length 5 ft. (1.5 m) • Route cable away from sources of interference, such as power cables
C	IP Phone power adapter (for local power configuration only)	• Plug IP Phone power adapter and the computer into the same surge-suppressing power bar
D	Surge suppressing power bar	• Recommended model is American Power Conversion “SurgeArrest” • Route power cables away from Ethernet cables
E	Power outlet for desktop equipment	• Use outlet to supply power to computer and IP Phone power adapter only • Do not plug other devices such as florescent lights, coffee makers, kettles into this outlet
F	Phone to power brick Ethernet connection	• Use CAT 5 or CAT 5e cables (certified to TIA/EIA 568A) • Maximum length 5 ft. (1.5 m) • Route cable away from sources of interference, such as power cables
G	Monitor power cord	• Plug into computer power bar • Route cable away from Ethernet cables
H	Computer power cord	
I	Computer	
J	Phone to computer Ethernet connection	• Use CAT 5 or CAT 5e cables (certified to TIA/EIA 568A) • Maximum length 5 ft. (1.5 m) • Route cable away from sources of interference, such as power cables
K	Keyboard to computer connection	• Route cable as required for convenience
L	Monitor to computer connection	• Route cable away from Ethernet cables
M	Power connection to auxiliary equipment	• Use a separate power outlet for potential noise generating devices such as a lamp, coffee maker, or radio
N	Florescent light power cord	• Route cable away from Ethernet cables
O	Florescent desk light spikes	• Ballast circuitry inside florescent lamps will create noise on power cables when the lamps are turned off. Ensure that florescent lamps are plugged into dedicated surge suppressing power bars. Voltage limiting devices inside the power bars reduce noise spikes and reduce the risk of data errors. Some desks have power outlets that are designated for the computer and utility devices. These outlets have built-in surge protection. In this case, a power bar is not required.

Table 4 Maximum Cable Lengths

Under Desk	10 ft. (3 m)
Floor to ceiling	11.5 ft. (3.5 m)
Horizontal span in ceiling	300 ft. (90 m)
Equipment closet	11.5 ft. (3.5 m)
Total maximum length	333 ft. (100 m)

Guidelines for the Equipment Room

Refer to the following figure and the corresponding cabling guidelines to minimize electrical interference in the equipment room.

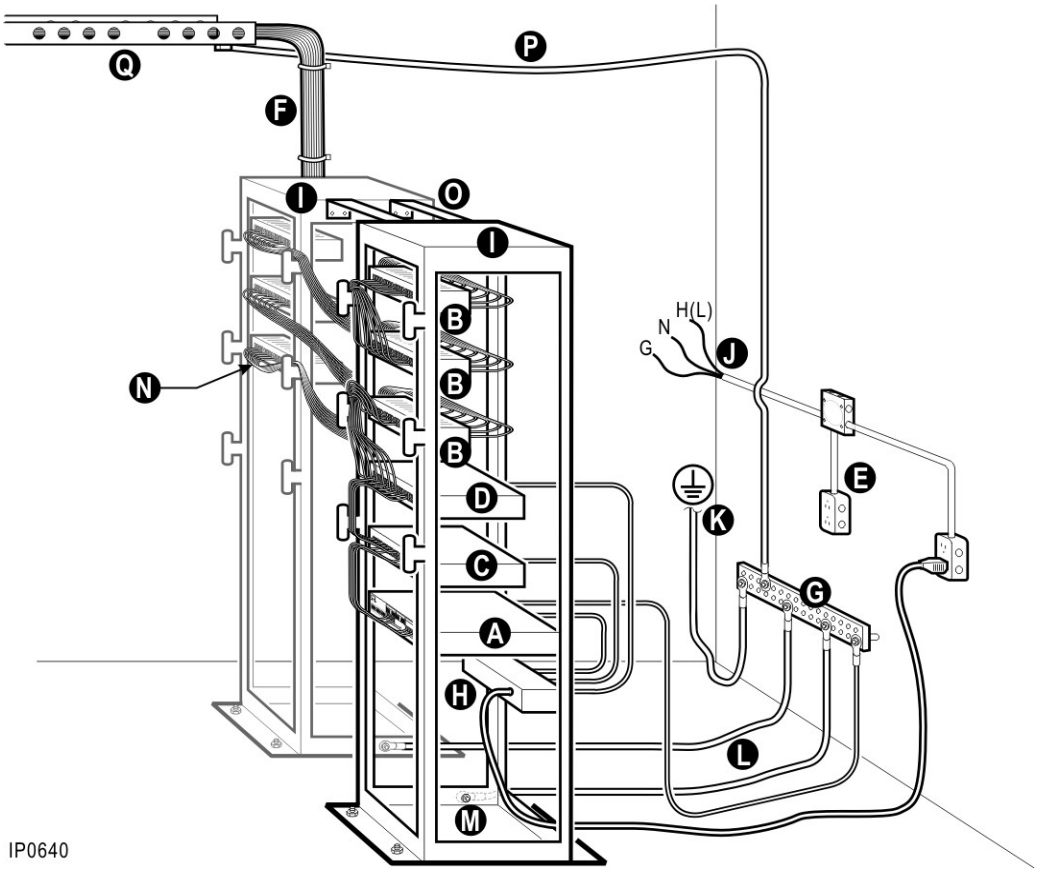

Figure 5 Equipment Room Cabling Guidelines

Table 5 Equipment Room cabling Guidelines

Connection		Guidelines
A	Call Control Server	• Use CAT 5, CAT 5e, or CAT 6 Ethernet connector blocks and cables • CAT 5e or CAT 6 certified cable provides better immunity to crosstalk • Connect ground stud on back of controller to ground bar bus (G) with a dedicated ground wire
B	Patch panel	• Patch panels must be certified for CAT 5 cable • Do not use punch-down blocks that are designed for voice-grade telephony signals to interconnect 100 Mbps Ethernet signals. • Recommended connector blocks can be obtained from www.anixter.com (part number 201011)
C	Layer 2 switch	• If a ground stud is provided, connect it to the ground bar bus (G) with a dedicated ground wire. Use the wire gauge specified by the manufacturer • Powered hubs supply IP Phones with power through the Ethernet cable either through the spare wires or the signal pairs. IP Phones that have power adapters do not use powered hubs. • If a ground stud is provided, connect it to the ground bar bus (G) with a dedicated ground wire. Use the wire gauge specified by the manufacturer
D	Powered hub	• Powered hubs supply IP Phones with power through the Ethernet cable either through the spare wires or the signal pairs. IP Phones that have power adapters do not use powered hubs. • If a ground stud is provided, connect it to the ground bar bus (G) with a dedicated ground wire. Use the wire gauge specified by the manufacturer
E	Protected power system	• Dedicate the use of the power outlets to the equipment in the equipment room only. • Ensure that the power outlets in the equipment room are wired for 15 Amp service directly to the electrical service panel with ideally one circuit breaker per outlet. • If the site is configured with resilient IP phones, ensure that the Call Control servers are powered by dedicated power bars. • Switching power supplies common in computers and telecommunications equipment generate noise voltages, known as harmonics. Use oversize neutral conductors to minimize harmonics. • Ensure that conduits include a dedicated copper ground
F	Cable	Ensure that the maximum cable runs do not exceed 333 ft. (100 m).
G	Ground bar bus	• Use a ground bus bar that is ¼ inch thick and 2 inches wide and long enough to accommodate the grounding for all the rack-mounted equipment • Recommended bus bar is ANIXTER part number 179639 • Mount the bus bar on the wall with insulated standoffs • Use compression style fittings to fasten the ground wire lugs to the bar • Connect the bus bar to the main building ground with a 6 AWG copper, stranded, green-colored cable. • For grounding specifications see ITU-T K.27 “Building configurations and earthings inside a telecommunications building” and ANSI/TIA/EIA-607
H	Protected rack-mount power strip	• If you cannot provide dedicated 15 Amp power outlets for each unit in the rack, mount a surge-arresting power strip on the front or rear of the rack.

Connection		Guidelines
		• Recommended model is the Surge Arrest - Rack Mount model from American Power Conversion. The ground from the rack forms part of the shield for the power strip. • Plastic floor type models are not recommended because they are more likely to be turned off by accident. **CAUTION**: Power bars have a circuit breaker. If the circuit breaker is tripped due to a power surge, the power to all the outlets on the power bar is shut off. If the site supports resilient IP Phones, ensure that the call controllers are plugged into different power bars.
I	Standard metal rack	• Bolt each rack securely to the floor and connect a dedicated ground wire between the frame and the ground bus bar. • If rack-mounted equipment obtains safety ground from the metal rack, ensure that a good electrical connection is made between the rack and the cabinet metalwork. Use “star” washers to obtain a solid electrical connection to painted cabinets • Route any power cables contained within the rack away from any UTP patch cabling **Note**: Fiber optic cabling can be routed anywhere within the rack because it is not susceptible to electrical emissions.
J	AC Mains metal conduit	• Metal conduit that contains power wiring must have three wires for each dedicated circuit: Ground (bare), Neutral (White), Hot or Line (Black). Do not use the conduit as the ground.
K	Telecoms main ground	• Main ground connector must be 6 AWG stranded, copper, green-colored cable connected to the main building ground. **CAUTION**: A proper ground is required for proper equipment operation and safety. A power quality engineer can provide advice on new and existing installations. Refer to row G in this table for additional information.
L	Rack grounds	• Use separate wires to ground each rack to the ground bus bar
M	Equipment grounds	• Use separate wires to ground each piece of equipment to the ground bus bar. If a ground stud is provided on the back of the unit, connect it to the ground bus bar with a dedicated ground wire (use the gauge specified by the manufacturer).
N	Patch cable	• Interconnect Ethernet equipment supporting 100 Mbps transmission with CAT 5 UTP patch cable. Label the cables and route them neatly through the channels provided in the metal rack. **CAUTION**: Do not use voice grade twisted pair interconnect patch cables or voice grade punch-down blocks on an Intermediate Distribution Frame.
O	Metal rack interconnect	The metal brackets used to connect the racks provide a mechanical connection only. Use a dedicated ground wire to ground each rack separately to the ground bus bar.
Q	Cable tray	• The tray should contain Ethernet cables only. Do not mix power cables with Ethernet cables

Appendix A Category 3 Wiring Practices

Category 3 cabling has been superseded by several newer cabling technologies such as Category 5, 5e and Category 6. Due to these advances in cabling technology CAT-3 cabling should not be considered for any new installations. However, because of the wide spread deployment of CAT-3 cable for telecom purposes it may still be encountered in many older installations so CAT-3 wiring practices are included here for reference should a building with CAT-3 cabling plant be encountered.

Category 3 (CAT 3) refers to a type of UTP copper cabling that meets specific transmission characteristics (see CAT3/EIA/TIA-568 wiring standards). CAT 3 also refers to the installation practices observed when routing these cables as well as the interconnection and end point termination methods used. The following sections detail further practical issues to be used in conjunction with the specification.

Although CAT 3 cabling is not recommended for new installations, there may be instances where CAT 3 is encountered in an existing installation. CAT 3 installations can fall into different categories with unique pitfalls:

- CAT 3 cabling plant was installed for supporting traditional telephony equipment. This type of installation will potentially contain a number of CAT 3 violations that did not interfere with traditional telephony applications but will present problems for data transmission and VoIP.
- CAT 3 cabling plant was originally installed for supporting traditional telephony equipment.
- At a later date spare cable runs were inspected and qualified to support 10M Ethernet. Part of this cabling plant will be CAT 3 compliant and part will not be CAT 3 compliant. An installation in this category needs to be carefully re-qualified to CAT 3 standards.
- CAT 3 cabling plant was installed to support a LAN technology other than 10M Ethernet, such as Apple Talk, Token Passing Ring, or a proprietary networking technology. An installation in this category needs to be carefully qualified to CAT 3 standards.

Most network devices are capable of operating at 10BaseT, 100BaseT and 1000BaseT data rates. Network devices will typically select the highest data rate. Use of CAT 3 cabling means that the connection speed will be restricted to 10BaseT because of the cable's capabilities.

Guidelines and Restrictions for CAT 3 Installations

- Connections between L2 switches should be made at 100BaseT or better (using CAT 5 wiring or better), including connections to the ICP controllers.
- The network infrastructure and capabilities should be considered in a network that still employs CAT 3 cable. It may not be capable of handling the Packet Per Second rate needed for a number of voice devices, as well as the bandwidth throughput. If a connection exists to data devices, such as PCs, the use of VLANs and a priority mechanism is recommended.
- It is highly recommended to not connect PCs to the phones, and to connect these on a separate LAN infrastructure. The second port on the IP Phones can be disabled in the 3300 ICP/MiVoice Business Class of Service (COS) form, option 193, under the heading “PC Port On IP Device – Disable”. Note that although the second port may be disabled for access, it may still be used for monitoring.
- Telecom cable is **not** CAT3, but CAT 3/CAT 5 can be used as telecom cable. Make sure it really is CAT 3 or better by consulting the manufacturer of the cable, before installing the equipment.

- Note that cables used as telecom wiring may also have different wiring pairs in the termination jacks as well as termination resistors, e.g. if ISDN has been used. These need to be corrected, or removed. Ensure that any bell capacitors and master/slave jacks have been removed. The cable route should be point to point without spurs or stubs. A cable tester that uses Time Domain Reflectometry should be used to verify the integrity of cabling runs. Visual inspection and ohmmeter tests may be insufficient. Be careful about pair splitting which may not be apparent on telecom cable (this is where the two pairs result in a Tx/Rx & Tx/Rx combination, rather than Tx+/Tx- and Rx+/Rx- pairs). Ensure that any bend radii have not been exceeded. In effect – be suspicious of an older wiring plant – Test!
- Pay close attention to wiring practices at the distribution frame and at the desktop and ensure that these practices comply with CAT3/EIA/TIA-568 wiring standards. These standards are much more stringent than the wiring practices used for traditional voice wiring. For example, in traditional voice cabling when an installer punched down cabling pairs on a termination block (BIX/Krone block) it was very common to unwrap the twisted pairs from an individual cable for ease of installation or to use untwisted cables to implement a cross- connect. While this practice was acceptable in a voice network it will introduce problems in a data network.
- Typically Ethernet cables are an in-house building wiring, and normally should not leave the building. Telecom cables have special protection applied to cables used outside the building. It may be required that routers and special cable protection be applied at either end of the link in order to extend Ethernet outside the building.
- The EIA/TIA-568 standard provides numerous structured wiring recommendations regarding the routing of cables. The CAT 3 cabling plant should comply with these recommendations so that the chances of encountering network impairments due to cross-talk and electrical noise is minimized.

Summary of CAT 3 Network Recommendations

There are a number of different installation combinations and devices that can run with CAT 3 cables. There are also many exceptions and variations that prevent this from working. The underlying principles in making the installation work are:

- The devices connected via CAT 3 must be restricted to 10BaseT operation only.
- Standard 10/100/1000 auto-negotiation cannot be relied on to restrict data rates to 10BaseT operation with CAT 3 cable and should be avoided. Use manual programming at either, or both, ends of the link.
- Power over Ethernet may not be guaranteed. Phantom power feed will allow the CAT 3 data pairs to be used.
- If auto-negotiate fails because one end device is programmed manually, the default is to use 10BaseT half duplex. Manually setting ports to 10BaseT half duplex will result in a correctly configured connection.
- Where multiple devices are connected to a common network port, use of CAT 5 is recommended, with the higher available speeds.
- The following devices should only be installed with CAT-5E cabling: MiVoice Conference (UC360), 5320e, 5330e and the 5340e.

To simplify installation, the following installation rules can be applied:

- Where CAT 3 wiring is used, the network device ports should be manually configured for 10BaseT half duplex. This will allow devices to be moved and maintain their settings as well as fixing the speed based on the cable run.

- Phones with a single connection can use CAT 3. Exceptions are the TKB5550 and MiCollab Client Softphone.
- The 5550 IP Console should be connected to the network with CAT 5 only.
- The MiCollab Client Softphone should be connected to the network with CAT 5 only.
- MiCollab Client is essentially a PC.
- Phones that connect to the network with an attached PC should use CAT 5, as should the connection to the PC.
- Individual PCs can use CAT 3.
- Servers generally require high-speed connections and should use CAT 5 only.
- Connections from the ICP WAN port should be via CAT 5 cable.
- All other connections between the ICP controller to ASU units, to NSU units and between NSU units should use CAT 5. Note that there is a distance limit of 30 m on these connections.