By Merwyn Andrade

A report for understanding issues in the cabling and working of UTP networks

This report hopes to serve as an aid to understanding issues in the cabling of UTP type networks. This information has been compiled from a number of sources and endeavors to provide correct information to the best of my knowledge. Please get back to me with your comments/criticisms at Phone: (408) 526 4628 or via email "mandrade@cisco.com" in case of any inadvertent inaccuracies that may have crept in. I will attempt to keep revising the document based on the feedback that I receive.

1.0 Twisted-Pair Cable Types

Twisted-Pair cables are grouped in categories according to various factors. Levels specify a certain speed rating on the cable. IBM Cable Types specify a certain kind of cable. Please note that what is shown below is a very abbreviated description. Each Level or Type has specific physical and electrical characteristics and those details can be found in most cable vendors' catalogs. The number of twists per foot is at least two for data grade cable.

As the name implies, twisted pair cable is composed of pairs of wires; each pair is insulated from each other and twisted together within an outer jacket. There is no physical shielding in UTP (Unshielded Twisted-Pair) cable; it derives all of its protection from the cancellation effect of the twisted pairs. The mutual cancellation effect reduces crosstalk between pairs and EMI/RFI noise. Cable vendors vary the number of twists in the different wire pairs within each cable to reduce the electrical coupling and crosstalk between the pairs. UTP cable relies solely on this cancellation effect to minimize the absorption and radiation of electrical energy.

Shielded Twisted-Pair (STP) as the name implies, combines both shielding and cancellation techniques. STP cable designed for networking comes in two varieties. The simplest STP is called "100 ohm shielded" because, like UTP, it has a 100 ohm impedance and has an added shield of copper braid around all the wire pairs. But the most common form of STP, introduced by IBM and associated with the IEEE 802.5 token-ring networking architecture, is known as 150 ohm STP because of its 150 ohm impedance. Note that unlike coaxial cable, the shielding on 150 ohm STP isn't part of the signal path, but is grounded at both ends. (Not covered in this paper)

The 100 ohm STP, used primarily for Ethernet installations, improves the EMI/RFI resistance of twisted-pair without a significant gain in size or weight. The shield is not part of the data circuit, so it is only grounded at one end - typically at the wiring closet or hub end. However, properly grounding the shield on the cable isn't easy, particularly if you want to make use of older wiring hubs that aren't designed for STP. If it isn't grounded at one end, the shield becomes an antenna and your problems multiply.

Mod-Tap and other companies market patch panels that can grasp the cable shield and ground it. You can terminate all of the 100 ohm STP cables in the patch panel and retain the wiring hub and LAN adapters you've already installed, but you'll need a good ground connection for the patch panel. 100 ohm STP offers more protection from interference than UTP. It also maintains compatibility with 10Base-T wiring hubs and avoids the conduit crowding problems of 150 ohm STP.

1.1 Cable conductors and Testing

Cable conductor gauge is specified as AWG (American Wire Gauge). A higher number is a smaller diameter. Telephone cable used indoors is typically 24 or 26 AWG, whereas household electrical wiring is typically 12 or 14 AWG. Cable testers come with a variety of capabilities.

1.1.1Cable Distance

The various IEEE networking standards specify maximum cable lengths. In case of IEEE 802.3 (Ethernet), the overall length directly affects the ability of the network nodes to share the cable; a cable that is too long degrades the system.

Cable scanners measure the distance to an open-ended or shorted cable by sending a pulse down the cable ad then timing its reflection back from the end of the cable, a technique known as time-domain reflectometry (TDR).

When you measure a cable with an electrical pulse instead of a tape measure, the pulse doesn't travel at the same speed in every type of cable. The size of the wires, type of insulation, and electrical shielding all effect the speed of the electrical pulse. A factor called the nominal velocity of propagation (NVP) is the ratio between the speed of an electrical pulse in a specific type of cable and the speed of light. The scanner must apply the appropriate NVP to the cable to accurately measure the cable length. Scanners should contain a table that has the NVP for a variety of cable types, but you also might want to measure the NVP for a particular spool or lot of cable in order to get more accurate distance measurements.

The scanner can calculate the cable's NVP if you know the cable length, so it is wise to carefully measure a few hundred feet of cable from the typical 1,000-foot spool and to use what is usually called the scanner's calibration function to measure the NVP of that of a known length of cable. Cable checkers normally allow you to enter that figure (typically between 0.6 and 0.9) into memory for future use.

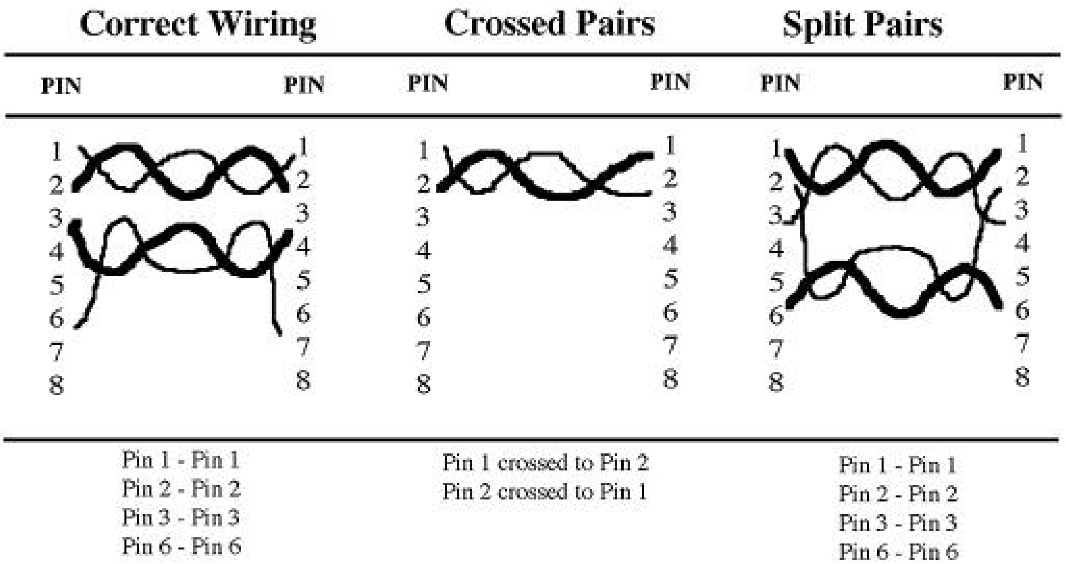
Hint: Once you know the NVP of a cable or obtain a standard NVP from the cable checker's memory, it is easy to determine how much cable is left on a spool. Put a connector on the cable and use the cable checker to test the cable length; it's a lot easier than unrolling the spool and measuring it foot by foot. (You can also use the markings on wetote type cable spools).

In a UTP installation, taking distance measurements assures you of at least minimal quality on your punch-down blocks or cross-connect panels. When you measure distance on a cable, the cable checker sends a wave that is reflected when it encounters the most distant open connection. If you measure through the punch-down block or cross-connection, you'll know whether the cable check detects a large lump of impedance, like an open circuit. If the cable checker reports the distace to the punch-down block or cross-connect instead of detecting some more distant point, then you know that you have an equipment or connection problem.

Some cable checkers come with a special port for an oscilloscope. If you use a good scope with a 200 MHz bandwidth, you can see the TDR pulse put out by the cable checker, measure it's return, and obtain a much finer measurement of cable distance and quality. If you are experienced, the scope trace will show lumped impedances - perhaps marginal connectors - that the cable checker would ignore.

1.1.2Wire Map

Some cable testers offer a wire map function among the distance measurement features, and others make it a stand-alone function. *Wire map*, a feature unique to twisted-pair installations, shows you which wire pairs connect to what pins on plugs and sockets. This test quickly detects whether an installer connected the wires to a plug or jack in reverse order- a common problem. It is also valuable for detecting the common cause of data problems in twisted-pair cabling: split pairs. The split pair condition is shown below. A similar crossed condition called crossed pairs is also troublesome. You can only spot split pairs through visual inspection or by seeing the effect of a split-pair condition in the crosstalk measurements.



The conditions called Crossed pair and split pair are similar but slightly different. A crossed pair reverses the Tip and Ring. A cablechecker that does wire map will detect this condition. However Split pairs will check out OK on a wire map and can only be detected by checking the Near end Crosstalk.

The twisting in the wire pairs shields the desirable signals from external signals. This shielding only occurs if the wires in a pair are part of the same circuit. Unfortunately, it's common for the wires in a pair to be accidentally split, so they are a part of different circuits. A current can flow in a circuit and the system appears to work - particularly over a short distance and in limited trials - but no self-shielding is protecting the signals, and eventually near-end crosstalk becomes a problem (See section 1.14).

1.1.3 Attenuation

Various electrical factors, primarily resistance, reduce the power of the signals as they pass through the copper wire. Other factors such as capacitive and inductive reactance drag down the signals at different frequencies. Cable testers measure attenuation at several frequency bands.

Typically, a tester measures attenuation on a signal received from a signal injector, that attaches to the far end of the cable. Testers often measure attenuation at 64 KHz, 256 KHz, 512 KHz, 772 KHz, 1 MHz, 2 MHz, 4 MHz, 5 MHz, 8 MHz, 10 MHz, 16 MHz, 20 MHz, 32 MHz, 62.5 MHz and 100 MHz. Measurements are made up to 16 MHz for Category 3 cables, and up to 100 MHz for Category 4 and 5 cables. *(Note when testing twisted-pair cables, be sure the tester switches between all the cable pairs in the cable).

Attenuation is measured in decibels (dB) and the lower the number the better. Since the dB scale is logarithmic, even a small change of 1 or 2 dB indicates a significant change of power. As an example of the range, the 10Base-T specification allows for a maximum of an 11.5 dB loss in the 5 to 10 MHz band on the 328 feet (100 meters) of wire from the hub to the desktop. The EIA/TIA-568 specification addresses the attenuation problem in more detail. For example, horizontal UTP is measured at 10 frequency points, and it allows for a maximum attenuation of 2.8 dB per 1,000 feet at 64 KHz, 7.8 dB per 1,000 feet at 1 MHz, and 40 dB per 1,000 feet at 16 MHz.

A signal traveling on a cable becomes weaker the further it travels. Each interconnection also reduces its strength. At some point the signal becomes too weak for the network hardware to interpret reliably.

Particularly at higher frequencies (10MHz and up) UTP cable attenuates signals much sooner than does co-axial or shielded twisted pair cable. Knowing the attenuation (and NEXT) of a link allows you to determine whether it will function for a particular access method, and how much margin is available to accommodate increased losses due to temperature changes, aging, etc.

1.1.4 Near-end Crosstalk (NeXT)

Near-end crosstalk is the feed-over of electrical energy between wire pairs in the same cable. Cable scanners use a signal injector to properly terminate the far end of the cable, then sweep through a set of frequencies to measure how much signal leaks between the active wire pair carrying the injector's signal and the inactive pair.

Crossed wires are the most common cause of high levels of near-end crosstalk. The wire map test performed by the cable scanner can identify those pairs for you, but it cannot identify split pairs. Other causes of near-end crosstalk include twisted pairs that are untwisted when attached to cross-connect devices, untwisted patch cables, and cables that are pulled so tightly around a sharp corner that the pairs change position inside the jacket.

Like attenuation, near-end crosstalk is measured in a series of frequency steps going up to a 100 MHz. But unlike attenuation, the higher numbers are better. A higher near-end crosstalk number indicates a greater difference between the size of the induced signal and the size of the induced crosstalk.

1.1.5 Noise Level Test

While near-end crosstalk is defined as the signals from adjacent wire pairs, many other signals can impose themselves on wire pairs. These signals from commonly found electrical sources often occupy specific frequency bands, as listed in the table below.

Table 1.

Type	Range	Source
Low frequency	10 KHz to 150 KHz	Fluorescent lights, heaters
Medium frequency	150 KHz to 100 MHz	Radio, electronic devices, air cleaners
High frequency	16 MHz to 1,000 MHz	Radio and TV, computers, electronic devices, motion sensors, radar
Impulse	10 KHz to 100 MHz	Motors, switches, welders, auto ignitions

Electrical noise on a cable is measured in millivolts (1/1000th of a volt), and instead of measuring the peaks of the pulses, the measurement is made on a weighted scale called root mean square (RMS), so typically a cable checker will display a noise reading in mV RMS. The lower the number in millivolts the less the electrical noise.

When you take a noise reading, you'll have the cables disconnected from the equipment. If the cable checker reports high readings, try unplugging electrical devices until you find the source of the noise.Note that simply turning off a device doesn't necessarily work, you may need to disconnect it from the mains.

1.1.6 How Far Away Should Cable be Installed from an EMI Source

Northern Telecom IBDN User Manual contains an Appendix D titled, UTP Separation Guidelines From EMI Sources. The values are the same as the cabling pathways standard, EIA-569, table 4.8-5.

Table 2. Min Separation Distance from Power Source at 480V or less

CONDITION	<2KVA	2-5 KVA	>5KVA
Unshielded power lines or electrical equipment in proximity to open or non-metal pathways	5 in (12.7 cm)	12 in (30.5 cm)	24 in (61cm)
Unshielded power lines or electrical equipment in proximity to grounded metal conduit pathway	2.5 in (12.7 cm)	6 in (15.2 cm)	12 in (30.5 cm)
Power lines enclosed in a grounded metal conduit (or equivalent shielding) in proximity to grounded metal conduit pathway	—	6 in (15.2 cm)	12 in (30.5 cm)
Transformers and electric motors	40 in (1.02 m)	40 in (1.02 m)	40 in (1.02 m)
Fluorescent lighting	12 in (30.5 cm)	12 in (30.5 cm)	12 in (30.5 cm)

Source: Integrated Building Distribution Network (IBDN) User Manual - Northern Telecom, doc # IBDN-UM-9105, 1991.

The EIA/TIA working group revising the EIA-569 standard is using the results of field and lab tests to update the recommendations. The target date for completion is Dec 1995.

1.1.7 What is the minimum bending radius for a cable

According to EIA SP-2840A (a draft version of EIA-568-x) the minimum bend radius for UTP is 4 x cable outside diameter, about one inch. For multipair cables the minimum bending radius is 10 x outside diameter.

SP-2840A gives minimum bend radii for Type 1A Shielded Twisted Pair (100 Mb/s STP) of 7.5 cm (3-in) for non-plenum cable, 15 cm (6-in) for the stiffer plenum-rated kind.

The ISO DIS 11801 standard, Section 7.1 General specs for 100 ohm and 120 ohm balanced cable lists three different minimum bend radii. Minimum for pulling during installation is 8x cable diameter, min installed radius is 6x for riser cable, 4x for horizontal.

Some manufacturers recommendations differ from the above, so it is worth checking the spec sheet for the cable you plan to use.

1.1.8 Summary of UTP cable testing

Many of the problems encountered in UTP cable plants are a result of miswired patch cables, jacks and crossconnects.

Horizontal and riser distribution cables and patch cables are wired straight through end-to-end i.e. pin 1 at one end should be connected to pin 1 at the other. (Crossover patch cables are an exception, as described later). Normally, jacks and crossconnects are designed so that the installer always punches down the cable pairs in a standard order, from left to right: pair 1 (Blue), pair 2 (Orange), pair 3 (Green) and pair 4 (Brown) (See section 1.5). The white striped lead is usually punched down first, followed by the solid color. The jack's internal wiring connects each pair to the correct pins, according to the assignment scheme for which the jack is designed: EIA-568A, 568B, USOC (See section 1.5). One source of problems is an installation in which USOC jacks are mixed with EIA-568A or 568B. Everything appears to be punched down correctly, but some cables work and others do not.

1.1.9 Cable Testers for Category 5

- LANcat V by Datacom Technologies, Everett, WA, Tel: 800/468-5557
- DSP100 by Fluke Corporation, P.O. Box 9090, Everett, WA 98206-9090 Tel: 206/356-5400, 800/44-FLUKE

- PentaScanner by Microtest, Inc, 4747 North 22nd St, Phoenix, AZ 85016 Tel: 602/952-6400 800/526-9675
- WireScope100 by Scope Communications, Inc, 100 Otis St, Northboro, MA 01532,Tel: 508/393-1236
- LANTech PRO by Wavetek, Inc, 9145 Balboa Ave, San Diego, CA 92123, Tel: 619/279-2200 800/854-2708

At present some vendors are calling their instruments CAT 5 conformant testing devices. Be aware that there is an on-going standards process to define field testing of CAT 5 cables. These standards or guidelines (currently called PN-3287) will not be complete until the late 1995 timeframe. The TIA TSB number will be TSB-67 when PN-3287 is approved. The standard is expected to define two accuracy levels of test equipment, and provide minimum performance standards for each. Current test equipment is likely to fall in the lower level. The higher class (Accuracy Level II) is intended for subsequent generations of test equipment capable of performing the increasingly numerous and stringent tests now being developed.

1.2 Standards Organizations

National and international organizations that develop fire and building codes, such as

- The Institute of Electrical and Electronic Engineers (IEEE)
- The Electronic Industries Association and the newer Telecommunications Industry Association (EIA/TIA)
- Underwriters Laboratories (UL)
- Government agencies at various levels

all issue specifications for cable material and installation.

EIA/TIA has issued the EIA/TIA-568 and -569 standards for technical performance, and has an active program to extend its requirements. (See the EIA/TIA-568 standard section 1.3.3 later on in this document.)

The IEEE has included minimal cable requirements in its 802.3 and 802.5 specifications for Ethernet and Token-Ring systems.

The National Electrical Code of the United States (NEC) describes various types of cables and materials used in the cable.

The UL focuses on safety standards, but has expanded its certification program to evaluate twisted pair LAN cables according to IBM and EIA/TIA performance specifications. UL has also established a program to mark shielded and unshielded twisted pair LAN cables to simplify the complex task of making sure the materials used in the installation are up to specification.

1.3 Cable Ratings

1.3.1 IBM Type Designations

- Type 1 - Two pair of 22 AWG solid wire (as opposed to the stranded wire in Type 6, below). Each pair foil wrapped inside another foil sheath that has a wire braid ground. This is usually what most people think of as "STP". Used for Token-Ring networks and has a cable impedance of 150 ohms. Tested to a bandwidth of 100 MHz and has a data transmission rate of 100 megabits per second. IBM has added a new specification that uses the same cable but subjects it to more rigorous testing. This specification, called Type 1A, calls for cable tested to 300 MHz and has applications in high speed data networks like ATM.
- Type 2 - Type 1 22 AWG solid wire with 4 telephone pair sheathed to the outside to allow one cable to an office for both voice and data. A new Type 2A with the same configuration but tested to 600 MHz is also available.
- Type 3 - Four pair of unshielded 24 AWG solid twisted pairs for voice or data with a characteristic impedance of 105 ohms, each pair wrapped at least twice per foot. Type 3 is IBM's version of twisted -pair telephone wire. The unshielded pairs in Type 2 and 3 cable are designed for only telephone and low speed data transmission of upto 4 megabits per second and do not meet the requirements for higher-speed data transmission. Do not confuse IBM Type 3 cable with EIA/TIA 568 Category 3 or UL Level III cable; it looks similar, but it is not the same.
- Type 4 - Lacks a published specification.

- Type 5 - Consists of two fiber optic strands of 100 micron core and 140 micron cladding. It has a window at 850 nm and a bandwidth of 100 MHz. Note that Type 5 cable differs considerably from the more popular 62.5/125 micron dual-window fiber optic cable. Type 5 is accepted as part of the Fiber Distributed Data Interface (FDDI) specification, but the 62.5/125 micron cable, also part of the FDDI specification, is more common.
- Type 6 - Two pairs of stranded, shielded 26 AWG cables. More flexible than Type 1 cable, and designed for data transmission. Type 6 is commonly used between a computer and a data jack in the wall. A Type 6A, tested to 600 MHz, is also available.
- Type 7 - Lacks a published specification.
- Type 8 - Two parallel pairs (flat wires with no twist) of 26 AWG used for under carpet installation.
- Type 9 - Plenum cable, with two pairs of individually shielded 26 AWG solid or stranded cable, covered with a special flame-retardant coating, for use between floors in a building. A Type 9A, tested to 600 MHz is also available.

1.3.2 National Electric Code (NEC)

The National Electric Code (NEC) is established by the National Fire Protection Association (NFPA). The language of the code is designed so that it can be adopted as law through legislative procedure. In general terms, the NEC describes how a cable burns. During a building fire, a cable going between walls, up an elevator shaft, or through an air handling plenum could become a torch that carries the flame from one floor or one part of the building to another. Since the coverings of the cables and wires are typically plastic, they can create noxious smoke when they burn. Several organizations including UL, have established standards for flame and smoke that apply to LAN cables. However, the NEC contains the standards most widely supported by local licensing and inspection officials. The standards among other things, set a limit to the maximum amount of time a cable burns after a flame is applied. Other standards developed by the NFPA and adopted by the American National Standards Institute (ANSI) also describe the type and amount of smoke a burning cable can generate. The NEC type codes classify specific categories of products for specific uses, as shown below.

Table 3.

Cable Type	Description
OFC (Fiber Optic)	Contains metal conductors inserted for strength
OFN (Fiber Optic)	Contains no metal
CMP (Communications plenum)	limited flame spread and low production of smoke. Typically coated with a special jacket such as teflon. The letter P defines a Plenum as a channel or a ductwork fabricated for handling air. A false ceiling or floor is not a plenum.
CMR (Communications Riser)	The letter R show that the cable has passed similar but slightly different tests. For e.g., riser cable is tested for its burning properties in a vertical position. Riser cables typically have a poly vinyl chloride (PVC) outer jacket.

1993 National Electrical Code

Article 725, Class 2

725-38(b)1	CL2X	Class 2 cable, limited use
725-38(b)1	CL2	Class 2 cable
725-38(b)2	CL2R	Class 2 riser cable
725-38(b)3	CL2P	Class 2 plenum cable Article 800
800-3(b)1	CMX	Communications cable limited use
800-3(b)1	CM	Communications cable

1993 National Electrical Code

Article 725, Class 2

800-3(b)2	CMR	Communications riser cable
800-3(b)3	CMP	Communications plenum cable

1.3.3 The EIA/TIA-568 (SP-2840) Standard

EIA/TIA Category Specification provide for the following (see below) cable transmission speeds with certain given specifications. (Note prior to Jan 94, UL and Anixter developed a LEVEL system which has been dropped or harmonized with the CATEGORY system); IA/TIA tackled the problem of specifying LAN cables by starting with the Annixter Level 5 model, but the EIA/TIA calls these divisions "categories" instead of levels and named it the EIA/TIA-568 Standard for Commercial Building Telecommunications Wiring.

The primary advantage of the EIA/TIA-568 is its publication as an open standard without the stamp of any single vendor. Note, however that the EIA/TIA categories are not tied to the NEC specifications, and they don't deal with shielded twisted pair wiring.

The three EIA/TIA standards of use are

- **EIA/TIA-568** Commercial Building Telecommunications Wiring Standards. Note EIA/TIA SP-2840 has been designated as the replacement for EIA/TIA-568.
- **EIA/TIA-569** Commercial Building Standard for Telecommunication Pathways and Spaces
- **EIA/TIA-570** Residential and Light Commercial Telecommunications Wiring Standard.

The EIA/TIA-568 standard describes both the performance specifications of the cable and it's installation.

- **Category 1** Says very little about the performance criteria.
- **Category 2** Same as Anixter Level 2 specification, and is derived from the IBM Type 3 cable specification. Uses 22 or 24 AWG wire in solid twisted pairs. Rated to 1 MHz and not tested for netar end crosstalk (NEXT) (used for telephone wiring). You can use this cable for IBM 3270 and AS/400 connections and for Apple LocalTalk.
- **Category 3** Same as Anixter Level 3, and generally is the minimum level of cable quality that should be allowed. Uses 24 AWG solid wire in twisted pairs and displays a typical impedance of 100 ohms, and is tested for attenuation and near-end crosstalk (NEXT) through 16 MHz (used for Ethernet 10Base-T), and sufficient for 4 megabit-per-second Token-Ring.
- **Category 4** Same as Anixter Level 4 cable. Uses 22 or 24 AWG solid wire in twisted pairs. Typical impedance of 100 ohms, and tested for performance at a bandwidth of 20 MHz. (used for Token-Ring, 10Base-T)
- **Category 5** 22 or 24 AWG unshielded twisted-pair cable with a 100 ohm impedance. Tested at a bandwidth of 100 MHz and can handle data signalling at 100 megabits per second under specified conditions. (Used for 100Base-T, 10Base-T type applications)

1.3.4 Underwriters Laboratories (UL)

UL has safety standards for cables similar to those of NEC. UL 444 is the Standard for Safety for Communications cable. UL 13 is the Standard for Safety for Power-Limited Circuit cable. Network cable may fall in either category. UL tests and evaluates samples of cable and then, after granting a UL listing, the organization conducts follow-up tests and inspections. This independent testing and follow-through make the UL markings valuable symbols to buyers.

The UL program deals with both shielded and unshielded twisted-pair wire, while the EIA/TIA-568 standard focuses on unshielded wire. The UL markings range from Level I through Level V. You can tell a UL cable from an Anixter cable because UL uses the Roman numerals.

For details on the UL LAN Cable Certification Program - Underwriters Laboratories publication 200-120 30M/3/92, 1992 [characteristics of Cat 3-5 UTP].

UL-910, FT-4 and FT-6 say nothing about the type or volume of toxic combustion products produced. All they cover is performance on a flameproof test.

- The UL Level I marking meets the appropriate NEC and UL 444 safety requirements. No specific performance specifications.
- The UL Level II marking meets the performance requirements of EIA/TIA-568 Category 2 and IBM Cable Plan Type 3 cable. Meets appropriate NEC and UL 444 safety requirements. Acceptable for 4-megabits Token-Ring but not for higher speed data applications such as 10Base-T.
- The UL Level III marking meets the performance requirements of EIA/TIA-568 Category 3 and NEC and UL 444 safety requirements.
- The UL Level IV marking meets the performance requirements of EIA/TIA-568 Category 4 and NEC and UL 444 safety requirements.
- The UL Level V marking meets the performance requirements of EIA/TIA-568 Category 5 and NEC and UL 444 safety requirements.

THIS DOCUMENT IS A GUIDELINE ONLY -- SEEK PROFESSIONAL ADVICE, CHECK LOCAL BUILDING CODES AND APPLICABLE STANDARDS.

- The US National Fire Protection Association (NFPA) revises the National Electrical Code (NEC) every 3 years. The NEC defines classifications of cable as per UL tests.
- The Canadian Standards Association (CSA) defines Premise Communication Cord (PCC) standards for physical wire tests. These are printed on the cable as CSA-PCC-FT6.
- FT4 = Flame Test 4 is described in CSA C22.2 0.3-1992
- FT6 = Flame Test 6 is described in NFPA 262-1985 and ULC S102.4

Physical Wire Tests C22.2 214-M-1990. These CSA documents can be ordered from the CSA. See sources in Section XX.

1.4 Vendor Specific Suggestions

- AMP NETCONNECT Open Cabling System
- HP SiteWire
- AT&T PDS
- DEC MMJ
- IBM STP (Type 1, Type 2, etc.)
- Northern Telcom IBDN

1.5 Cable Connectors and Pinout standards

The *RJ-45 Connector* which is technically an eight-position plug or jack and the *RJ-11 connector* is a six position plug or jack. The letters "RJ" stand for registered jack and are supposed to connote a specific wiring sequence.

Telephone wiring people use the term *polarization* to describe the physical form and configuration of the connectors. *Sequence* refers to the order of the wire pairs in the connectors, so taken together these terms describe the connectors and how they attach to the cable. Crimping tools are used connect the plug to the cable.

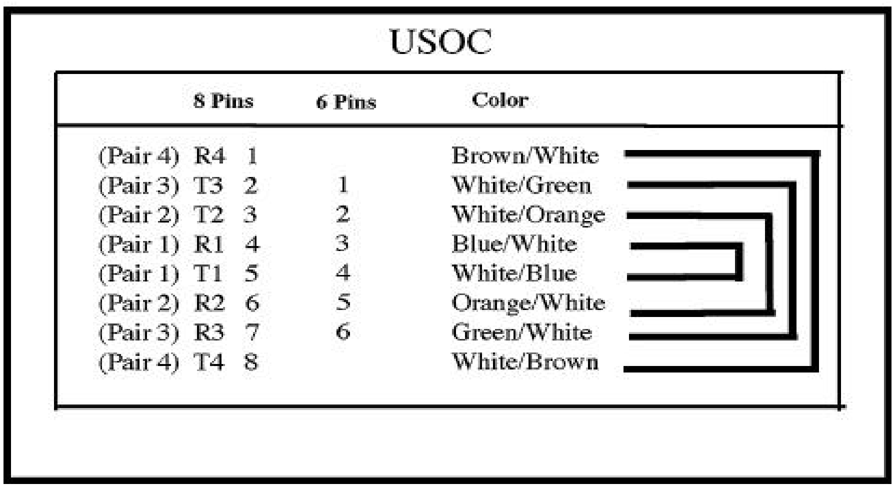
Tip and Ring: These terms go back to the early days of the telephone industry and refer to each of the two wires that connect to the end of a switchboard telephone plug (the tip) or to the back portion of the plug's connecting surface (the ring). Using the terms tip and ring is like talking about the positive and the negative wire. So in modern use, tip and ring designate each wire in a pair. The wires in the first pair in a cable or a connector are designated as T1 and R1, the second pair is T2 and R2, and so on.

In UTP horizontal wiring, there is general agreement on how to color code the wires in a cable. In a four-pair cable, the tip conductors (T1 through T4) in each pair are white with a stripe of a secondary color that designates the pair. The ring conductors (R1 through R4) have jackets of the secondary color with the white stripe.

The secondary color used in a 4-pair cable are blue, orange, green, and brown. The color slate is also assigned as a secondary color in cables with more wire pairs. So in UTP connections, wire T1 is white with a blue stripe, while it's partner R1 is blue with a white stripe. Wire T2 is white with an orange stripe, and R2 is orange with a white stripe., and so on. Some cables, like those connecting the 50-pin telco connectors used in wiring closets, need more pairs, so red, black, yellow and violet are assigned as other primary colors. Used together, the five primary and five secondary colors identify all the pairs in a 25-pair cable.

1.5.1 USOC

The Universal Service Order Code (USOC) is the oldest specification. It is derived from the original Bell System specifications, so it is widely used by telephone companies. Note the USOC system arranges the pair sequences from the center out. Note that pins 1 and 2 are not part of the same pair as they are in the other common configurations. The USOC wiring pattern does not confirm to the 10Base-T specifications, but then a USOC wired installation probably doesn't meet the data service requirements for crosstalk or noise either.


USOC

		8 Pins	6 Pins	Color
(Pair 4)	R4	1		Brown/White
(Pair 3)	T3	2	1	White/Green
(Pair 2)	T2	3	2	White/Orange
(Pair 1)	R1	4	3	Blue/White
(Pair 1)	T1	5	4	White/Blue
(Pair 2)	R2	6	5	Orange/White
(Pair 3)	R3	7	6	Green/White
(Pair 4)	T4	8		White/Brown

1.5.2 EIA Preferred Commercial Building Specification

Despite its imposing title, this is not the preferred wiring sequence. However you won't go wrong using this sequence as long as everyone who works on the cabling knows that the building is "EIA-standard."

EIA Preferred Commercial Building Specification

8 Pins	Color
(Pair 3) T3 1	White/Green
(Pair 3) R3 2	Green/White
(Pair 2) T2 3	White/Orange
(Pair 1) R1 4	Blue/White
(Pair 1) T1 5	White/Blue
(Pair 2) R2 6	Orange/White
(Pair 4) T4 7	White/Brown
(Pair 4) R4 8	Brown/White

1.5.3 AT&T 258A

Standard EIA/TIA T568B (also called AT&T specification, previously called 258A)

This is the configuration recommended and the one used by most installers. Pairs T2/R2 and T3/R3 carry the data. You should never simultaneously use pairs T1/R1 or T4/R4 for voice; instead use those pairs for spares or for other high speed data requirements that may demand more than two pairs (e.g 100Base-T4). In some installations, pins 7 and 8 are left open; this configuration is designated as AT&T 356A.

AT&T 258A

8 Pins	Color
(Pair 2) T2 1	White/Orange
(Pair 2) R2 2	Orange/White
(Pair 3) T3 3	White/Green
(Pair 1) R1 4	Blue/White
(Pair 1) T1 5	White/Blue
(Pair 3) R3 6	Green/White
(Pair 4) T4 7	White/Brown
(Pair 4) R4 8	Brown/White

Standard EIA/TIA T568A (also used for ISDN)"

Standard EIA/TIA 568A (also used for ISDN)

8 Pins	Color
(Pair 3) T3 1	White/Green
(Pair 3) R3 2	Green/White
(Pair 2) T2 3	White/Orange
(Pair 1) R1 4	Blue/White
(Pair 1) T1 5	White/Blue
(Pair 2) R2 6	Orange/White
(Pair 4) T4 7	White/Brown
(Pair 4) R4 8	Brown/White

1.5.4 IEEE 10Base-T

The IEEE simply took the AT&T 258A standard and stripped out the pairs normally used for voice. R1/T1 and R4/T4 ended up being useful as a spare for the other higher speed standards.

IEEE 10BaseT

8 Pins	Color
(Pair 2) T2 1	White/Orange
(Pair 2) R2 2	Orange/White
(Pair 3) T3 3	White/Green
(Pair 1) R1 4	
(Pair 1) T1 5	
(Pair 3) R3 6	Green/White
(Pair 4) T4 7	
(Pair 4) R4 8	

1.5.5 Rolm and Digital

Not only do Rolm and Digital Equipment Corporation have their own wiring sequences, but Digital also sometimes uses different plugs and jacks. Older Digital installations use a proprietary plug (the modified modular plug or MMJ) that has its little, plastic, locking tab offset to the side instead of in the center.

The fundamental connection concepts for the Digital and Rolm systems are exactly the same as the other sequence schemes, and Digital's Open DECconnect is compatible with AT&T 258A and the 10Base-T specification, except that Digital leaves T4/R4 as a spare and keeps T1/R1 (pins 4 and 5) open.

While the wiring and color-coding scheme described above works for the horizontal cables, patch cables have their own color-coding scheme. The wires inside the patch cables use solid colors in the following sequence.

Rolm and Digital

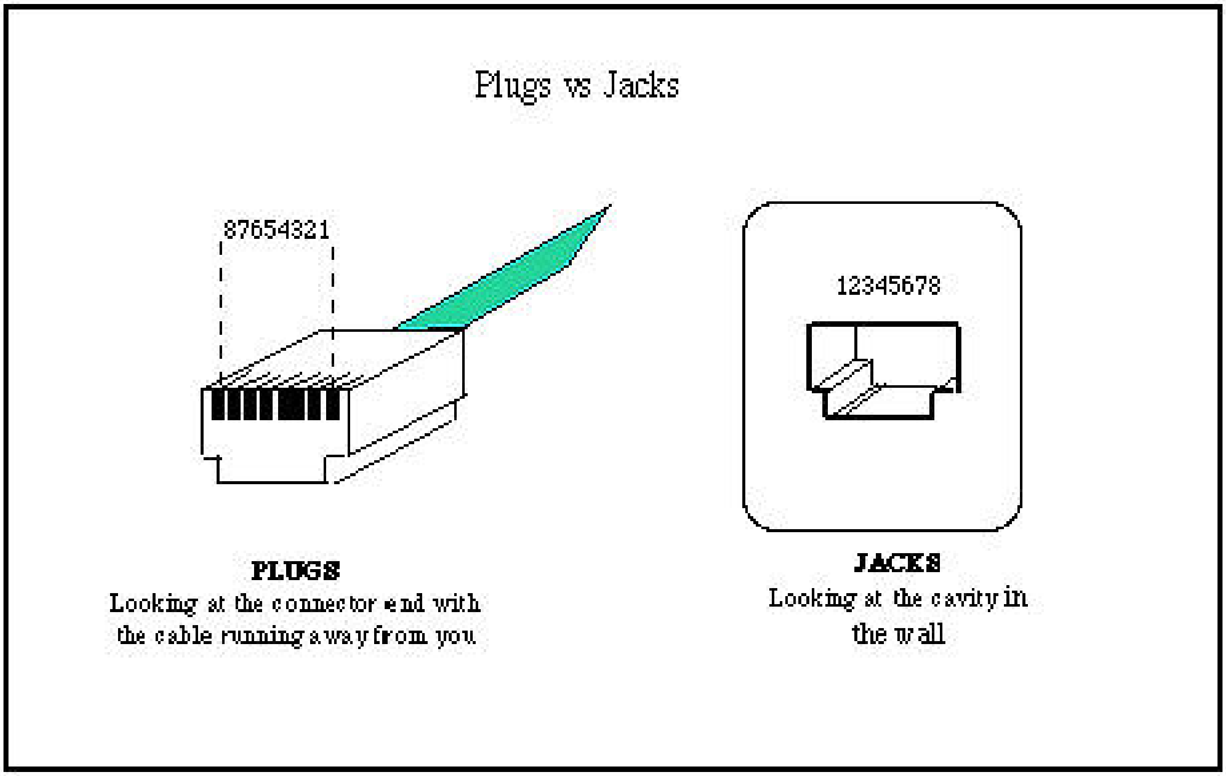
8 Pins	Color
(Pair 1) T1 1	Green
(Pair 1) R1 2	Red
(Pair 2) T2 3	Black
(Pair 2) R2 4	Yellow
(Pair 3) T3 5	Blue
(Pair 3) R3 6	Orange
(Pair 4) T4 7	Brown
(Pair 4) R4 8	White

Hint: Some telephone systems use patch cables that reverse the sequence of wires from end to end. Patch cables designated for data applications have the connectors on each end wired in the same sequence. Keep reversed patch cables away from your data patch panels.

1.6 Plugs vs. Jacks

The EIA/TIA specifies an RJ-45 (ISO 8877) connector for Unshielded Twisted Pair (UTP) cable. The plug is the male component crimped on the end of the cable while the jack is the female component in a wall plate or patch panel, etc. Here is the pin numbering to answer the question, where is pin one?

Plugs versus Jacks



1.7 Standard Networking Configurations

With reference to T568B above;

- ATM 155Mbps uses pairs 2 and 4 (pins 1-2, 7-8)
- Ethernet 10Base-T uses pairs 2 and 3 (pins 1-2, 3-6)
- Ethernet 100Base-T4 uses pairs 2 and 3 (4T+) (pins 1-2, 3-6)
- Ethernet 100Base-T8 uses pairs 1,2,3 and 4 (pins 4-5, 1-2, 3-6, 7-8)
- Token-Ring uses pairs 1 and 3 (pins 4-5, 3-6)
- CDDI/MLT-3 uses pairs 2 and 4 (pins 1-2, 7-8)
- 100VG-AnyLAN uses pairs 1,2,3 and 4 (pins 4-5, 1-2, 3-6, 7-8)

1.8 IEEE 10Base-T Cabling

Ethernet 10Base-T Straight Thru patch cord (T568B colors)

RJ45 Plug		RJ45 Plug
T2 1	White/Orange	1 TxData +
R2 2	Orange/White	2 TxData -
T3 3	White/Green	3 RecData +
R1 4	Blue/White	
T1 5	White/Blue	
R3 6	Green/White	6 RecData -
T4 7	White/Brown	
R4 8	Brown/White	

Ethernet 10Base-T Crossover patch cord

This cable can be used to cascade hubs/switches, or for connecting two Ethernet stations back-to-back without a hub. Note pin numbering in section 1.7 above.

RJ45 Plug One End **RJ45 Plug Other End**

1 Tx+ (White/Orange) to 3 Rx+

2 Tx-(Orange/White) to 6 Rx-

3 Rx+ (White/Green) to 1 Tx+

6 Rx- (Green/White) to 2 Tx-

Ethernet 10Base-T to USOC Crossover patch cord;

RJ45 8-pin Plug		USOC 6-pin Plug
	1 ---White/Orange--- 2	
	2 ---Orange/White-- 5	
	3 ---White/Green----- 1	
	6 ---Green/White---- 6	

Crossover Implementation

A simple way to make a crossover patch cable is to take a dual-jack surface mount box and make the crossover between the two jacks. This allows using standard patch cables, and avoids the nuisance of having a crossover cable find its way into use in place of a regular patch cable.

Stranded Patch Cables

The color code used in stranded patch cables is different from solid-conductor cables. For NorTel Digital Patch Cable (DPC), the coding is:

Pair 1: Green & Red

Pair 2: Yellow & Black

Pair 3: Blue & Orange

Pair 4: Brown & Gray

RJ-45 Loopback tester

Pin 1: White/Orange

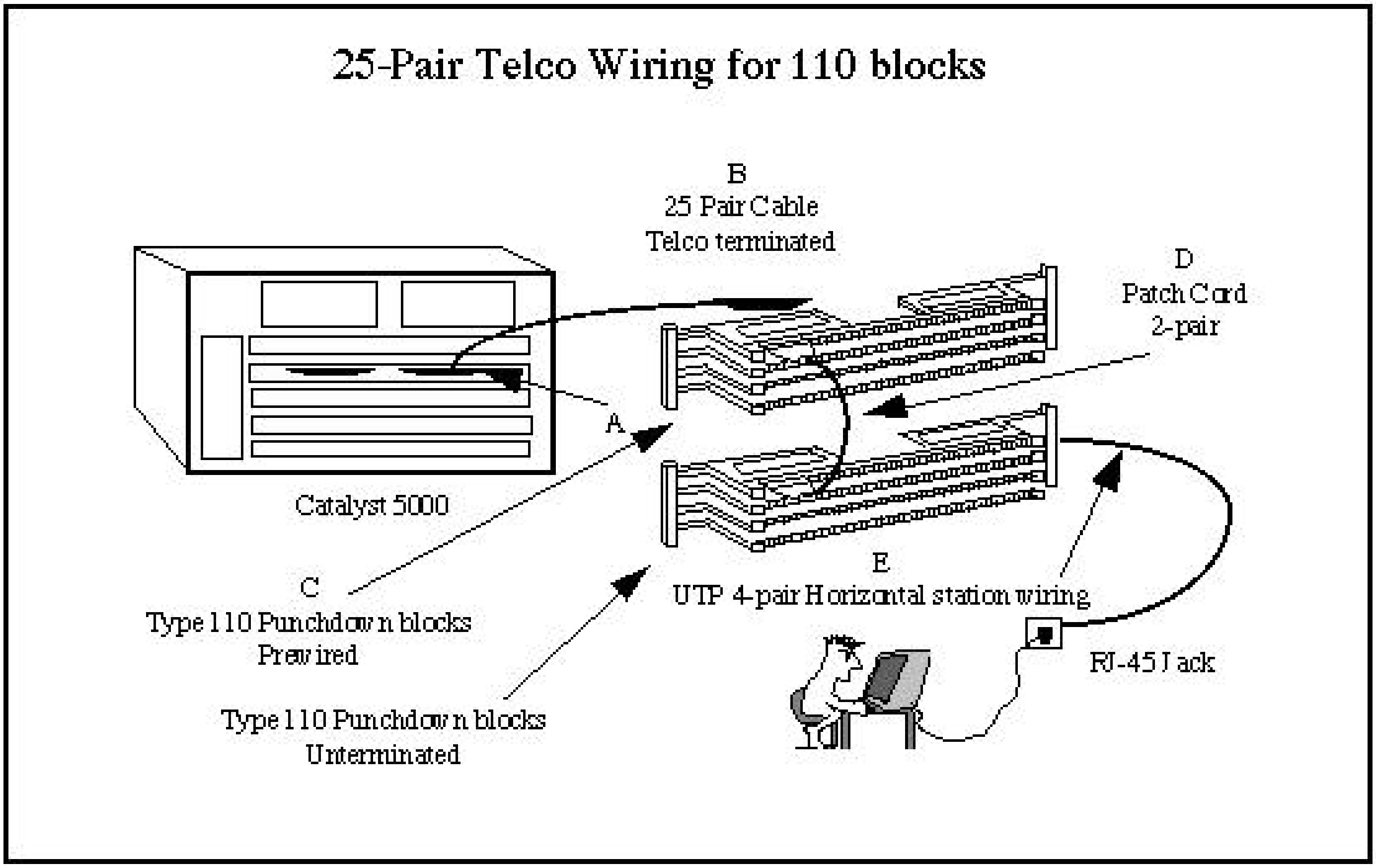
Pin 2: Orange/White

Pin 3: White/Orange

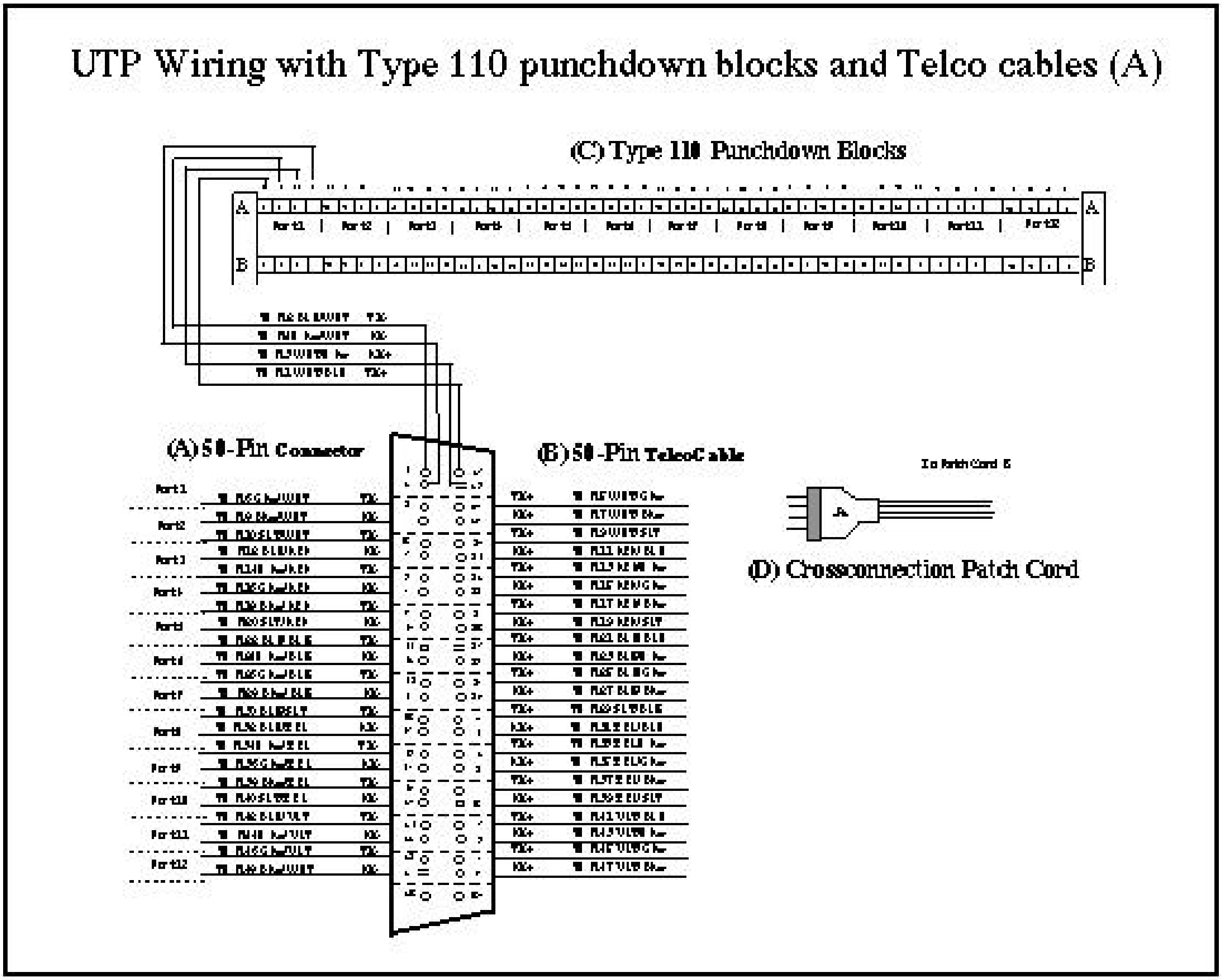
Pin 6: Orange/White

1.9 Typical wiring layouts (Catalyst 5000)

25-Pair Telco Wiring for 110 block



UTP WIRING WITH TYPE 110 PUNCHDOWN BLOCKS AND TELCO CABLES (A)



UTP WIRING WITH TYPE 110 PUNCHDOWN BLOCKS AND TELCO CABLES (B)

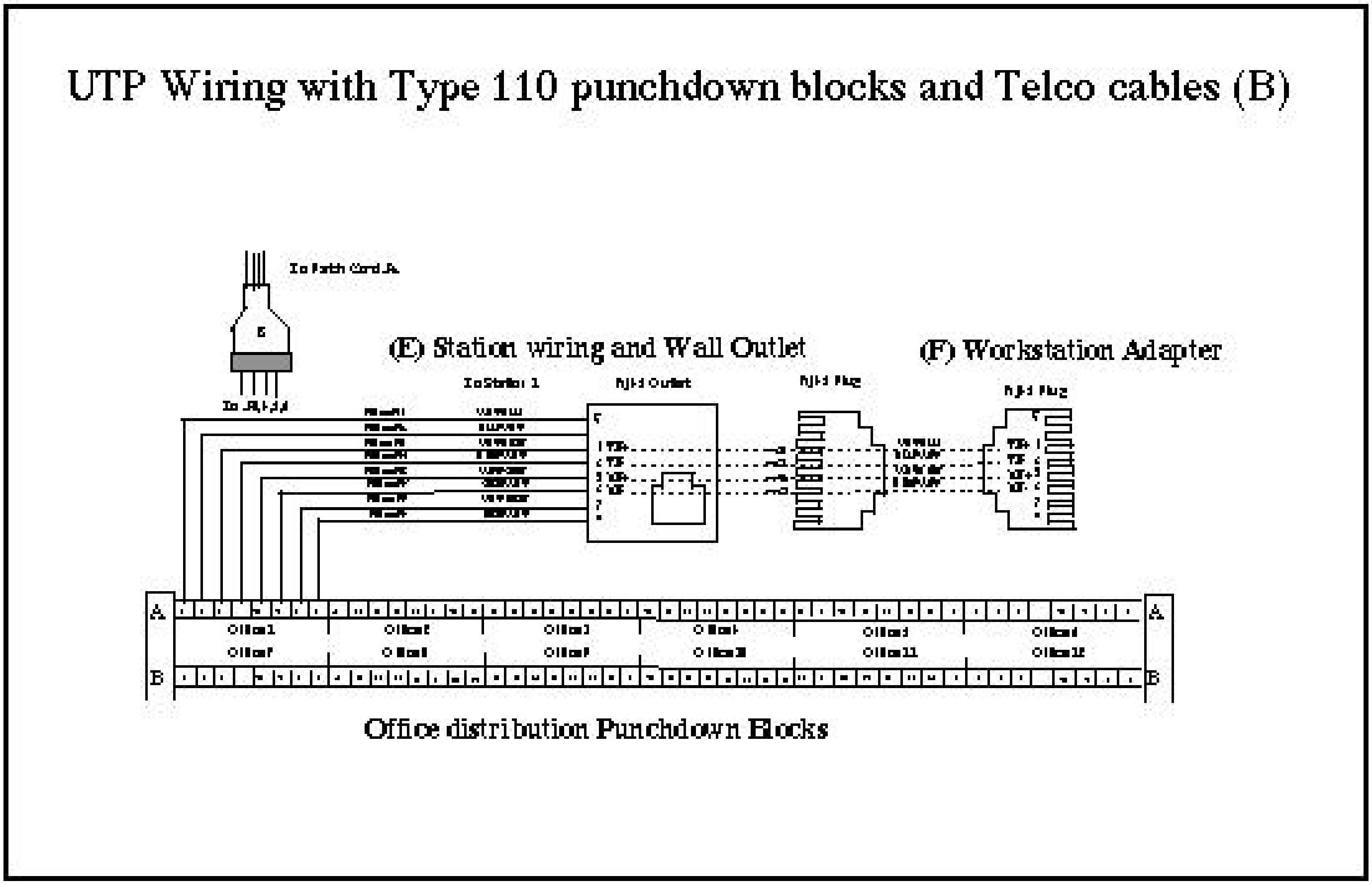


Table 4. Catalyst 5000 50-Pin Telco to Rj-45 Pin Configuration

50Pin Connector	Wire Color	Station end RJ-45	Port #
1	Blue/White	1	Port 1
26	White/Blue	2	
2	Orange/White	3	
27	White/Orange	6	
3	Green/White	1	Port 2
28	White/Green	2	
4	Brown/White	3	
29	White/Brown	6	
5	Slate/White	1	Port 3

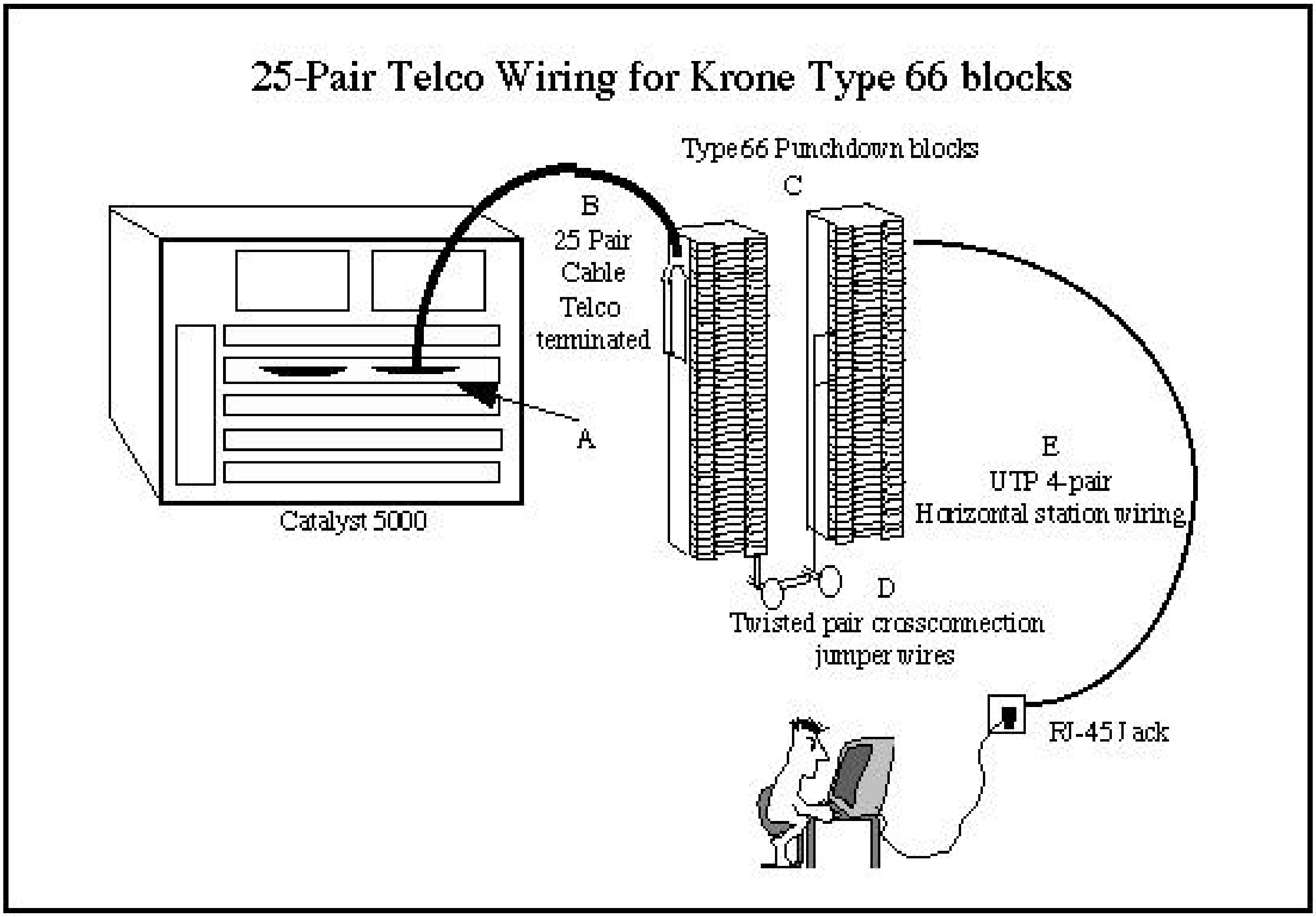
Table 4. Catalyst 5000 50-Pin Telco to Rj-45 Pin Configuration

50Pin Connector	Wire Color	Station end RJ-45	Port #
30	White/Slate	2	
6	Blue/Red	3	
31	Red/Blue	6	
7	Orange/Red	1	Port 4
32	Red/Orange	2	
8	Green/Red	3	
33	Red/Green	6	
9	Brown/Red	1	Port 5
34	Red/Brown	2	
10	Slate/Red	3	
35	Red/Slate	6	
11	Blue/Black	1	Port 6
36	Black/Blue	2	
12	Orange/Black	3	
37	Black/Orange	6	
13	Green/Black	1	Port 7
38	Black/Green	2	
14	Brown/Black	3	
39	Black/Brown	6	
15	Blue/White	1	Port 8
40	White/Blue	2	
16	Orange/White	3	
41	White/Orange	6	
17	Orange/Yellow	1	Port 9
42	Yellow/Orange	2	
18	Green/Yellow	3	
43	Yellow/Green	6	
19	Brown/Yellow	1	Port 10
44	Yellow/Brown	2	

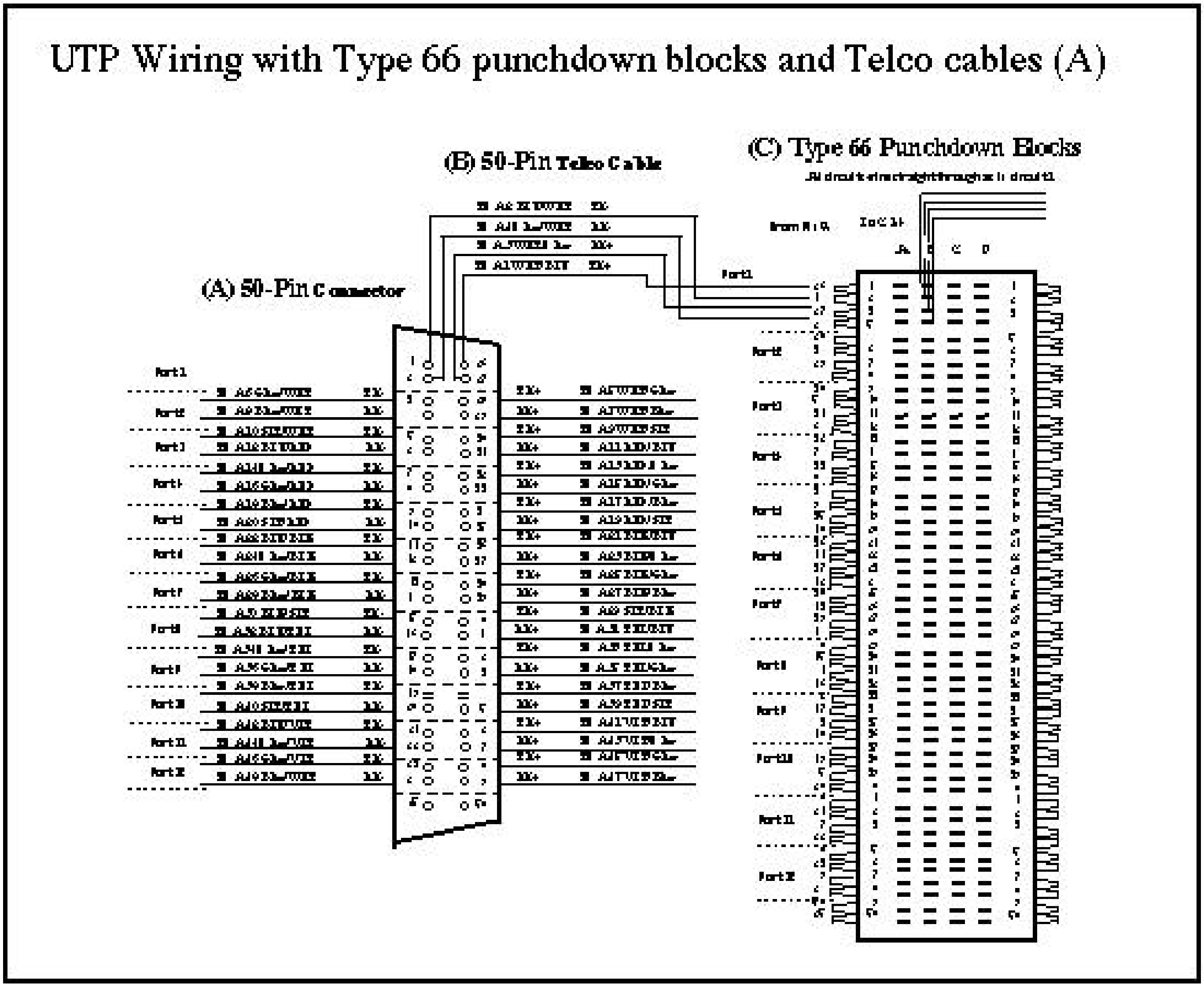
Table 4. Catalyst 5000 50-Pin Telco to Rj-45 Pin Configuration

50Pin Connector	Wire Color	Station end RJ-45	Port #
20	Slate/Yellow	3	
45	Yellow/Slate	6	
21	Blue/Violet	1	Port11
45	Violet/Blue	2	
22	Orange/Violet	3	
47	Violet/Orange	6	
23	Green/Violet	1	Port12
48	Violet/Green	2	
24	Brown/Violet	3	
49	Violet/Brown	6	

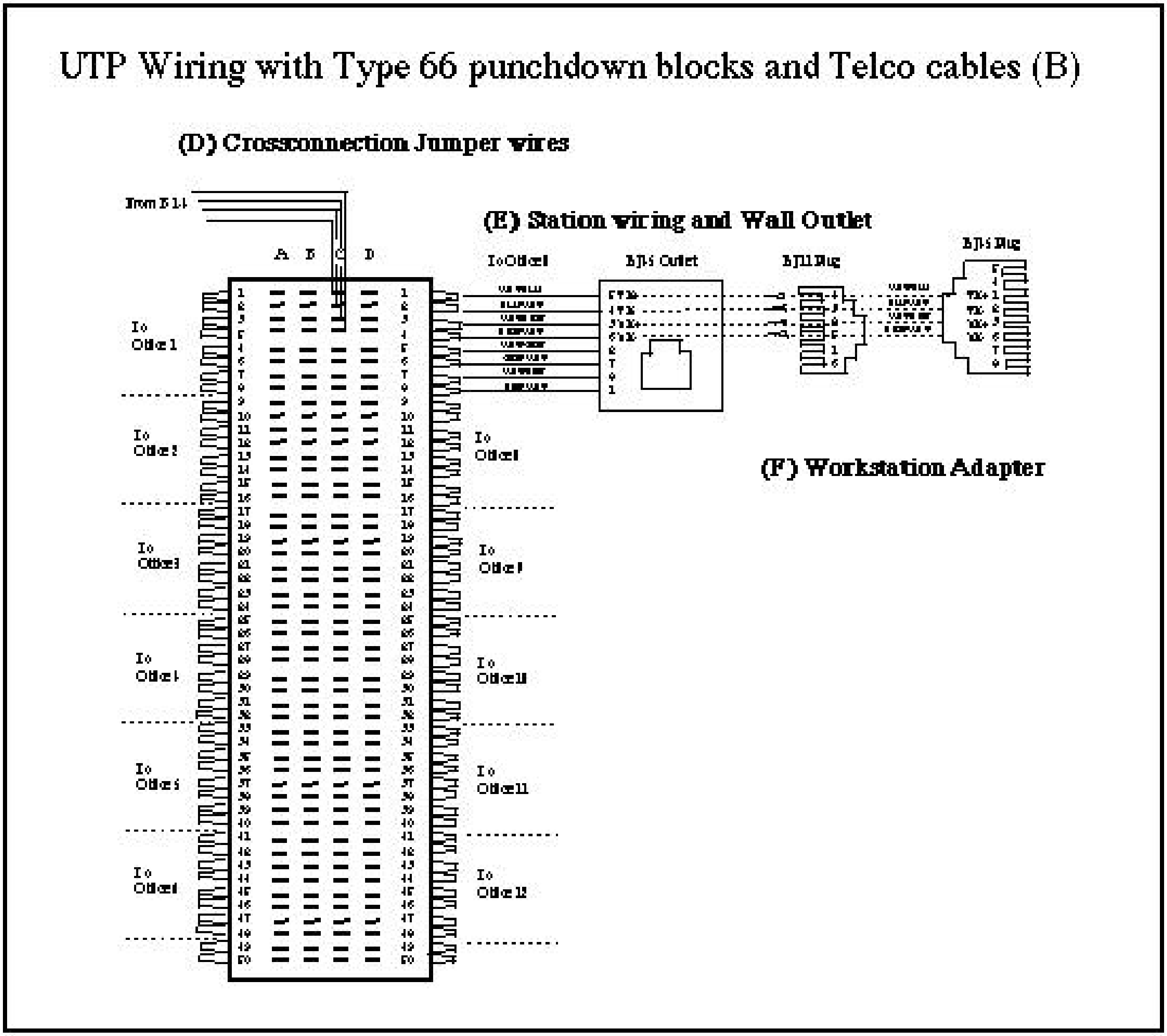
25-Pair Telco Wiring for Krone Type 66 Blocks



UTP WIRING WITH TYPE 66 PUNCHDOWN BLOCKS AND TELCO CABLES (A)



UTP WIRING WITH TYPE 66 PUNCHDOWN BLOCKS AND TELCO CABLES (B)



Note: On the 66 or 110 block, the white wire goes on top. Thus, going down the block you have White/Blue, Blue/White, White/Orange, Orange/White, White/Green, Green/White, White/Brown, Brown/White and so on.

Crossconnect: NorTel BIX1A, AT&T 110 and similar crossconnect blocks accommodate 4-pair, 25-pair or larger cables on the same mount. The same type of mount can be used for the voice field as well as data.

Telephone-only (66) blocks are seldom used except for low-speed data circuits such as are used for IBM 3270 terminals.

The newer types of crossconnect mentioned above cost about the same and accommodates growth much better. (The standard AT&T 110 and its BIX equivalent are rated at Cat 5).

AS OF DATE THERE IS NO CAT5 STANDARD FOR TELCO CONNECTORS AND TELCO CABLES

Crossconnect Field Colors

The color of label used on a crossconnect field identifies the field's function. The cabling administration standard (CSA T-528 & EIA-606) lists the colors and functions as:

Blue Horizontal voice cables

Brown Interbuilding backbone

Gray Second-level backbone

Green Network connections & auxiliary circuits

Orange Demarcation point, telephone cable from Central Office

Purple First-level backbone

Red Key-type telephone systems

Silver or White Horizontal data cables, computer & PBX equipment

Yellow Auxiliary, maintenance & security alarms

2.0 GLOSSARY

AWG - American Wire Gauge, the standard measure for the diameter of a wire. As the numbers increase, the wire diameter decreases. Normal wire for 10BaseT is 22 or 24 AWG.

Attenuation - The decrease in power of a signal as it travels along the cable.

Balun (BALanced UNbalanced) - An impedance matching device that connects a balanced line (such as twisted-pair) and an unbalanced line (such as coaxial cable).

Baseband - A network that transmits signals as a DC (direct-current) pulse rather than variations in a radio frequency signal.

Bell Standard Practices (BSP) - A set of procedures designed before the breakup of Bell Systems. The BSP described in detail how installers should cut, twist, and attach every wire, and how to secure every cable span.

Broadband signalling - A network that carries information riding on radio frequency (RF) waves rather than directly as pulses, and provides greater capacity at the cost of higher complexity.

Conductors - A piece of wire. For 10BaseT purposes it is solid (not stranded), copper wire.

Crimper - A plier like device used to attach connectors to the end of cables.

Cross-connect device - A device that terminates a cable or group of cables and makes the termination available for interconnection to other cables.

Crosstalk - The spillover of a signal from one channel to another. In datacommunications it is very disruptive, and in cable systems, crosstalk comes from adjacent pairs.

Data Cable Levels - A cable grading scheme used by cable manufacturers to identify the designed transmission speed for a given cable.

Distortion - Any change to the transmitted signal. May be caused by crosstalk, delay, attenuation, or other factors.

Distributed capacitance - The electrical property of capacitance developed within a cable that stores a direct current charge while passing an alternating current charge. This has the effect of diminishing the low frequency portion of the transmitted signals.

Distributed inductance - The electrical property of inductance developed within a cable that stores an alternating current charge while passing a direct current charge. This has the effect of diminishing the high frequency portion of the transmitted signals.

EIA/TIA-568 - The EIA/TIA's Standard for Commercial Building Telecommunications Wiring. The EIA/TIA-568 standard describes a set of performance classifications and installation parameters for network cable. This standard is scheduled to be renamed as SP-2840.

EIA/TIA-569 - The Commercial Building Standard for Telecommunication Pathways and Spaces.

EIA/TIA-570 - The Residential and Light Commercial Telecommunications Wiring Std.

EIA/TIA-606 - The Administration Standard for the Telecommunications Infrastructure of Commercial Buildings. The EIA/TIA-606 describes the method for numbering and labelling cabling, pathways and spaces.

EMI/RFI - Electro-magnetic Interference / Radio Frequency Interference. The electrical signals in the air that you don't want in your cables. If someone tells you there is no EMI/RFI in their office building, just turn on a radio.

EIA - The Electronic Industries Association. An organization of U.S manufacturers of electronic parts and equipment. The organization develops industry standards for the interface between data processing and communications equipment.

Four-wire circuit - A transmission arrangement where two half-duplex circuits (two wires each) are combined to make one full-duplex circuit.

Ground - An electrically neutral contact point.

Hertz (Hz) - The number of electrical cycles (vibrations) per second. An Hz is equal to one cycle per second.

Horizontal wiring - The cable that runs between each wall jack and its associated wiring closet.

IBM Cable Types - IBM, of course, has its own method of defining cable types.

Impedance - An electrical characteristic that measures opposition to the flow of an alternating current in a wire. Just like resistance is to a direct current flow. AC signals get very upset when cables of different impedances are connected. Elements of distributed inductance, distributed capacitance, and resistance combine to create impedance.

IEEE - The Institute of Electrical and Electronics Engineers (IEEE). A standards making organization responsible for many LAN based standards and rules.

International Consultative Committee on Telephone and Telegraph (CCITT) - The international organization responsible for developing many communication standards.

Link Beat - Once a second the Hub sends a signal to the workstation. If the workstation does not respond, the hub "segments" that workstation out of the net. This should prevent a bad cable or card from bringing down the whole network.

Main Distribution Frame (MDF) - The MDF is also called the cross-connection point, is a wiring point used primarily to distribute circuits coming in from outside the building.

NEC - National Electric Code. A code established by the National Fire Protection Association. NEC rates the cable for fire resistance and such. If you are going to run your cable above the ceiling in a space used for ventilation (a plenum), then you have to use plenum rated cable. This is a more expensive (Teflon sheath versus PVC) but is required to meet fire codes.

Near-end crosstalk (NEXT) - Interference measured on a wire that is located adjacent to the wire in which the signal is being sent.

NIC - Network Interface Card.

Ohm - Primarily a unit of resistance, but can also be used to express impedance.

Nominal Velocity of Propagation (NV) - The ratio between the speed of an electrical pulse in a specific type of cable and the speed of light.

Patch-panel - A panel built into a cabinet that contains jacks which terminate individual cables. Jumper cables make connections between the individual jacks. A patch panel makes it easy to redirect and change network connections.

Poly vinyl chloride (PVC) - Used as an insulating material in coaxial cables between the solid core and the outside braid.

Premise Distribution System (PDS) - A building-wide telecommunications cabling system. AT&T, Northern Telecom, and other vendors have specified PDS architectures.

Punch (down) Block - A device used in a central closet for managing wires. Available in a 66 or 110 model. The 110 is the new, electrically superior model, but the 66 seems to work fine. Wires are attached with a Punch (down) Tool. Punch Blocks are usually attached to the wall in a wiring closet on a patch panel.

RG-58 - A coaxial cable connector with a 50-ohm impedance and is used with thin ethernet.

RG-62 - A coaxial cable connector that has a 93-ohm impedance and used with ARCnet.

RJ-45 - A small plastic connector used on the end of a four pair cable. RJ-11 is the smaller one used for telephone connections.

Satin cable - Four parallel wires (0 twists) used for telephone only. One comes with every modem. Not for network use.

Screened-twisted-pair (SCTP) - Twisted-pair cabling with an outer foil shield to reduce EMI. It has performance and operating characteristics similar to UTP.

Station Cable - The cable that connects the network node to the wall jack.

STP - Shielded Twisted Pair. One or more twisted pairs inside an electrically conductive sheath (usually aluminum foil) that protects the pairs from outside interference. The shield should be grounded at the hub end. STP generally has an impedance of 150 ohms.

Systimax - An AT&T specification for installing and planning network cable.

Time-domain reflectometry - The technique of sending an electric pulse down a cable and then timing its reflection back from the other end. Most cable scanners use TDR to determine the length of the cable.

Twisted Pair - Two conductors that twist around each other for greater bandwidth.

Underwriters Laboratories (UL) - An organization, founded by the National Board of Fire Underwriters, that specifies safety standards.

UTP - Unshielded Twisted Pair. One or more twisted pairs inside an insulating sheath. UTP generally has an impedance of 100 ohms.

Vertical wiring (Riser cabling) - The cable that forms the backbone between the wiring closets and the main cross-connection point in the building.

3.0 Cabling Standards/Reference

1 *American National Standards Institute (ANSI)*

2 *Electronic Industry Association (EIA)*

3 *Telecommunications Industry Association (TIA)*

4 Current specification is the ANSI/EIA/TIA-568-1991 Standard, Commercial Building Telecommunications Wiring Standard, and two Tech Sys Bulletins:

5 Additional Cable Specifications for Unshielded Twisted-Pair Cables

6 EIA/TIA Tech Sys Bulletin TSB-36, Nov 1991

7 [Transmission Characteristics of Category 3-5 UTP cables]

8 Additional Transmission Specifications for UTP Connecting Hardware_

- EIA/TIA Tech Sys Bulletin TSB-40A, Dec 1993
- (Performance of Connectors and Patch Panels Above 20 MHz)

9 Extended Specifications for 150-ohm STP Cables and Data Connectors

10 EIA/TIA Tech Sys Bulletin TSB-53, 1992 [Type 1A cable]

11 EIA-570: Residential and Light Commercial Telecommunications Wiring Standard EIA/TIA, 1991

12 EIA-606: Telecommunications Administration Standard for Commercial Buildings - EIA/TIA (was PN-2290)

13 EIA-607: - Commercial Building Grounding and Bonding Requirements for Telecommunications - EIA/TIA

14 EIA/TIA PN-2840 - [draft for the EIA-568-A standard, incorporating TSB-36 and 40A, expected in early 1995]

15 EIA/TIA PN-2840A - [draft for next version of the EIA-568-A standard]

16 American National Standards Institute (ANSI)/

17 National Fire Protection Assoc. (NFPA):

18 70 National Electrical Code (1993)

19 78 Lightning Protection Code

20 Canadian Standards Association (CSA): C22.1-1994 Canadian Electrical Code, Part 1

21 CAN/CSA-T527: Bonding and Grounding for Telecommunications in Commercial Buildings - Canadian Standards Assoc. [harmonized with EIA-607]

22 CAN/CSA-T528: Telecommunications Administration Standards for Commercial Buildings - CSA, Jan 1993 [harmonized with EIA-606]

23 CAN/CSA-T529-M91: Design Guidelines for Telecommunications Wiring System in Commercial Buildings, - CSA [harmonized with EIA-568]

24 CAN/CSA-T530-M90: Building Facilities, Design Guidelines for Telecommunications - CSA, 1990 [harmonized with EIA-569]

25 ISO/IEC 11801: [international equivalent of EIA-568 and CSA T-529, includes 120 ohm Screened Twisted Pair cable]

26 IEC 603-7, Part 7 - [Modular connector physical dimensions, mechanical and electrical characteristics. Level A: 750 mating cycles min; B: 2,500 min; C: 10,000 min.]

27 ISO 8877: Information Processing Systems - Interface Connector and Contact Assignment for ISDN Basic access interface located at reference points S and T - International Organization for Standardization [same pin/pair assignments for 8-line modular connector as EIA T-568A]

28 National Electrical Safety Code Handbook (NESC): Institute of Electrical and Electronic Engineers (IEEE)/American National Standards Institute (ANSI): C2-1993 National Electrical Safety Code ISBN 1-55937-210-9 (order # SH15172)

29 [In USA, governs the area between the property line and the building entrance]

30 National Research Council of Canada, Institute for Research in Construction (NRC-IRC):

31 National Building Code of Canada (1990) - order NRCC 30619

32 Supplement to the National Building Code of Canada (1990) - order NRCC 30629

33 National Fire Code of Canada (1990) - order NRCC 30621

34 A Guide to Premises Distribution - NCR/AT&T order #555-400-021, Apr 1988

35 Building Network Design - Bell Canada, 1992

36 The Corporate Cabling Guide - M. McElroy, Artech House, ISBN 0-89006-663-9, Dec 1992

37 Telecommunications Distribution Methods Manual (1050 pages) - Building Industries Consulting Service International (BICSI), 1994

38 Universal Transport System Design Guide, Release II - Siecor Corp, 1991 [fiber-optic cable plant]

39 Requirements Beyond Jacks and Cable: an Installation Guide - Leviton Telecom, Second edition, T15-00004-003, Jan 1994

40 SiteWire Twisted-pair Installation Guide - Hewlett-Packard, p/n 5959-2208, Jan 1988

41 SiteWire Planning Guide - Hewlett-Packard, p/n 5959-2201, Sept 1989

42 Tech Ref Guide for Workgroup LANs - Hewlett-Packard, p/n 5091-0663E, Apr 1991

43 Tech Ref Guide for Site LANs and MultiSite LANs - Hewlett-Packard, p/n 5091-0666E, Apr 1991

- Understanding Fiber Optics - J. Hecht Howard Sams & Co., ISBN 0-672-27066-8, 1988
- Optical Fiber Communications, I & II - S. Miller Academic Press, ISBN 0-12-497350-7 & -5
- Optical Fiber Splices and Connectors: Theory & Methods - C. M. Miller, Marcel Dekker, 1986
- Principles of Optical Fiber Measurements - D. Marcuse Academic Press, ISBN 0-12-470-980-X, 1981
- Single-Mode Fibers: Fundamentals - E. G. Neumann Springer-Verlag, ISBN 0-387-18745-6, 1988

44 Get a grip on network cabling - Frank J.Derfler, Jr, and Les Freed, Ziff-Davis Press, ISBN 1-56276-057-2, 1993

45 CATV Cable Construction Manual, 3rd edition - Comm/Scope Inc., 1980 [Outside Plant tools and procedures: trenching, boring, installing aerial and buried cable]

46 Marking Guide: Wire and Cable - Underwriters Labs, 1993 [How to interpret UL cable jacket markings]

4.0 Addresses/Additional Sources of information

AMP
Addr: Harrisburg, PA 17105-3608
Tel: 1-800-722-1111
1-800-245-4356 (Faxback service, USA)
(905) 470-4425 Canada
(617) 270-3774 (Faxback service, Canada)

Anixter
(An international cable products distributor also has a Anixter 1995 Cabling Systems Catalog)
Addr: Anixter, Inc; 4711 Golf Road, Skokie, IL 60076
Tel: (708) 677-2600
1-800-323-8167 USA
1-800-361-0250 Canada
32-3-457-3570 Europe
44-81-561-8118 UK
65-756-7011 Singapore

ANSI:
Addr: American National Standards Institute, 11 W. 42nd St, 13th floor, New York, NY 10036
Tel: (212) 642-4900

AT&T Canada:
Addr: Network Cables Div, 1255 route Transcanadienne, Dorval, QC H3P 2V4
Tel: (514) 421-8213
Fax: (514) 421-8224

AT&T documents:
Addr: AT&T Customer Information Center, Order Entry, 2855 N. Franklin Road, Indianapolis, IN 46219 USA
Tel: (800) 432-6600 (USA)
(800) 255-1242 (CDN)
(317) 352-8557 (International)
Fax: (317) 352-8484

Belden Wire & Cable:

Addr: POB 1980, Richmond, IN 47375
Tel: (317) 983-5200

Bell Canada:
Addr: Bell Canada, Building Network Design, Floor 2, 2 Fieldway Road, Etobicoke, Ontario
Canada M8Z 3L2
Tel: (416) 234-4223
Fax: (416) 236-3033

Bell Communications Research (Bellcore):
Addr: Customer Service, 60 New England Ave, Piscataway, NJ 08854
Tel: (800) 521-2673 Fax: (908) 336-2559

Berk-Tek: (copper & f/o cable)
Addr: 312 White Oak Rd, New Holland, PA 17557
Tel: (717) 354-6200, 1-800-BERK-TEK
Fax: (717) 354-7944

BICSI: A telecommunications cabling professional association. Offers education, and administers the RCDD (Registered Communications Distribution Designer) certification.
Addr: Building Industries Consulting Service International, 10500 University Center Drive, Ste 100, Tampa, FL 33612-6415
Tel: (813) 979-1991, 1-800-BICSI-05
Fax: (813) 971-4311

Blackbox
Black Box Catalog: The Source for Connectivity (r)
Addr: Black Box Inc, P.O. Box 12800, Pittsburgh, PA 15241
Tel: 1-800-552-6816 USA
(412) 746-5500 Tech Support USA
(416) 736-8013 Tech Support Canada
Inet: info@blackbox.com

CABA:
Addr: Canadian Automated Buildings Association, M-20, 1200 Montreal Rd, Ottawa, ON K1A 0R6
Tel: (613) 990-7407
Fax: (613) 954-5984

CableTalk: (racks & physical cable management)
Addr: 18 Chelsea Lane, Brampton, ON L6T 3Y4
Tel: (800) 267-7282
(905) 791-9123
Fax: (905) 791-9126

Cabling Business:
Addr: Cabling Business Magazine, 12035 Shiloh Road, Ste 350, Dallas, TX 75228
Tel: (214) 328-1717
Fax: (214) 319-6077

Cabling Installation & Maintenance Magazine:
Addr: Cabling Installation & Maintenance, Editorial Offices, One Technology Park Dr, POB 992, Westford, MA 01886
Tel: (508) 692-0700
Subscriptions: Tel: (918) 832-9349 Fax: (918) 832-9295

CCITT: See ITU

Comm/Scope Inc.
Addr: POB 1729, Hickory, NC 28603
Tel: (800) 982-1708 (USA) (704) 324-2200
Fax: (704) 328-3400

Corning:
Addr: Corning Optical Fiber Information Center
1-800-525-2524
Guidelines - publication/newsletter on fiber technology
Inet: fiber@corning.com

CSA:
Addr: Canadian Standards Association, 178 Rexdale Blvd, Rexdale, Ont, Canada M9W 1R3
Tel: (416) 747-4000, Documents Orders: (416) 747-4044 Fax: (416) 747-2475

EIA:
Addr: EIA Standards Sales Office, 2001 Pennsylvania Ave., N.W., Washington, DC 20006
Tel: (202) 457-4966

GED:
Addr: Global Engineering Documents, 1990 M Street W, Suite 400, Washington, DC 20036
Tel: (800) 854-7179 (CDN/USA)
(202) 429-2860 (International) (714) 261-1455 (International)
Fax: (317) 352-8484

Global Engineering Documents (West Coast),2805 McGaw Ave., Irvine, CA 92714
Tel: 800-854-7179

Graybar: (An international cable products distributor) 1-800-825-5517
Tel: (519) 576-4050 in Ontario
Fax: (519) 576-2402

Hubbell:
Addr: Hubbell Premise Wiring Inc. 14 Lords Hill Rd, Stonington, CT 06378
Tel: (203) 535-8326
Fax: (203) 535-8328

IEC:
Addr: International Electrotechnical Commission, rue de Varembre, Case Postale 131,3, CH-1211, Geneva 20, Switzerland

ISO:
Addr: International Organization for Standardization, 1, rue de Varembre, Case Postale 56, CH-1211, Geneva 20, Switzerland
Tel: +41 22 34 12 40

ITU: (Previously called CCITT)
Addr: International Telephone Union, Place des Nations, CH-1211, Geneva 20, Switzerland

MOD-TAP: (Cable and Equipment Supplier)
Addr: Mod-Tap, 285 Ayer Rd, P.O. Box 706, Harvard, MA 01451

Tel: (508) 772-5630
Fax: (508) 772-2011

NFPA (US National Electrical Code (NEC) and other docs):
Addr: National Fire Protection Association, One Battery March Park, P.O. Box 9146, Quincy, MA 02269-9959
Tel: (800) 344-3555
Fax: (617) 984-7057

NIST:
Addr: U.S. Dept. of Commerce, National Institute of Standards and Technology, Technology Building 225, Gaithersburg, MD 20899

NIUF:
Addr: North American ISDN Users Forum, NIUF Secretariat, National Institute of Standards and Technology, Bldg 223, Room B364, Gaithersburg, MD 20899
Tel: (301) 975-2937
Fax: (301) 926-9675
Internet: sara@isdn.ncsl.nist.gov

Northern Telecom (cable and physical network products):
Addr: Business Networks Div., 105 Boulevard Laurentien, St. Laurent, QC H4N 2M3
Tel: (514) 744-8693, 1-800-262-9334 Fax: (514) 744-8644

NTIS:
Addr: U.S. Dept. of Commerce, National Technical Information Service, 5285 Port Royal Rd, Springfield, VA 22161
Tel: (703) 487-4650
(800) 336-4700 (rush orders)
Fax: (703) 321-8547

NRC of Canada:
Addr: Client Services, Institute for Research in Construction, National Research Council of Canada, Ottawa, ON K1A 0R6
Tel: (613) 993-2463
Fax: (613) 952-7673

Ortronics:
Addr: 595 Greenhaven Rd, Pawcatuck, CT 06379
Tel: (203) 599-1760
Fax: (203) 599-1774

RCDD: See BICSI

Saunders Telecom: (racks, tray and accessories)
Addr: 8520 Wellsford Place, Santa Fe Springs, CA
Tel: (800) 927-3595
Fax: (310) 698-6510

SCC:
Addr: Standards Council of Canada, 1200-45 O/Connor St, Ottawa, Ont Canada K1P 6N7
Tel: (613) 238-3222
Fax: (613) 995-4564

Siecor:
Addr: 489 Siecor Park, POB 489, Hickory, NC 28603-0489

Tel: (704) 327-5000
Fax: (704) 327-5973

Siemon: The Siemon Co (Cabling System Supplier)
Addr: 76 Westbury Park Rd, Watertown, CT 06795
Tel: (203) 274-2523 Fax: (203) 945-4225

TIA:
Addr: Telecommunications Industries Association (TIA), 2500 Wilson Boulevard, Suite 300,Arlington, VA 22201
Tel: (703) 907-7700
Fax: (703) 907-7727

UL: Underwriters Labs (UL) documents:
Addr: Underwriters Labs Inc, 333 Pfingsten Road, Northbrook, Illinois 60062-2096 USA
Tel: (800) 676-9473 (from CDN/USA East coast)
(800) 786-9473 (from CDN/USA West coast)
(708) 272-8800 (International)
Fax: (708) 272-8129
Inet: 0002543343@mcimail.com
MCI Mail: 254-3343

CISCO SYSTEMS

Corporate Headquarters
Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134-1706
USA
Tel: 408 526-4000
800 553-NETS (6387)
Fax: 408 526-4100

Cisco Systems has over 100 sales offices worldwide. Call the company's corporate headquarters (California, USA) at 408 526-4000 to contact your local account representative or, in North America, call 800 553-NETS (6387).

1/96