Structured Cabling

***Structured Cabling*: a system in which the main components of the system, once installed, do not change. In its most basic form, a structured wiring system consists of horizontal wiring and appropriate connecting hardware.**

Introduction

Traditionally, most computer system and network designers have developed their products with the idea in mind that they will operate on a specific type of cable using a specific type of connector. Each manufacturer has its own cable and connector "standard," which is another way of saying, "There are no standards!" Here are some examples:

DEC	3-pair UTP & Modified Modular Connectors
FDDI	62.5 Micron Fiber & MIC Connector
IBM S/3x and AS/400	100 Ohm Twinax & Twinax Connectors
IBM 3270	93 Ohm Coax & BNC Connectors
IBM Token Ring	150 Ohm Shielded Twisted Pair & IBM Data Connector
Hewlett Packard 3000	RS-232 Cable & DB Connectors
Ethernet	50 Ohm Coaxial Cable & BNC or N Connectors
Wang	Dual 75 Ohm Coax & BNC-TNC Connectors

It's easy to see from the list above that migrating from one type of computer system or network to another is very difficult in a traditionally wired cabling system. In most cases, the entire cabling system, and the investment it represents, must be abandoned. A new cabling system must be installed. The new cabling system can cost more than the networking hardware itself.

Another expense related to any traditionally wired cabling system is the cost of making moves, changes or additions after the original installation is completed. The topology, or physical layout of the cabling system, has a lot to do with how easy it is to make changes. For example, the daisy chain or bus topology, which is used for both Thinwire Ethernet and IBM's System/3X and AS/400, does not lend itself well to change because cables either have to be moved, extended, or added whenever a new person is hired or an existing employee is moved. In a large network, this can become a full-time job in and of itself! The most common network topologies are shown on our Network Topologies Page.

The problems described above are common with these "non-structured" wiring systems. The two foremost characteristics of this type of cabling system are:

1. It is difficult or impossible to migrate from one computer system to another without replacing the entire cabling system, and

2. To make moves, changes or additions, the cabling system has to be changed. In this sense, the cabling system has no real structure since it is constantly changing as user requirements change, hence the term "non-structured."

To overcome these problems, many companies are installing structured wiring systems similar to the one shown in **Figure One**, in which the cabling, once installed, rarely needs to be changed. Of the three topologies illustrated on the Network Topologies Page, the star is the most flexible, since all cable runs are brought to one central location. By prewiring all possible locations in a new or existing building in a star topology, all future moves, changes and additions can be made quickly and easily by simply moving patch cables in a centralized wiring closet. Also, by simply changing the attachment cables and devices at the equipment rack and the workstation outlet, a structured cabling system can be adapted to a variety of systems and interfaces.

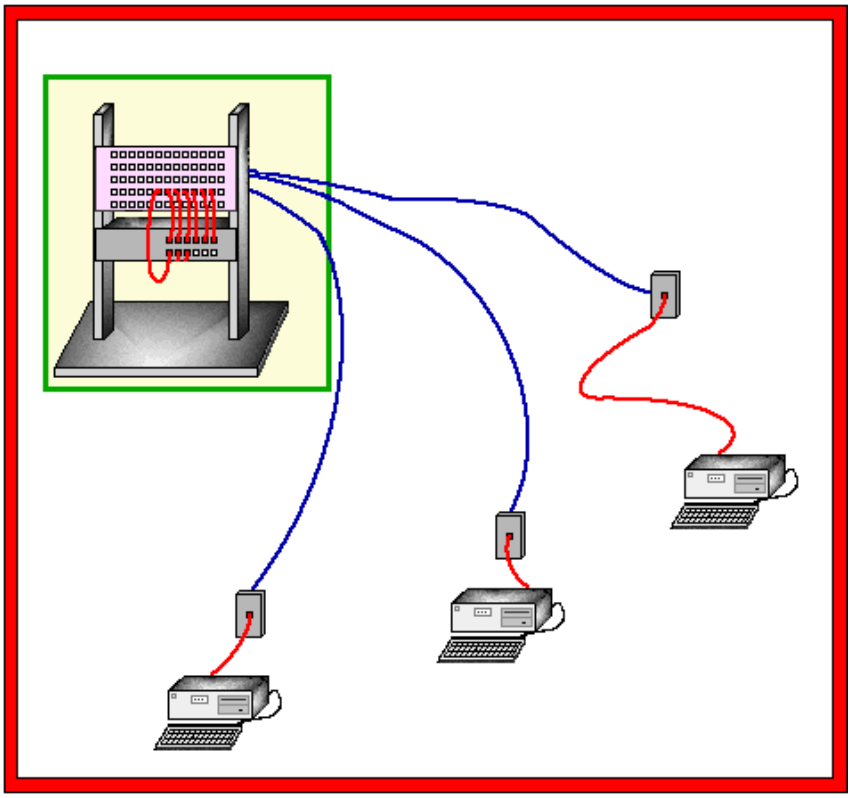

Figure One
Typical Structured Cabling System

Components

As defined earlier, a structured wiring system is one in which the main components of the system, once installed, do not change. In its most basic form, a structured wiring system consists of horizontal wiring and appropriate connecting hardware. Before proceeding farther, let's define some of the terms used in structured cabling.

Category

The EIA/TIA 568 standard specifies certain performance and speed characteristics for structured cabling systems. These specifications follow a "Category" system, where each Category specifies a certain level of performance. The EIA/TIA 568 standard starts with Category 3, and goes to Category 5. Categories 1 and 2 are not oficially recognized, but are generally used in the cabling industry as being useful at frequencies of 1 MHz and 4 MHz, respectively. Category 3 specifies a cable rated for frequencies up to 10 MHz, Category 4 cables are rated at up to 20 MHz, and Category 5 is rated up to 100 MHz.
Nowadays, Category 3 cable is widely regarded as being a "voice grade" cable, and most new data installations use Category 5.

Horizontal Cabling:

This is the wiring that runs from the telecommunications wiring closet to the workstation outlet. For each workstation outlet, there will be one or more cable runs back to the wiring closet, depending on how many jacks are needed at the workstation outlet.

Backbone Cabling:

This is the cabling that provides the interconnection between wiring closets and equipment rooms, whether in the same or different buildings. It includes the backbone cabling itself, as well as cross-connects, mechanical terminations, and patch cables used to provide backbone-to-backbone cross-connection.

Connecting Hardware:

Connecting hardware is used to terminate the horizontal wiring in the wiring closet or at the workstation outlet. Patch panels, used in the wiring closet, and wall plates, used at the desktop, fall into this category. The EIA/TIA 568 standard specifies RJ-45 jacks to be used in these types of products. Patch panels provide multiple RJ-45 jacks, often in multiples of twelve, and are designed to fit into standard racks or cabinets with 19" mounting rails. Wall plates come in a variety of types ranging from single outlet, flush mount styles to multi-outlet, multi-media surface mount versions. Most connecting hardware will also accommodate other types of connectors, such as RJ-11, BNC, and fiber optic, for use in telephone or non-EIA/TIA applications.

Category 5 (or 100 MHz capable) connecting hardware is routinely constructed using a circuit board design with RJ-45 jacks mounted on the front and AT&T 110 type contacts mounted on the rear. The 110 contact uses insulation displacement technology to terminate the horizontal wiring to the RJ-45 jack. Although the AT&T 110 contact is the most popular method of terminating the horizontal wiring to the jack, other types, such as the Krone and 66 contact, are also used by some

manufacturers.

Patch Cables:

Patch cables are used to make the physical connection between the connecting hardware and the network or telecommunications equipment. At the wiring closet, patch cables are used to facilitate fast and easy moves, changes or additions to the network. At the desktop, they make connection to user equipment like network interface cards.

It is debatable as to whether patch cables can be considered a part of the structured wiring system. By definition, they are not because their use changes as the needs of the network users change, but they are so well defined by the ANSI/TIA/EIA-568-A standard that it is an easy intellectual jump to include them in any discussion of structured wiring.

Installation Planning and Practices

It has been said that "a chain is only as strong as its weakest link." Similarly, a structured wiring system is only as fast as its slowest component. When planning and installing your wiring system, pay particular attention to the components you choose. It does no good, for example, to install the highest quality Category 5 cabling and connecting hardware and then use Category 3 patch cables. At best, your structured wiring system will provide you with Category 3 performance. Installing higher performance products may cost a bit more up front, but not so much as replacing components later. Pinching pennies makes short term sense, but the long term flexibility of your wiring system will be limited, and you could spend more upgrading to a Category 5 cabling system than you would have installing it in the first place.

Figure Two (below) illustrates the way in which the various components mentioned above are connected together to create a structured wiring system. Keeping in mind that every connection you make is a point of weakness, plan your installation with as few connections as possible between the wallplate and patch panel. With the right products and careful planning, your structured wiring installation will be a great success.

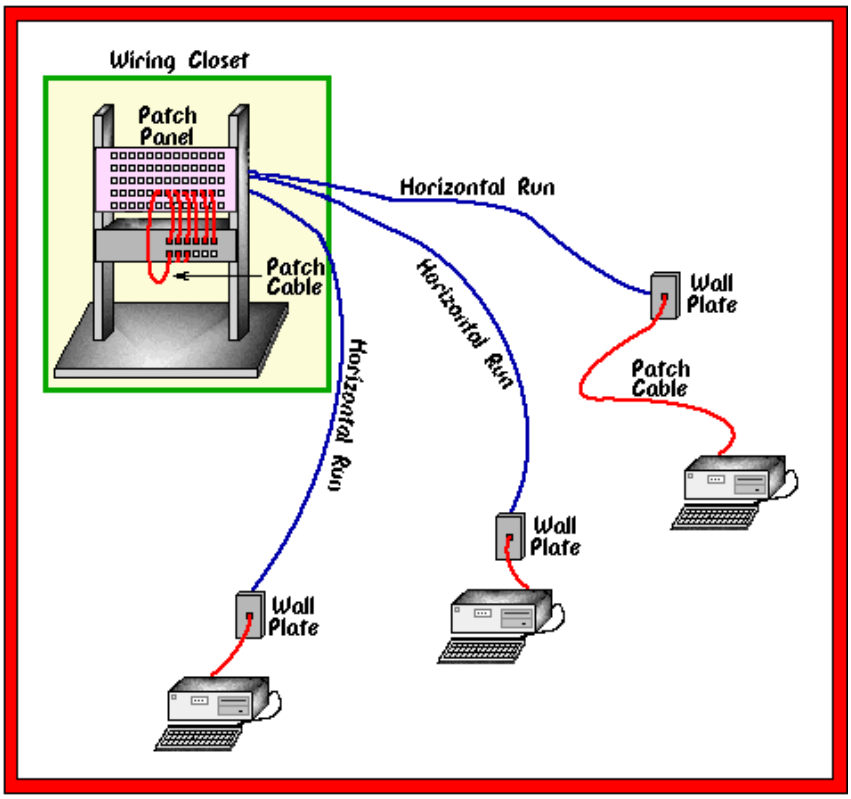

Figure Two
Structured Cabling System

Horizontal Cabling

The cable used for horizontal wiring is constructed of four unshielded twisted pairs under one jacket and comes in two types: PVC and plenum. Both types of cable perform the same electrically; however, local and national building codes require the use of plenum cable when the cable is being run above certain types of dropped ceilings. If you are in doubt as to the type of cable you should install, check with your installer or local electrical inspector before pulling any cable. Pulling the wrong kind of cable can cost you dearly in time and materials.

When planning your installation, it's important to know where each workstation will be located in relation to the wiring closet. You must plan your installation so that the length of each run of horizontal wiring does not exceed 90 meters (295 feet). Keep in mind that we're talking about actual cable length, not the physical distance between the wiring closet and the workstation outlet. If any single horizontal wiring run is greater than the 90 meter limitation, there are products available that will allow you to exceed that distance; however, if you find that a large number of workstations will be located beyond the 90 meter limit, you should plan for more than one wiring closet. The two wiring closets can be connected together with either a copper or fiber backbone cable.

Often, it's not possible for horizontal cable runs behind walls to reach all the way to workstation outlets without crossing open floors. This is particularly true in open office settings using modular furniture clusters. To accomodate such situations, it is permissible for a horizontal cabling run to include one transition point where the round UTP cable connects to flat undercarpet cable. Category 5 undercarpet cable typically consists of four unshielded twisted pairs in a flat PVC jacket. When using it, you should use carpet squares rathen than regular carpet in that area to allow access to the cabling later.

While you're still in the planning stage, consider your requirements for telephones or additional data jacks. It's more cost effective to install all of your cabling at one time rather incrementally. It is also a lot less disruptive if you're doing an installation in a "working" office.

When it comes time to actually install your cabling, here are some guidelines to follow that will help you avoid problems:

1. Many networks that run on UTP cable use only two of the four pairs of wires available in the cable. It can be tempting to try to save a little money by pulling only one four-pair cable and using the first two pairs for data and the second two pairs for telephone or additional data. While this may work in some instances, there exists a strong potential for problems caused by crosstalk between the two types of systems. To avoid problems of this kind, you should never run more than one type of data (ie: Token Ring and 10 Base-T) or data and telephone in the same cable. The rule of thumb is: if the pairs are under the same jacket, use them for only one system or type of data. If you're really trying to save money and want to pull only one cable, you can use a "Siamese" four-pair cable which consists of two two-pair cables in separate jackets physically fused together in a fashion similiar to a lamp cord. Each two-pair cable meets the Category 5 electrical specification. Since each of the two-pair cables is under its own jacket, it is permissible to use one side for data and the other side for telephone or an additional data circuit, without the fear of crosstalk between the systems. The only caveat is that with just two pairs to work with, you will only be able to wire your data jack partially. This will limit you to wiring your system for specific applications, such as Token Ring or 10 Base T, but not both, thus defeating the universal nature of a structured cabling system. In addition, some network standards, such as 100VG-AnyLAN and 100 Base T4, require the use of all four pairs, which would not be available for use.

2. UTP cabling is relatively immune to outside sources of interference that can corrupt data, but it's always good practice when routing your cables through walls and ceilings to keep them as far away as possible from sources of electromagnetic interference (EMI) and radio frequency interference (RFI). Likely sources of EMI/RFI include fluorescent lights, electric panels, and light dimmers. Electric motors, such as those found in air handlers and elevator rooms can also generate high levels of interference. Also, never run your data cables in the same conduit as electrical wiring. Not only is this a dangerous practice, but it's nearly guaranteed to result in high levels of EMI/RFI, and lost data. When using undercarpet cabling, try

to keep the undercarpet cable at least 6" away from any undercarpet electrical power circuits.

3. Pulling a cable with too much force (over 25 pounds) or bending it too sharply can change the electrical characteristics of the cable and degrade its performance, so care must be taken during the installation process to prevent any undo stress on the cable. The cable should move freely at all times and be protected from sharp edges while it is being pulled. When pulling around tight or multiple corners, you should generally pull the cable at the first bend, then the second, and so on until reaching the far end of the run. Do not attempt install cable around multiple tight bends in one pull.

4. You will do yourself a big favor if you take a few extra minutes to mark both ends of each cable run with a wire marker of some kind. Taking a little time now will save you lots of time later when you don't have to hunt for which cable goes where.

Backbone Cabling

As previously discussed, the 90-meter limitation on horizontal cabling runs often necessitates the use of multiple wiring closets to serve users spread out over large facilites. A means for interconnecting wiring closets and equipment rooms, backbone cabling should use a tree topology, with each horizontal cross-connect in a wiring closet cabled back to one main cross-connect in a central equipment room, as illustrated below in **Figure Three**. If needed, there can be one intermediate cross-connect between horizontal cross-connects and the main cross-connect, but under no circumstances should there be more than three levels of cross-connects (main, intermediate and horizontal).

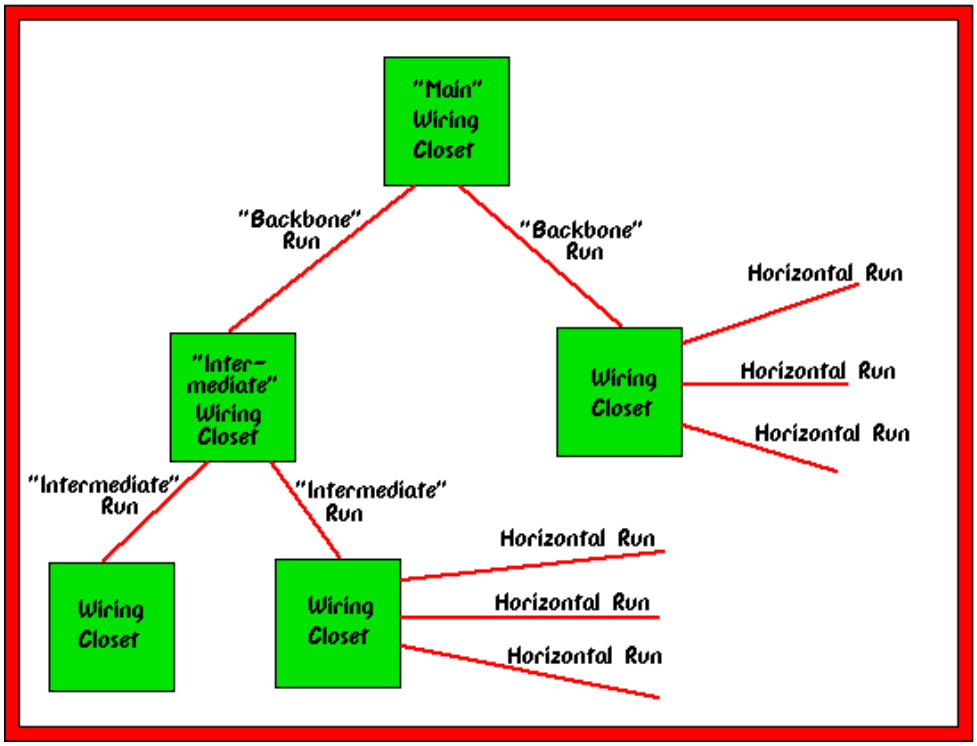

Figure Three
Multiple Wiring Closet Interconnection Heirarchy

Multiple Wiring Closets With Backbone Connection

The backbone cabling media itself can be 100 ohm UTP, 150 ohm STP-A, 62.5/125 micron fiber optic cable, singlemode fiber optic cable, or any combination thereof. The cross-connect devices located in the wiring closets may be patch panels or 110-type connecting blocks. Patch panels are discussed in more detail below.

Connecting Hardware

The connecting hardware you choose will depend on the size of your network, the flexibility you will need and the way in which you want to organize and manage your structured wiring installation. Connecting hardware components generally fall into two categories: They are either fixed or modular in design. Fixed components have a set number of RJ-45 ports and cannot be reconfigured for other applications (ie: telephone). Modular components can be configured and re-configured for a variety of applications and can often be color-coded to help identify multiple systems running over the same structured cabling system.

For small, single-system installations with few moves, additions or changes, fixed type components are usually adequate. If, however, the structured wiring system is intended to support multiple networks plus telephones, a more flexible approach should be considered.

In today's corporate computing environment, it's not uncommon to see Token Ring, 10 Base T and IBM midrange being used under one roof. Having one wiring system that supports all of these, plus being able to color-code patch panel and wall plate jacks by system, is an advantage when moving or adding people, and for troubleshooting, it's invaluable!

Connecting hardware components that use the modular approach lets you create virtually any type of wall plate or patch panel. You don't have to settle for stock configurations anymore.

At the same time you are deciding what type of patch panels to purchase, consider how you are going to mount them. If ease of access is important, open distribution racks are a good choice. If, however, your concern is for security, a locking cabinet may bebe preferable. Cabinets with clear plexiglass front doors allow you to view indicator lights that may be present on network concentrators or other equipment while still maintaining system security. For heat dissipation, cooling fans can be installed in most cabinets.

Smaller installations or ones with limited floor space can benefit from using wall mount distribution racks. These types of racks provide easy access for cabling to the back of the patch panels and take up no floor space.

Before purchasing any connecting hardware, it's vitally important to decide which wiring standard you are going to follow. The wiring standard designates which color wire from the horizontal wiring connects to which pin on the RJ-45 modular jack. The original EIA/TIA wiring standard is known as T568A. An alternative wiring standard, known as T568B, conforms to the old AT&T 258A wiring standard and is the more commonly used standard in the U.S. Availability of products for both standards is good but will be somewhat better for T568B. The proper wiring for each standard is shown below. **Figure Four** and **Table One** illustrate T568A, and **Figure Five** and **Table Two** illustrate T568B. You will note that the only difference between the two is that the position of pairs 2 & 3 (orange and green) on the RJ-45 jack is reversed.

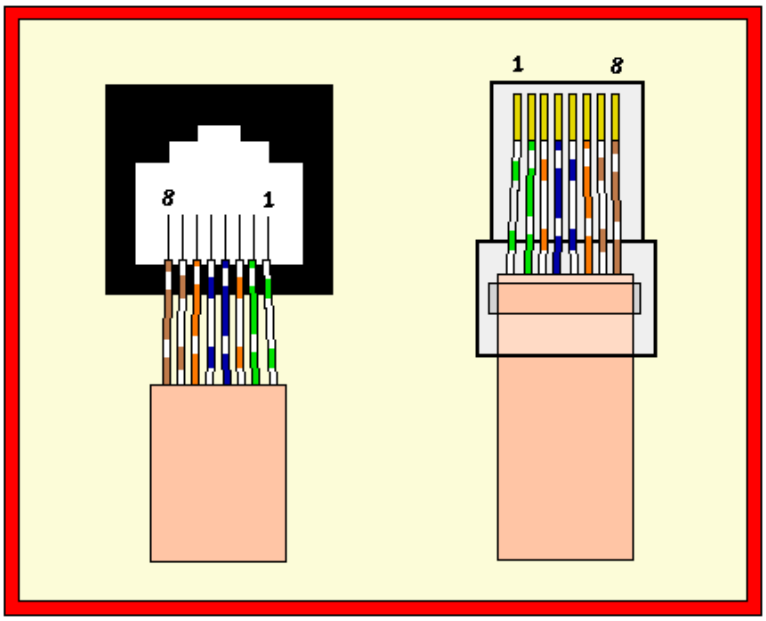

Figure Four
EIA/TIA T568A Wiring Standard

EIA/TIA T568A Standard	
Pin	**Color**
1	White/Green
2	Green/White
3	White/Orange
4	Blue/White
5	White/Blue
6	Orange/White
7	White/Brown
8	Brown/White

Table One
EIA/TIA T568A Color Code

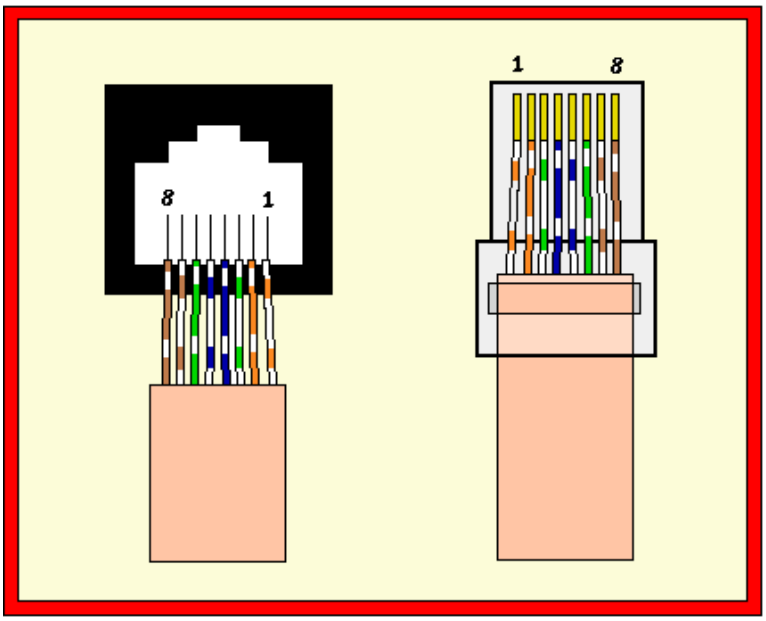

Figure Five
EIA/TIA T568B Wiring Standard

EIA/TIA T568B Standard	
Pin	**Color**
1	White/Orange
2	Orange/White
3	White/Green
4	Blue/White
5	White/Blue
6	Green/White
7	White/Brown
8	Brown/White

Table Two
EIA/TIA T568B Color Code

Care must be taken when terminating the horizontal wiring at the connecting hardware so as to maintain the highest level of performance possible. The first step you can take to accomplish this is to use the proper terminating tool.

As mentioned earlier, the AT&T 110 contact is most commonly used to connect the wires from the horizontal cable to the connecting hardware. These contacts pierce the insulation to make contact with the wire underneath. Never try to use screwdrivers, pliers or cutters to push the wires into the 110 contact. This might work in an emergency but

wonOt result in good, long-term connections. To get consistently reliable terminations, you must use what is called a 110 punch down tool. We recommend using a tool that terminates only one wire at a time. There are tools that will terminate four pairs of wire simultaneously, but the termination quality is questionable, and they tend to put undue strain on connecting hardware that is based on a circuit board design.

The 110 contacts are normally color-coded, making it easy to connect the right color wire to the right spot on the modular jack. The color code on the jack will correspond to either T568A or T568B, depending on the wiring standard you have chosen. To terminate the wire, you simply lay it in the appropriate color coded slot and use the 110 tool to "punch" the wire down. Be sure to trim off any excess wire that is left after you have punched down the wire. Better quality punch-down tools will automatically do this for you. If yours does not, you will have to do it manually.

A typical four-pair cable is shown in **Figures Four and Five** along with the color coding of the pairs. One important point to notice is that each pair is twisted. This twisting is very important to maintaining the electrical and performance specifications of the cable. To ensure peak performance, you MUST maintain the pair twisting to within 1/2" or less of the point of termination on the connecting hardware. Any untwisting of the pairs greater than this length will adversely affect the performance of the cable and can reduce its ability to transmit data at a Category 5 level.

This one point may seem trivial but can cause major problems if not considered. You should use the same wiring standard, either T568A or T568B, throughout your structured wiring system. For example, if you use T568B wall plates, you should also use T568B patch panels and patch cables everywhere. Not doing this can cost you a lot of wasted time trying to troubleshoot non-existent cabling "problems," when in fact the only problem that exists is a wiring standard mismatch between various components of your wiring system.

Physically terminating the wires to the back of the panel is actually a very simple procedure. The 110 contacts on the back of the patch panel are color coded with a blue, orange, green, and brown dot. These colors match the colors of the wire pairs in the UTP cable. To the left of each dot, punch down the white wire of the pair corresponding to the dot's color, and to the right of the dot punch down the solid colored wire. This is shown below in **Figure Six**.

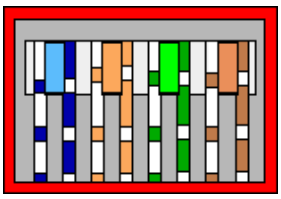

Figure Six
110 Punchdown Pattern

Patch Cables

The quality and performance of the patch cables you use for connecting to your patch panels and wall plates should not be minimized. They are as important as any other component in your structured cabling system.

By their very nature, patch cables are intended to be moved and flexed. For this reason, patch cables should be made from cable with stranded conductors, which offer a much greater flex life and are better suited for this application than solid conductors.

It was mentioned earlier that some patch panels and wall plates can be color-coded to help differentiate between various systems running on the same cabling system. Colored patch cables are available and can be used to color coordinate with color-coded patch panels and wall plates to make identification of various systems extremely fast and easy. For example, you might want to use blue patch cables for Token Ring and red patch cables for 10 Base T.

When planning your installation, you must take into account the length of the patch cables. As stated earlier, the maximum horizontal cable run cannot exceed 90 meters (285 feet). In addition, the EIA/TIA 568 standard allows for a maximum patch cable length of 6 meters (20 feet) in the wiring closet and 3 meters (10 feet) at the workstation outlet. If either of these lengths is exceeded, the main horizontal cable run must be reduced by the excess amount, so as not to exceed an overall length of 100 meters, including both horizontal cabling and patch cables.Another decision you will need to make concerning patch cables is whether to purchase them pre-assembled or to build them yourself. On the surface, building your own may seem like a way to save money, but of all the components in a structured wiring system, patch cables are probably the most difficult and time consuming to assemble.

To assemble your own patch cables you will need three things: the proper cable, the proper connectors and the proper crimp tool.

The cable you choose must meet all of the mechanical, electrical and performance specifications of Category 5 cable. In addition, you should choose the cable type and color based on the above discussion.

Modular plugs are available for both solid and stranded conductors. It is recommended that you use plugs made for solid wire regardless of what type of cable you are using. It has been determined that, long term, this type of connector makes a more reliable contact with the wire.

The crimp tool you use should be a ratchet type tool or some other type that gives a repeatable crimp performance. Inexpensive tools that rely on the user's physical strength to determine the amount of crimp pressure applied to the RJ-45 plug do not give consistent crimping results. With these types of tools, the quality of the crimp will vary from person to person and even from crimp to crimp. Ratchet type tools, on the other

hand, will not release until the minimum acceptable crimp pressure has been applied. The only strength criteria a person needs to meet is that he or she can apply enough force to put the tool through the full crimp cycle.

You must also verify that the tool will crimp the connectors you are using. Even though all connectors are compatible once terminated on the cable, the way the tool terminates them may be different. Problems can arise when you use one manufacturer's tool to crimp another manufacturer's connector. Although this is not always a problem, it is a safer bet to stay with one manufacturer for both the connectors and the tool.

When terminating the connector, you must maintain the pair twisting to within 1/2 inch or less of the terminating point just as you did when connecting your horizontal cable runs to the patch panels and wallplates. Ignoring this rule will degrade your overall system performance.

In contrast to building your own, purchasing pre-assembled patch cables takes one less worry out of your installation process. Most pre-assembled cables are crimped with air or electric presses, so the crimps are extremely consistent, resulting in a highly reliable termination. In addition, most manufacturers of pre-assembled patch cables have implemented quality assurance programs which ensure you top quality and top performance.

Application Testing and Certification

Once you've completed your installation, you should spend some time testing each of your cable runs to ensure that they meet or exceed the electrical performance specifications for the intended application.

The EIA/TIA provides guidelines for field testing of installed UTP channels for Category 5 compliance in TSB 67. For testing purposes, a UTP channel is defined as one entire cable run, including the workstation outlet, a transition point from undercarpet cable to round cable if applicable, the horizontal cable run of up to 90 meters, the horizontal cross-connect consisting of two patch panels or connecting blocks, and up to 10 meters of patch cables.

Hand-held field testers, or "cable scanners" as they are often called, are capable of measuring channel parameters such as attenuation and near-end crosstalk (NEXT). A cable scanner may also include a built-in time domain reflectometer, or TDR, that can determine the total channel length or pinpoint where on the channel a problem, such as a cable short or open, is located. Most testers can also provide a hard copy record of the measurements taken for each channel. When used properly, a cable scanner can be a valuable troubleshooting and diagnostic tool. It can also be used for documentation and acceptance of a cabling system for a specific network application.

If you are considering purchasing such a cable tester, be sure to choose a model that meets the guidelines for testing provided in TIA/EIA TSB 67. And always remember, your best guarantee of ending up with a compliant cabling system is to be certain that all components in the channel are Category 5 compliant and are installed according to ANSI/TIA/EIA-568-A standards.

If you don't want to invest in test equipment of your own, there are independent companies that specialize in testing and certifying structured wiring systems for specific network applications. Also, firms that specialize in the installation of structured wiring systems usually have the equipment and know-how to properly test your cabling system. If you do hire an outside company to perform your testing, be sure to get hard copies of the test results for each channel and save them for future reference. Original test results can be a valuable point of reference when troubleshooting a network problem. With test results in hand, you can show that a particular UTP channel was good on a given date. You can then look at what changes have occurred since then to try to narrow down where a problem might exist.

Documentation

One of the worst things you can do is install an exemplary structured wiring system and then not label and identify where each wall plate and patch panel jack goes. That would almost be like returning a book to the wrong section of the library. It's as good as lost!

Each wall plate jack should be marked with a unique identifier that corresponds to a jack on a patch panel in the wiring closet. Once this is done, it's a simple matter to make moves, changes or additions, since finding various locations throughout the building is as easy as comparing the identifiers on the wall plate and patch panel. Troubleshooting is also made easier when you know where to look. For more information concerning standards for documentation, you should reference ANSI/EIA/TIA-606.

Conclusion

This guide was written with the goal of giving an overview of what a structured wiring system is and what it can do for you. In addition, we talked about various Category 5 structured wiring components and how they all fit together. What we have not done is given a comprehensive overview of the ANSI/EIA/TIA 568 standard or the TSBs. Additional information regarding installations with multiple wiring closets, fiber optics, shielded twisted pair (STP) cable, plus much more can be found in these documents.

Standards And Technology Update

In the time since the Category 5 standard was defined, many companies have introduced cabling products purported to be tested at speeds far exceeding the 100 MHz limit specified for Category 5. The benefits of using this type of cable in lieu of "standard" Category 5 cable may be hard to determine. There is no standard yet written or approved that addresses testing of cabling products at these higher speeds. The only claim that can really be made is that these types of cables exceed the electrical performance specifications of standard Category 5 cable by some variable factor. Does this mean that all the claims made for these "enhanced" Category 5 cables are nothing more than hype? Not necessarily.

Although it's not something we like to think about, the reality is that not all installation jobs are perfect, so, if for no other benefit, these types of cables can provide a "fudge factor" to help overcome any marginal UTP channels. More to the point, however, is the fact that, while 100 Mbps networks are becoming commonplace, networks running at even higher speeds are anticipated. In order to be able to keep pace with changing technologies, installing the best cabling available can be economically prudent when compared to replacing a cabling system in the future.

Appendix

To obtain copies of ANSI/TIA/EIA-568-A or TSB 67, contact Global Engineering Documents at the address and phone number listed below. Global is an authorized distributor of EIA/TIA documents.

Global Engineering Documents
15 Inverness Way East
Englewood, CO 80112-5704
Phone: (800) 854-7179

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