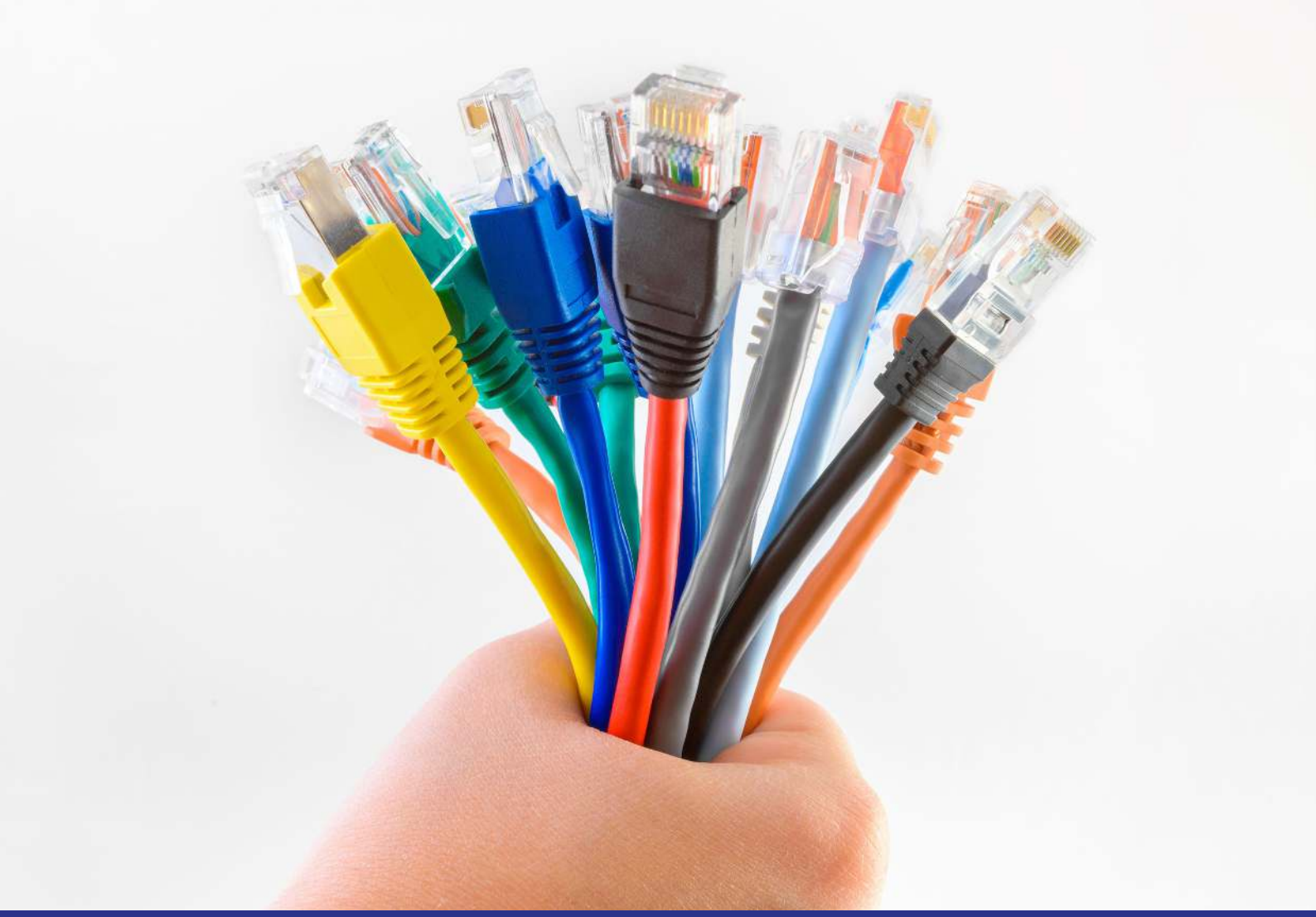
Intelligently Designed Rack and Cable Management



AnD CABLE PRODUCTS

INTELLIGENTLY DESIGNED RACK MANAGEMENT

UNDERSTANDING ETHERNET PATCH CORDS IN MODERN NETWORKS

Louis Chompff - Founder & Managing Director

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Ethernet patch cables have modular characteristics and some important differences that can limit their interchangeability. This whitepaper explores the differences in ethernet cable and connector properties, the relevant Standards and provides a guide to best use cases within data center environments.

These ubiquitous cables have played a central role in the development of generic and structured cabling systems, and today are used for connecting virtually all networking components, without regard to a particular application or industry. In many ways, patch cables are the Ether of the Ethernet.

As Ethernet systems provide increasingly flexible and cost-effective ways of transmitting voice, data, and multimedia over integrated networks, Ethernet patch cords are fast becoming a familiar part of our everyday experience.

We can see them in the work areas of commercial and educational buildings as they trail away from the backs of computers to wall plates and other computers. If we follow their trail, we can see them snake along the paths leading from wall plates to patch panels, and then sprout up again from patch panels to meet nearby hubs or switches.

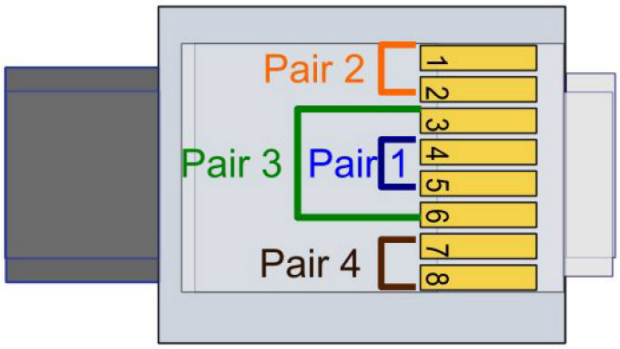
But while the modular characteristics and abundance of patch cables seem to imply that their use is completely universal, they do have some important differences among them that can limit their interchangeability. Some of these differences stem from variations in the wiring configurations of their cable conductors and connector pins, and these are the differences that will be discussed here.

1. Ethernet Patch Cords and RJ-45 Connectors

Ethernet patch cords are flexible leads fitted at each end with an 8P8C ("8 position, 8 conductor") connector plug for joining two corresponding 8P8C jacks together. Because they look like modular connectors originally used in telephone wiring systems, the 8P8C connectors used in Ethernet systems have adopted the common name RJ-45, an FCC designation for a Registered Jack with a similar 8P8C configuration.

In Ethernet networks, these RJ-45 plugs and jacks form a modular, gendered connector system that makes moving work areas and changing network components fast and easy. The male plugs and female jacks are held together by a spring-loaded tab—called a hook—that keeps them securely in place while in use, but allows them to be easily unplugged when changes are made to a network system or work area.

This modularization is accomplished through the eight conducting pins located on the top of RJ-45 plugs (shown in Figure 1), and just inside the tops of RJ-45 jacks. By connecting the ends of the conducting wires in a patch cable to individual pins in its two RJ-45 end-plugs, electronic data can be transferred via an 8-conductor Ethernet cable from one jack to another through its 8 connector pins.



8P8C ("8 Position, 8 Conductor") Connector Plug

Figure 1. In Ethernet Systems, 8P8C plugs and their corresponding jacks are commonly referred to as Rj-45 modular connectors. This RJ-45 plug shows the numbering convention for the pins and pin pairs from above, with the locking facing downward

2. Ethernet Patch Cords and UTP Cabling

The patch cords used in most Ethernet systems are constructed using UTP (Unshielded Twisted-Pair) cable. UTP cable consists of eight insulated copper-core conductors grouped into four pairs, with each pair twisted together along the cable's length.

The conductor pairs and individual conductors in UTP cables are represented by a color code that assigns a primary color—blue, orange, green, or brown—to each of the 4 twisted pairs. The insulation of a conductor within a pair is either a solid primary color, or white striped with that primary color. In this way, all conductors are identified as members of a specific twisted pair, and as individual members within that pair.

The conductor pairs are numbered 1 to 4, with Pair 1 corresponding to the blue pair, Pair 2 to the orange pair, Pair 3 to the green pair, and Pair 4 to the brown pair. The individual conductors in UTP cables can be solid copper-core wires with a well-defined thickness, or bundles of fine copper wire strands.

Unshielded Twisted Pair (UTP) Cable Cross Section

Figure 2.
Pair 1 - Blue, Blue/White
Pair 2 - Orange, Orange/White
Pair 3 - Green, Green/White
Pair 4 - Brown, Brown/White

Even though the solid-conductor cables are less expensive and (much, much) easier to terminate, patch cords are almost always made from stranded cables. This is because the stranding of the conductors increases the cable's flexibility and durability.

The extra flexibility of patch cords allows them to be readily switched among various wall outlets and patch panels, or easily routed through tight spaces between interconnected equipment. Their extra durability allows them to remain flexible and intact with repeated bending back and forth, giving them a longer lifetime.

This is especially important at the connector ends of the cable, where greater stresses are placed on the conductors through frequent handling, bending, and moving around at the cable-connector interface.

3. What's All the Twisting About?

The twisted conductor pairs in UTP cables form a balanced circuit. This is because the voltages of each member in a given pair have the same amplitude (the same voltage magnitude), but their voltages are opposite in phase (one voltage is positive, and the other is negative). The uniform twisting of each of these balanced pairs reduces electromagnetic interference (EMI) and radio frequency interference (RFI) originating from other conducting pairs inside the cable, or from equipment in the cable's environment.

Category 5E Unshielded Twisted Pair (UTP) Cable

Figure 3. Category 5E Unshielded Twisted Pair (UTP) Cable

The conductor pairs inside a twisted-pair cable influence one another through a type of EMI called crosstalk. Crosstalk occurs when the electromagnetic field generated by one pair is large enough (the pair's signal is strong enough) to cross over to the location of a neighboring pair. This 'talking' is a kind of co-mingling of the two fields through a constant exchange of energy between them, with some parts of each signal imparted to the other during each energy exchange. For the smaller signal, the result of all these exchanges will be the canceling out of its finer details (always the good parts), or an increase in the level of noise surrounding it. External sources of EMI and RFI interfere with signals in a similar way, further distorting or degrading them as they travel along cables located near 'noisy' office and communication equipment.

Twisting individual conductors together to form conducting pairs reduces the size of the current-produced electromagnetic fields surrounding them, limiting their influence on signals traveling inside other conductors by limiting the field interactions between the conducting pairs. Since the

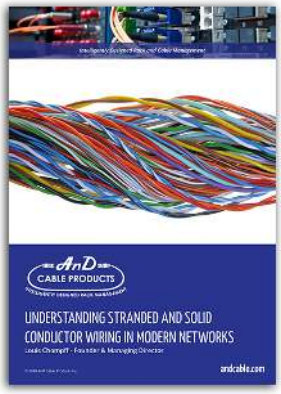
pairs are also balanced—with the two wires in each pair carrying signals of equal and opposite polarity—their twisting ensures equal exposure to interference generated by the fields of other pairs or external sources.

Subtracting the magnitudes of the opposite-polarity signals gives the total magnitude of the transmitted signal as it arrives at the opposite end of the cable, and automatically cancels out the same-magnitude, same-polarity interference signals. In this way, the twisting and balancing of the conductors in UTP cables can effectively remove the noise components within transmitted signals without removing or disturbing the signals themselves.

The greater the number of conductor twists, the better a cable's immunity to EMI and RFI. This immunity gets even better when the number of twists per unit length (the twist rate) is varied among the four pairs. For example, manufacturers of higher-grade cables employ variations in the twist rates of individual conductor pairs, using a different twist rate for each of the four pairs in order to minimize the crosstalk between them. But adding any more variety than this to the twists will bring cable performance down instead of up, since signals traveling along the individual conductors within a pair will no longer be influenced equally by the interfering fields.

This results in interference components for the two signals that are different in magnitude, and an incomplete cancellation of these components when the signal voltages are later subtracted. So each of the pairs has to stick with the same twist rate along its entire length, or any added immunity provided by applying different twist rates to each of the pairs will be lost.

Wrapping each conductor pair with a foil shielding further reduces the crosstalk among pairs, and wrapping all four of the twisted-pairs in a foil or braided metallic shield reduces a cables susceptibility to EMI and RFI in noisy cable environments. STP (Shielded Twisted Pair) cables employ both types of shielding, giving them the highest immunity to all interference types. FTP (Foil Twisted Pair) and ScTP (Screened Twisted Pair) cables employ only the outer foil or braided-conductor shielding, giving them enhanced immunity against external EMI and RFI, but no more protection against crosstalk than an equally-constructed UTP cable.



Further Reading: Understanding Stranded and Solid Conductor Wiring Whitepaper

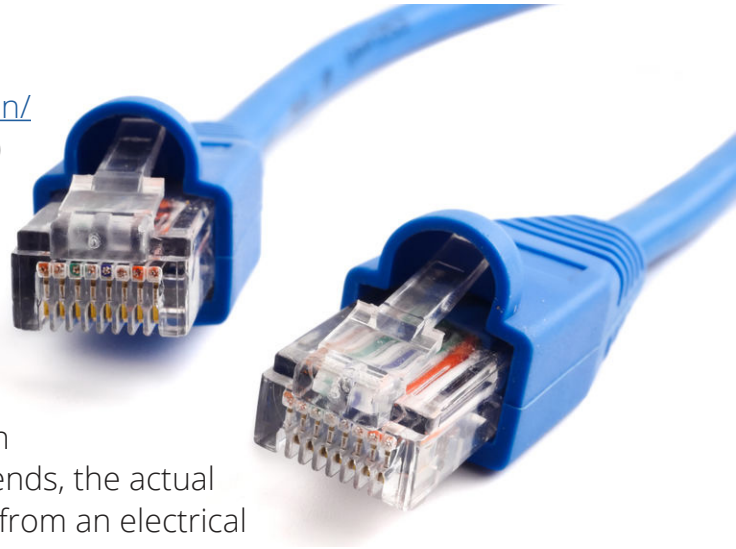
Explores the differences between stranded and solid conductor wiring, their properties and best uses

4. Ethernet Applications

10Base-T and 100Base-T are the IEEE (Institute of Electrical and Electronics Engineers) standards defining the electrical and physical characteristics of twisted-pair cabling for use in 10 Mbps (Megabits per second) and 100 Mbps Ethernet connections. The "T" stands for Twisted pair, and these two Ethernet connections use wire pairs 2 and 3 to transmit and receive information, corresponding to the orange and green twisted pair conductors shown in Figure 2, and pins (1,2) and (3,6) in the RJ-45 connector plugs and jacks shown in Figures 1 and 4.

One of these balanced conductor pairs is used for sending information, and the other is used for receiving information. The two pairs are usually labeled (TX+, TX-) for the transmitting pair, and (RX+, RX-) for the receiving pair. For 10Base-T and 100Base-T connections, the other two cable pairs—corresponding to the blue and brown cable pairs and the four remaining connector pins (4,5) and (7,8) on RJ-45 connectors—are not used. This recently changed with the introduction of Gigabit Ethernet (or 1000Base-T), in which all four conductor pairs are used to transmit and receive information simultaneously

5. 568A and 568B Wiring Standards



568A and 568B are Electronics Industry Association/ Telecommunications Industry Association (EIA/TIA) wiring standards specifying two different RJ-45 pin assignments for the orange and green conductor pairs in Category-type twisted-pair cables. Since these are the same conducting pairs (pairs 2 and 3) used for Ethernet connections, having two different conductor/pin configurations might seem like trouble at first. But for Ethernet patch cords with connectors wired using the same standard on both ends, the actual differences between them is surprisingly small, both from an electrical and a physical wiring viewpoint.

As shown in the RJ-45 connector plugs and jacks below, the differences between the 568A and 568B specifications amounts to a swapping of the green and orange wire pairs. The striped green and solid conductors assigned to pin pair (1,2) in the 568A standard are assigned to pair (3,6) in a plug or jack wired according to the 568B standard, and the striped orange and solid orange conductors assigned to pin pair (3, 6) in 568A are assigned to pair (1,2) in 568B. This is a symmetric swapping of stripe-for-stripe and solid-for-solid within the two conductor pairs, and a symmetric swapping of their corresponding pin positions on the RJ-45 connector plug or jack.

This means that the positive and negative voltage signals (corresponding to solid and striped wires) still alternate in both wiring schemes. Also, since pairs 2 and 3 in a UTP cable are adjacent to one another, this swapping shouldn't significantly change the distances between them or their electrical interactions (see Figure 2).

RJ-45 Connector Plug, EIA/TIA 568A Standard

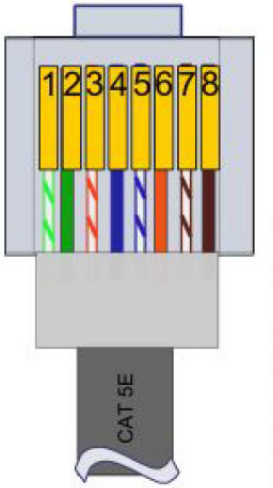
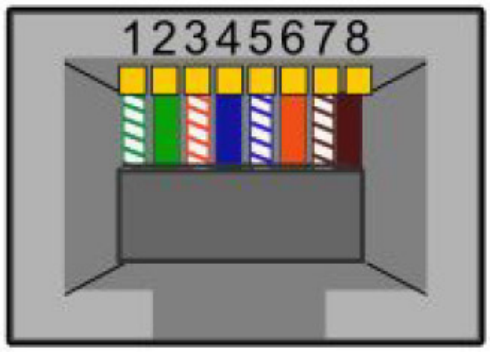


Figure 4a.
Pin 1 - Green/White
Pin 2 - Green
Pin 3 - Orange/White
Pin 4 - Blue
Pin 5 - Blue/White
Pin 6 - Orange
Pin 7 - Brown/White
Pin 8 - Brown



RJ-45 Connector Jack, EIA/TIA 568A Standard

RJ-45 Connector Jack, EIA/TIA 568B Standard

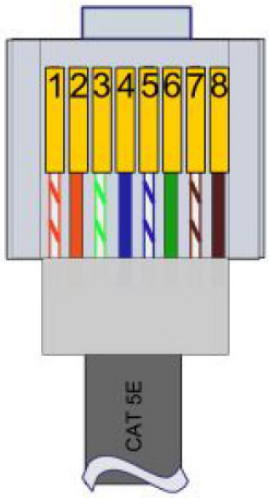
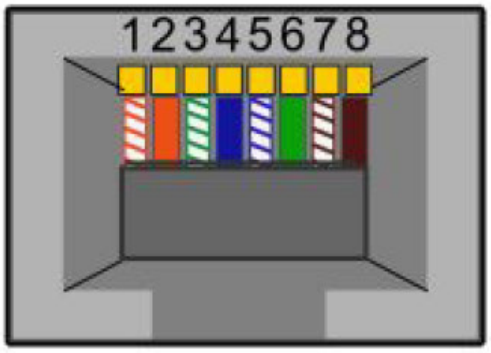


Figure 4b.
Pin 1 - Orange/White
Pin 2 - Orange
Pin 3 - Green/White
Pin 4 - Blue
Pin 5 - Blue/White
Pin 6 - Green
Pin 7 - Brown/White
Pin 8 - Brown



RJ-45 Connector Plug, EIA/TIA 568B Standard

The end result is that the transmitting and receiving paths in the cable are switched from one pair of wires to another pair of adjacent wires, and that these paths are equal in every respect but the color of the insulation surrounding the conductors (which the electrons can't see anyway).

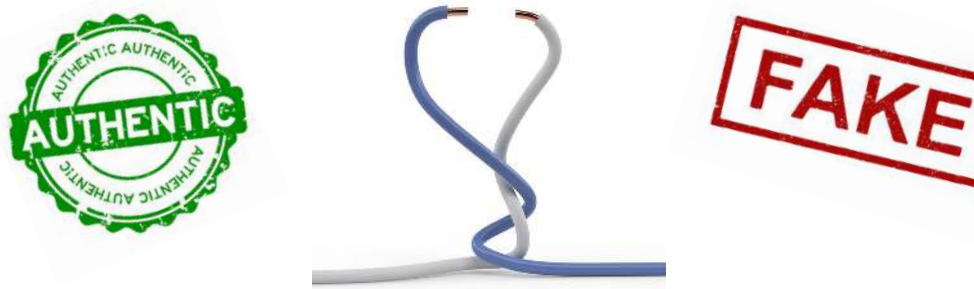
The only thing that is important for Ethernet patch cables with regard to these two standards is that both ends of the patch cord be wired according to the same standard. If they aren't, the cable is a crossover cable, and will not function correctly with most devices (crossover cables are discussed in more detail in the next section). To determine the wiring standard used for the connector ends of a patch cable, hold the cable with the gold contact pins of the connector plug up, and the locking tab down as in the two figures above. The wire colors will then be visible, and the pins will be numbered 1-8 from left to right.

5.1 Beware of Copper Clad Aluminum (CCA) Cables

When purchasing CAT5e or CAT6 network cables, make sure you are comparing apples to apples. A common tactic of "low cost leaders" is to use aluminum instead of copper wire. This can lead to network issues from using inferior materials to transmit the signal. The problem is further heightened because there are no visual differences between a CCA cable and a pure copper cable.

Looking to cut costs, manufacturers started using aluminum wire dipped in a thin coating of copper. This technique created an aluminum core cable surrounded by a thin layer of copper. If you have ever purchased coax cable, you may have purchased cable that is copper clad. If you scrape the center conductor, the gold copper will flake off and expose the silver metal core.

The performance and safety of CCA cables however are radically different. In fact, aluminum network cables violate TIA and IEC standards for CAT5e and CAT6 cables - and for good reason!



CCA Performance Risks

Aluminum patch cables, often marked as CCA or CCE (for Copper Clad Ethernet), have higher attenuation than pure copper cables. This results in a greater loss of data, as packets have to be re-transmitted. The more data that is re-transmitted, the slower your network performs. These problems are compounded by every foot of cable you use; the longer the cable, the worse the performance.

When heat is applied to a CCA cable, the cable becomes brittle and breaks. A pure copper patch cable responds totally differently. It will retain its shape under heat - in fact, the jacket is more likely to catch on fire before the conductors are damaged.

CCA cables have a 55% higher DC resistance. This increases the amount of energy that is transferred into heat and reduces the amount of power that can be transferred. This issue makes them unusable for power over Ethernet (PoE). These cut corners also affect installers because aluminum wire creates installation issues.

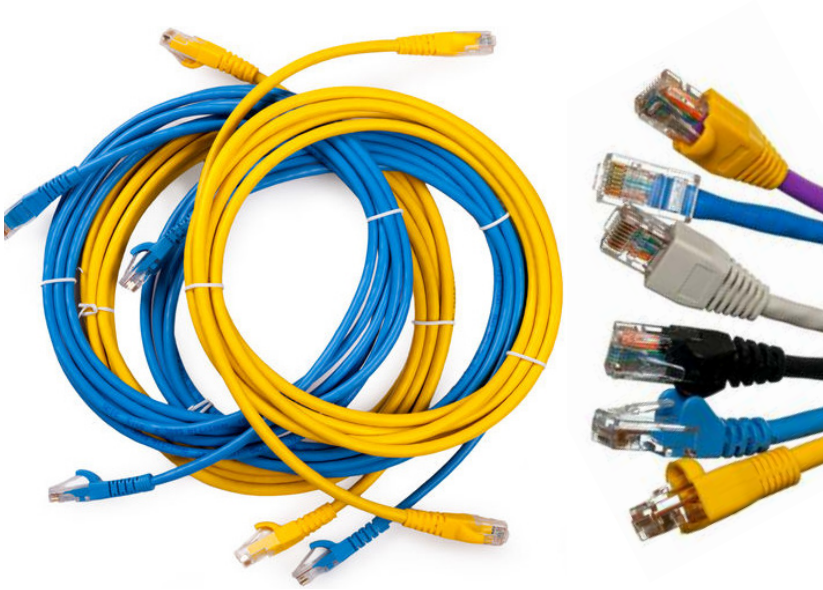
Due to the lower tensile strength, aluminum cables can be damaged when being pulled. Single conductors can break, making the cable useless, or the whole cable can snap. Aluminum also has a lower bend radius than pure copper cables. This means you can't bend it as much before it fails. In short, copper clad cables are more fragile than pure copper cables.

6. Which One to Use?

Since there are no differences in the electrical properties of Ethernet patch cords wired according to either one of the 568 specifications, both can be used with impunity in any structured Ethernet cabling system that is wired under one of these two standards. Looking forward, we see that both are equally appropriate for high-speed data transmission. Looking backward, we see the reason for the existence of both configurations lies in the old AT&T 258A wiring standard, which is identical to the 568B standard described here.

The purpose of the EIA/TIA and other standards organizations has been to develop a common set of rules for everyone in the various industries using this technology to follow. The EIA/TIA-568-B standard, in which these two wiring configurations are defined, specifies a commercial premises cabling system that is not proprietary and not exclusive to a particular vendor or industry. In this way, the standards committee formed by the two organizations set out to reduce some of the confusion in their industry, but some of it was put back in with respect to these two wiring standards.

Although the standards documentation specifies T568A as the main standard pin/pair assignment (T568B is specified as an alternate standard for use only when necessary to maintain backward compatibility), 568B still remains the predominant wiring standard for cabling systems and patch cords in the United States. In contrast, both types are used equally throughout the rest of the world, and the International standards do not define a preferred specification or a technical advantage in using one over the other.

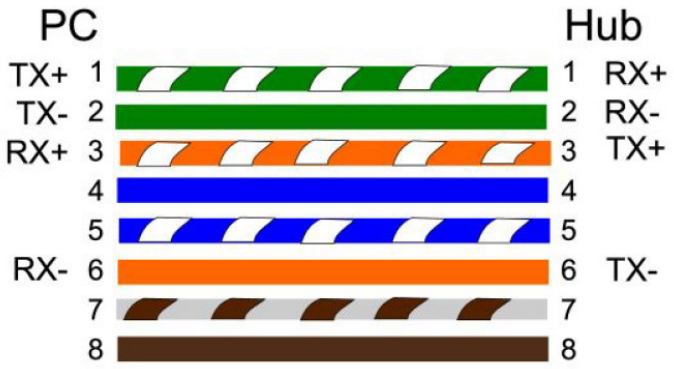


So the older AT&T standard has proven to be very long-lived, and tradition seems to be the primary reason for the predominance of the 568B standard for cabling systems and patch cables in the United States.

7. Straight-Through and Crossover Cables

Along with the 568A & B wiring standards, there are two types of patch cord cables commonly used in Ethernet systems. These are called straight-through cables and crossover cables, and the differences between them are related to the network interfaces of the various components they connect.

A common connection for which a straight-through patch cable is used is the one between a PC and a Hub. In the diagram shown in Figure 5, the (TX+, TX-), (RX+, RX-) transmitter and receiver pairs are shown at their pin locations for the PC (left) and Hub (right) interfaces. In order for the transmitting voltages (TX+, TX-) sent by the PC to be received by (RX+, RX-) on the Hub, the patch cable needs to be wired straight through from one connector end to the next—just as its name implies—with no crossing of the conductors at either end. The same is true for transmitting from the Hub to the PC, with the transmitting pairs on the Hub interface again corresponding to the receiving pairs on the PC interface.

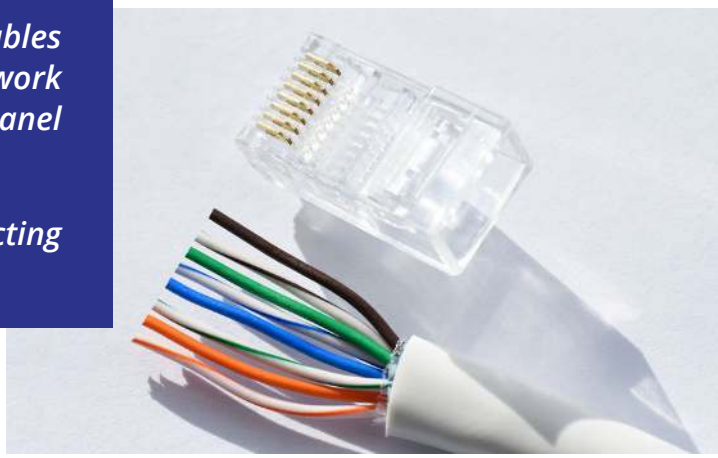


Straight-Through Cable (568A)

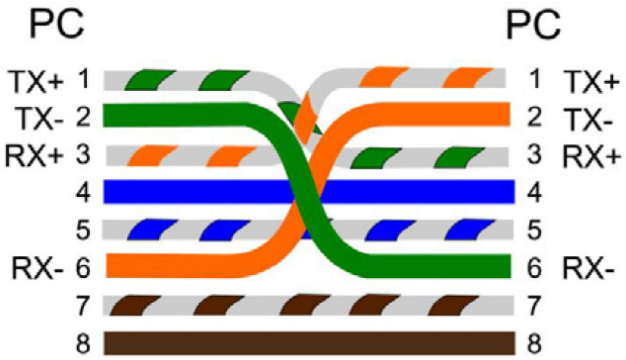
Figure 5. Straight-Through Cable - 568A Standard

STRAIGHT-THROUGH CABLES *are the standard patch cables commonly used to connect computers and other network components to wall panel jacks, and to connect wall panel jacks in turn to "keystone" jacks on patch panels.*

CROSSOVER CABLES *are generally used for connecting computers in a network to one another.*



For an example of a crossover patch cable, the diagram in Figure 6 shows how a patch cord needs to be wired at both ends in order to connect two PCs. The pin configurations in the two PC interfaces are this time mirror images of each other, with the first two pins (TX+, TX-) used for transmitting data, and their third and sixth pins (RX+, RX-) used to receive data. If a patch cord were wired straight through as in the diagram above, the transmitting pairs for each PC would perpetually "talk" at each other, and the receiver pairs would perpetually listen for the chatter of the other, but no information would ever be exchanged between the two PCs. The wires in a crossover cable, then, also do just what their name implies. The pin positions of individual wires in the transmitting and receiving conductor pairs are swapped inside the cable's end connector, so that they will be in the appropriate positions when they get to the other PC interface.



Crossover Cable (568A to 568B)

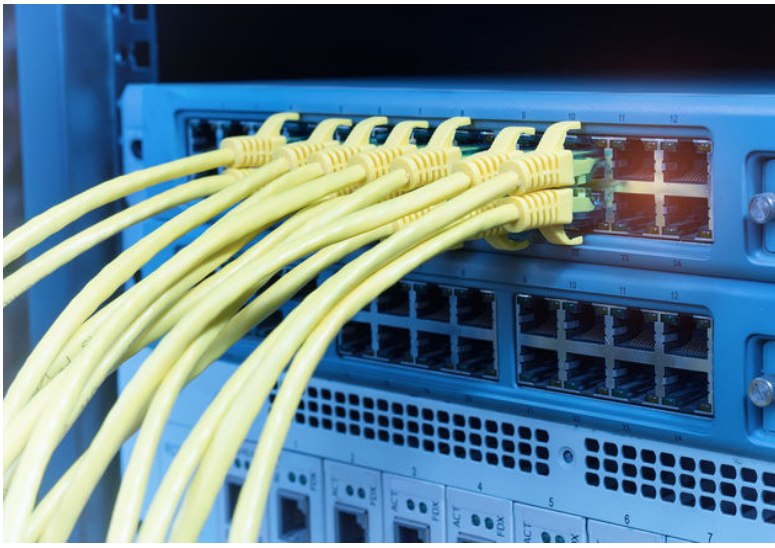
Figure 6. Crossover Cable - 568A to 568B Standard

7.1 Data Communications Equipment (DCE) and Data Terminal Equipment (DTE)

A kind of general rule of thumb says that straight-through cables patch between different types of Ethernet equipment—like the connections running from a computer's network interface card to a hub or a switch—and crossover cables patch between similar types of equipment having similar interfaces, like two PCs in a network.

This is because the two wiring schemes were originally used to connect two broad classes of nodes in data communications networks. The first class was comprised of components that only communicated by forwarding data (Data Communications Equipment, or DCEs), and the second of components could generate new data by reading and manipulating the data they received (Data Terminal Equipment, or DTEs). A network with a star topology, for example, would be constructed by connecting a single DCE device (a hub) to a ton of DTEs (the networked computers and peripherals).

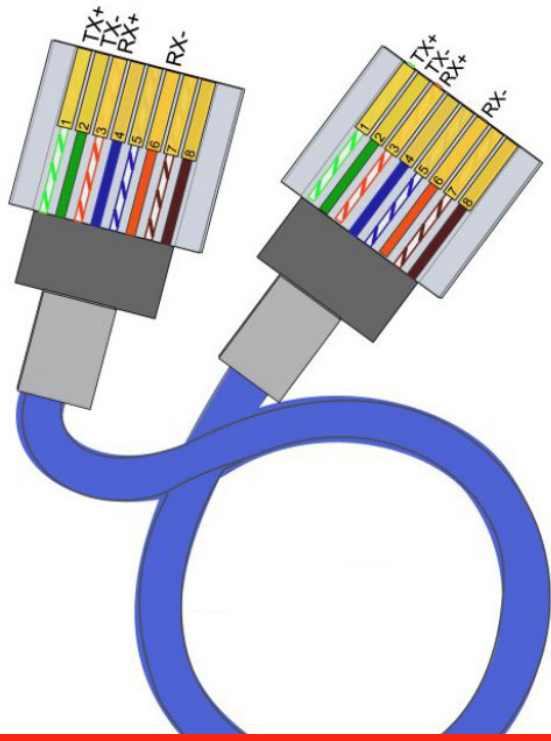
T568A is the pin-out configuration used by DCE devices, and T568B is the configuration used by DTE devices. In general, DTEs will only communicate directly with DCE components, and vice-versa, so that crossover cables are needed to connect two like components together. Seen in this way, the swapping of the transmitting and receiving pairs in a crossover patch cable provides a convenient disguise to make DTEs look like DCEs for the purpose of connecting them to other DTEs, or to make DCEs look like DTEs in order to connect them to other DCEs.



The reason for the preponderance of straight-through cables is that most hubs and wall jacks are wired to perform the crossover internally. In fact, some of the newer hubs are able to differentiate between crossover and straight-through patch cables, and then make changes to their own internal wiring to match the type connected to them. But for the most part, you're on your own in this area, so knowing how to tell the difference between the two types of patch cables can be very useful, in the same way it proves useful for these smart new hubs.

The easiest way to tell what kind of patch cord you have is to look at both of its ends together:

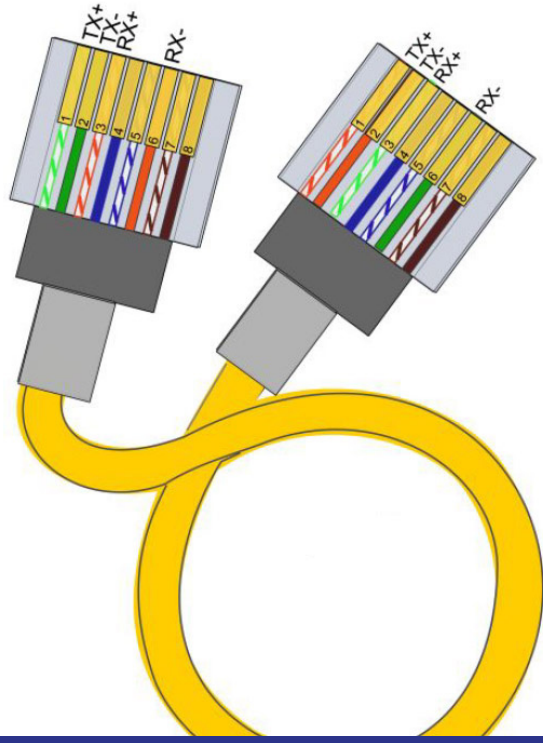
If the cable conductors are configured according to the T568A standard for both connector ends, then the cable is a straight-through patch cord (Figure 7). Similarly, if both cable ends are wired according to the T568B specification, it is also a straight-through patch cord.



Straight-Through Cable
T568A OR T568B Connectors

Figure 7. Straight-Through Cable

If you have a cable that is wired according to the T568A standard at one end, and the T568B at the other end, the cable is a crossover cable (Figure 8). Crossover cables sometimes have orange or yellow sheaths to make them easier to identify.



Crossover Cable
T568A AND T568B Connectors

Figure 8. Crossover Cable

8. Glossary

8P8C CONNECTOR PLUG A Connector Plug with 8 position and 8 conductor components

BRAIDED METALLIC SHIELDING A high-grade cable manufacturing process where some wire conductor pairs in a stranded cable are wrapped in a braided metallic material to reduce Crosstalk.

CONDUCTOR PAIR A specific twisted pair, usually one with a solid primary color and the other with a primary color with a white stripe.

CROSSOVER CABLES Generally used for connecting computers in a network to one another.

CROSSTALK When the electromagnetic field generated by one pair is large or strong enough to cross over to the location of a neighboring pair, causing noise.

DCE "Data Communications Equipment". Components only communicate by forwarding data.

DTE "Data Terminal Equipment". Components generate new data by reading and manipulating the data they receive.

EMI "Electromagnetic Interference". Interference originating from other conducting pairs inside the cable, or nearby equipment.

FEMALE JACKS Half of a gendered connector system. When connected with its matching Male Plug, data can be transferred via an 8-conductor Ethernet cable from one jack to another through its 8 connector pins.

FOIL SHIELDING A high-grade cable manufacturing process where some wire conductor pairs in a stranded cable are wrapped in foil to reduce Crosstalk.

FTP "Foil Twisted Pair" cable. FTP has the same 4-pair (8-conductor) configuration as UTP cable, but employs a single piece of metal film shielding surrounding the entire 4 pairs. This extra shielding combines with the twisting of the wire pairs protects against EMI and RFI, but is ineffective against Crosstalk.

MALE PLUGS Half of a gendered connector system. When connected with its matching Female Jack, data can be transferred via an 8-conductor Ethernet cable from one jack to another through its 8 connector pins.

MBPS Megabits per second.

RFI "Radio Frequency Interference". Interference originating from other conducting pairs inside the cable, or nearby equipment.

RJ-45 CONNECTOR PLUG A Federal Communications Commission (FCC) designation for a Registered Jack with a configuration similar to the 8P8C Connector Plug.

ScTP "Screened Twisted-Pair" cable. ScTP has the same 4-pair (8-conductor) configuration as UTP cable, but employs a single piece of metal film or braid shielding surrounding the entire 4 pairs. This extra shielding combines with the twisting of the wire pairs protects against EMI and RFI, but is ineffective against Crosstalk.

SOLID-CONDUCTOR WIRING A single, solid conducting wire, usually of bare copper wires with diameters between 22 and 24 AWG (American Wire Gauge) units.

STAR TOPOLOGY A topology allowing only one device at each end of a wire, requiring repeaters for more than two devices.

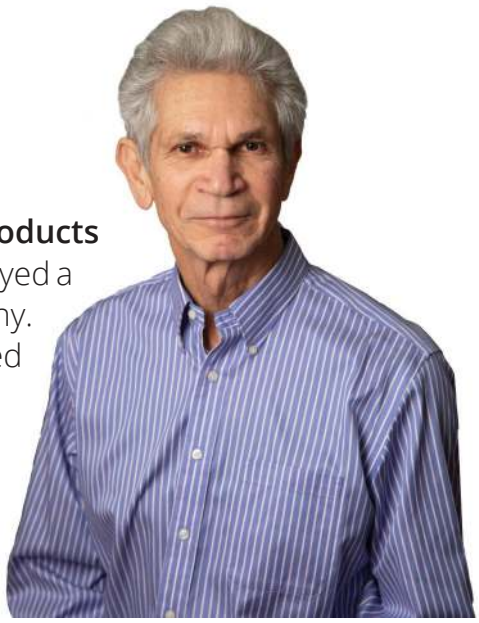
STP "Shielded Twisted Pair" cable. Where both Foil and Braided Metallic shielding has been applied - highest immunity to all interference types.

STRAIGHT-THROUGH CABLES Standard patch cables commonly used to connect computers and other network components to wall panel jacks, and to connect wall panel jacks in turn to "keystone" jacks on patch panels.

STRANDED CABLES Each individual conductor is made up of a bundle of smaller-gauge wire strands inside the twisted pairs.

TOPOLOGY The physical format of a network.

UTP "Unshielded Twisted Pair" cable. The most common LAN networking cable in the US, UTP cables do not employ any additional electrical shielding, relying instead on the electrical balance provided by their twisted-pair wiring scheme for the prevention of cross-talk between conductor pairs, and for the cancellation of EMI and RFI from outside sources.



About the Author

Louis Chompff - Founder & Managing Director, AnD Cable Products
Louis established AnD Cable Products in 1989. Prior to this he enjoyed a 20+ year career with a leading global telecommunications company. He worked in a variety of data management positions that ranged from service, product development and sales to management.

Louis is of Dutch ancestry and was born in Indonesia, where he lived until his family moved to Holland when he was 12. At age 18, he came to the USA and joined the U.S. Marine Corps in 1967, eventually being honorably discharged as a sergeant (E-5).

Louis is an enthusiastic inventor and has designed, patented and brought to market a variety of industry-leading rack and cable management products, which form the basis of AnD Cable Products range.

About AnD Cable Products

AnD Cable Products manufactures and supplies Cable Management and Cable Organizer products and systems to data centers across the United States and internationally. We manufacture a select range of industry-leading products that optimize the data center physical layer and supply only those cable management products that meet our strict quality, efficiency and cost saving standards.

Our proprietary Cable Managers and Cable Labels are intelligently designed to increase efficiency, are re-usable and easy to use, and are durably constructed to reliably withstand hard use in commercial settings – contributing to significant reductions in equipment costs. All our self-manufactured products are backed unconditionally by our Unlimited Lifetime Warranty and we live our core value of being committed to exceptional customer service.

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