Category 5 Cable 101

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Anybody who wants to know about CAT-5 wiring should probably know about all of the Category cable specs and some of the history of twisted pair wiring and ethernet cabling schemes in general. This document doesn't get into much of that. This document also doesn't pretend to be the ultimate authority on CAT-5 wiring. The author has no credentials anyway. Hopefully, it's enough good information to get a DIYer at home hooked up.

Category Wiring: The EIA/TIA grading system which describes UTP cabling or connecting hardware with associated transmission characteristics. The TIA/EIA uses "category" definitions to describe cables, connectors and links.

Category	Maximum Data Rate	Usual Application
CAT 1	Less than 1 Mbps	"Inside Wire" - Analog voice (POTS), Integrated Services Digital Network Basic Rate Interface in ISDN, Doorbell wiring
CAT 2	4 Mbps	Mainly used in the IBM Cabling System for token ring networks (based on IBM type 3 cable)
CAT 3	16 Mbps	Voice and data on 10BASE-T Ethernet
CAT 4	20 Mbps	Used in 16 Mbps Token Ring
CAT 5	100 Mbps 1000 Mbps (4 pair)	100 Mbps TPDDI, 10Base-T, 100BASE-T or Fast Ethernet, 155 Mbps ATM, Gigabit Ethernet (Now obsolete and replaced by CAT 5E)
CAT 5e	100 Mbps	"Enhanced CAT 5" -- 10 Base-T, 100 Mbps TPDDI (100BASE-T or Fast Ethernet), 155 Mbps ATM. Category 5e exceeds Cat 5, and has improved specifications for NEXT, PSELFEXT, and Attenuation.
CAT 6	200-250 MHz	Super-fast Broadband Applications (10 Gbps ?). More. Category 6 is a proposed standard that aims to support transmission at frequencies up to 250 MHz over 100 ohm twisted pair. The lack of an adequate connector spec is hurting the adoption of CAT-6.
CAT 7	600 MHz	Nobody knows what this is yet. Category 7 is a proposed standard that aims to support transmission at frequencies up to 600 MHz over 100 ohm SSTP and will require better connector characteristics than an "RJ-45" connector can muster.

Sometimes you may see Category 5e / Class D or Category 6 / Class E listed. For ISO/IEC and CENELEC standards, the term “category” is used to describe component performance (i.e., cable and connecting hardware). The term “class” is used to describe cabling (i.e., link and channel performance).

Dateline:

1844 - May 24th - Telegraph invented by Samuel Morse.
1845 - English patent for telegraph by William Cooke and Charles Wheatstone.
1846 - Royal House invented a printing telegraph-required two operators at each end.
1851 - Western Union Company was formed by the merger of 12 telegraph companies
1855 - David Edward Hughes - Received patent for type printing telegraph.
1861 - Phillip Reis invents device for transmitting musical tones called a 'Telephone'.
1874 - Jean-Maurice-Emile Baudot patented the Baudot telegraph code.
1876 - February 14th - Alexander Graham Bell filed a patent for the Telephone.
1876 - February 14th - A few hours after Bell, Elisha Gray filed a patent for the Telephone.
1878 - David Edware Hughes invented carbon microphone.
1889 - Almon Brown Strowger invented the 'Dial Telephone' and 'Strowger Switch'.
1948 - Bell Labs invented the transistor.
1966 - ASCII code was created.
1969 - RS232 serial standard was established.
1976 - Paper on Ethernet published by Robert Metcalfe and David Boggs at PARC.
1979 - DEC and Intel team with with Xerox (DIX) to develop Ethernet.
1980 - DEC, Intel and Xerox publish the 'Ethernet Blue Book' or DIX standard.
1983 - IEEE 802.3 Ethernet standard (10Base5).
1984 - IBM introduces 4Mbps Token Ring.
1985 - IEEE 802.3a Thin Ethernet standard, 10Base2.
1985 - IEEE 802.3b Ethernet standard 10Broad36, 10Mbps using broad band.
1987 - IEEE 802.3d Fibre Optic Inter-Repeater Link (FOIRL)
1987 - IEEE 802.3e 1Mbps Ethernet over twisted pair.
1990 - IEEE 802.3i Ethernet standard, 10BaseT.
1991 - July - EIA/TIA 568 standard for telecommunications wiring in commercial buildings.
1991 - August - EIA/TIA TSB 36 for higher grade cables (Cat 4 and Cat 5).
1992 - August - EIA/TIA TSB 40 for higher grade connecting hardware.
1993 - IEEE 802.3j Ethernet standard 10BaseFL, Ethernet fibre links up to 2km.
1994 - January - EIA/TIA TSB 40A - included patch cords and testing in more detail.
1994 - January - EIA/TIA 568 revised to EIA/TIA 568A
- includes TSB 36, TSB 40A & other amendments.
1995 - IEEE 802.3u Fast Ethernet standards 100BaseTX (2 pair Cat 5)
1995 - IEEE 802.3u Fast Ethernet standards 100BaseT4 (4 pair Cat 3)
1995 - IEEE 802.3u Fast Ethernet standards 100BaseFX
1997 - IEEE 802.3x Full duplex Ethernet standard.
1997 - IEEE 802.3y 100BaseT2 Fast Ethernet standard (2 pair Cat 3)
1998 - IEEE 802.3z 1 Gbps 1000Base-X standards)
1998 - IEEE 802.3ac VLANs
1999 - IEEE 802.3ab 1000Base-T (1 Gbps over 4 pair Cat-5)
1999 - EIA/TIA 570-A Residential Telecommunications Cabling Standard
2000 - Formation of IEEE 802.3ae working group for 10 Gbps Ethernet
2001 - May - New 568B Standard - ANSI/TIA/EIA-568-B.1, 2 & 3
2002 - June - TIA ratifies Category 6 (Article)
2002 - August - TIA publishes Category 6 Standards and Systems Overview

Ethernet quickly:

Ethernet is now the most commonly used local area network (LAN) technology. The first version of Ethernet supported a data transmission rate of 10 Mb/s over coaxial cable. Newer versions of Ethernet called "Fast Ethernet" and "Gigabit Ethernet" support data rates of 100 Mbps and 1 Gbps (1000 Mbps) on UTP. Ethernet specifications exist for coaxial cable, specified grades of twisted pair wiring, and fiber optic cable. All wiring for Ethernet is, logically, a bus topology; however, star configurations, given specific equipment, are common. Ethernet devices compete for access to the network using a protocol called Carrier Sense Multiple Access with Collision Detection (CSMA/CD). Newer Ethernet devices can create a transmission environment in which the likelihood of collisions are unlikely. We're assuming, of course, that your CAT-5 wiring is being used for the typical home network Ethernet specification. To understand the logic behind the Ethernet paradigm, some knowledge of cabling methods dating from the 1980's isn't a bad idea. The cost of electronic devices is still plummeting however, and at some point, it is to be expected that any resemblance to this model will disappear as might Ethernet itself. Meanwhile, I suggest you not hold your breath while waiting for this event.

Category 5 Cable

A word on half-duplex and full-duplex operation...

OK, this isn't strictly about cabling, but something must be said about it somewhere.

The original Ethernet specifications called for use of coaxial cable and Ethernet was designed to use CSMA/CD because the media is shared. For coax media, many devices are attached to the transmission media but only one device can talk at a time. When a workstation talks on the wire, all other devices must listen. If two devices attempt to talk on a coaxial cable at the same time, a collision occurs and the net effect (sorry) is that no data is transferred. In a 10 Mbps network based on coax cable, the total bandwidth available is dedicated to transmitting by one device and listening by every other device. CSMA/CD is a set of rules that allows data to be transferred in an environment where collisions can occur. This can be called half-duplex operation. Any given device at any given time can transmit or receive, but cannot do both.

In the twisted-pair world, hubs or switches are employed and all workstations are attached to the network distribution device by a dedicated cable. One pair of conductors in this cable can transmit while another pair can receive as long as the network device is smart enough to isolate traffic for each port in the device.

Half-duplex mode is a legacy from strict bus topology standards required by 10Base5 and 10Base2. 100BaseX employs hubs with dedicated point-to-point links. Because each link is not shared, full-duplex mode becomes possible, given the *separate* receive and transmit wire pairs in the cable. Full-duplex mode permits stations to transmit and receive at the same time because no collision detection is required -- there is no required isolated transmit mode and receive mode operation. Usable bandwidth increases for each workstation given that the backbone can handle the traffic.

A 100BaseX device operating in full-duplex mode can utilize 200 Mbps of bandwidth -- 100 Mbps for transmitting and 100 Mbps for receiving. However, as usual, the real world doesn't always run that smoothly. Both the workstation and the network device to which it connects must configure to run in full duplex mode. Drivers for Windows NT, for instance, may not support full duplex mode.

IEEE 802.3x specifies a standard for full-duplex operations for 10BaseT, 100BaseX, and 1000BaseX that defines a method of flow control. The receiver of data can send back a special frame, called a pause frame, to the source whenever a buffer overflow condition occurs. The pause frame announces a need for data to be stopped for a period of time. Alternately, a second pause frame can be sent to override the timer and reset it to zero, indicating to the sender that data transmission can be started.


Category 5e Cable

Category-5 quickly:

UTP (Unshielded Twisted Pair) cable rated as Category-5 typically contain (8 conductors) 4 pairs of 24 awg solid copper wire. Each of the pairs is two conductors twisted together, and each pair in a cable has a different number of twists per inch when compared to the other pairs. Stranded cable may be used in patch cables, but stranded cable is more likely to cause attenuation and should be used for as short a run as possible. There are shielded specifications for CAT-5 cable but the USA mostly uses UTP. The minimum grade wiring accepted for structured wiring is now CAT-5e. EIA/TIA 568 limits UTP copper to a 100 meter (328 feet) run maximum. In practice, cable runs are usually limited to 295 feet to allow for the distance to be run with patch cables. A standard specification is that no more than 10 meters (30 feet or so) of a 100 meter run should be patch cable. However, high quality patch cables have been run for 200 feet or so with success. Many home networks (where runs seldom exceed 75 feet or so) only use patch cables, but such an installation is not considered a high quality installation. If it works, it works, and if it doesn't, don't be wondering why. I can vouch for Belkin 100 ft. CAT-5e patch cords in home use, but I'm sure that any reputable manufacturer's product will do as good. While unusual for a home LAN, if the run is longer than 300 feet, a copper to fiber media converter (about $200 each) will be needed and fiber must be used to make the run. Some concentrators have a fiber backbone by default.

The cable sheath for CAT wiring can be PVC or rated for plenum usage. PVC cannot be used in spaces where the space is also used for air handling systems; the cable for such spaces must be rated for plenum use. Burning PVC is highly toxic, so not to put it where it can't vent or where it will provide a hazard to people needing fresh air from ventilation systems. Teflon is one of the cable sheath materials used for cable that must be run in a plenum space. Any cable rated for plenum use will have low flame and low smoke characteristics.

In general, do not strip off more than 1" of cable sheath (or jacket) when terminating a cable. Also do not fold, spindle, mutulate, bend, kink, stretch, yank, splice, twist, squeeze, loop, coil, or knot cable segments. On the other hand, you may want to leave some slack at the patch panel. Don't king-kong the cable ties -- slightly snug will do it. Cables, as they are run, should not sag nor should they be taut.

If you have a drop ceiling, don't lay the cable on top of the ceiling. Cable should be independently supported at least every 5 feet using cable stand-offs or other cable supports. If going through metal studs, use grommets.

The use of the pairs is standardized. The pin-out for connections can be according to one of two specifications: EIA/TIA 568A or EIA/TIA 568B. Nominally, EIA/TIA 568A is the standard for new installations. **568A** is the Ethernet equivalent of **DCE**. This is the pin-out usually found on hubs, switches, routers, patch panels, etc. **568B** is the Ethernet equivalent of **DTE**. This is the pin-out usually found on NICs (network interface cards.) Most patch cables sold in the USA are **568B**. The standards committee allowed 568B wiring because so much of it already existed at the time of standards ratification. Though they stated that 568A was to be used for new installations, a lot of people didn't listen. 568B has become the defacto standard.

10Base-T uses two pairs, orange and green. Blue and Brown pairs get used for bi-directional data configurations or are unused. 100Base-T uses the same color scheme. 100Base-T4 uses all 4 pairs (I've never seen a 100Base-T4 installation.)

Wiring Standards Table

Pin	**EIA / TIA 568A**	**EIA / TIA 568B, or AT&T 258A**	**10Base-T 10 Mbps Cat3**	**100Base-TX 100 Mbps Cat5**	**100Base-T4 100 Mbps Cat3**	**100Base-T2 100 Mbps Cat3**	**1000Base-T 1Gbps Cat5+**
1	white / green	white / orange	TX+	TX+	TX D1+	BI DA+	BI DA+
2	green / white (green)	orange / white (orange)	TX-	TX-	TX D1-	BI DA-	BI DA-
3	white / orange	white / green	RX+	RX+	RX D2+	BI DB+	BI DB+
4	blue / white (blue)	blue / white (blue)	na	na	BI D3+	na	BI DC+
5	white / blue	white / blue	na	na	BI D3-	na	BI DC-
6	orange / white (orange)	green / white (green)	RX-	RX-	RX D2-	BI DB-	BI DB-
7	white / brown	white / brown	na	na	BI D4+	na	BI DD+
8	brown / white (brown)	brown / white (brown)	na	na	BI D4-	na	BI DD-

BI=BI directional data RX=Receive Data TX=Transmit Data
(Pair Colors may be solid and striped/color,
or color with white stripe and white with color stripe)

Terms (in no particular order):

UTP (Unshielded Twisted Pair) refers to pairs of wires without an electrical shield of the type used to prevent cross-talk between pairs and/or radio interference.

ScTP is *Screened Twisted-Pair* cable. It has the same 4 pairs of wires as UTP, with a single piece of shielding (metal film or braid) surrounding the entire group of 8 wires. Specifications that call for shielded cabling generally also specify that the shielding will be maintained through all components.

SSTP Is fully-shielded twisted-pair cable. It has the same 4 pairs of wires as UTP, with a piece of shielding (metal film or braid) around each pair and a fifth piece of shielding surrounding the entire group of 8 wires.

RJ - Registered Jack

dB (Decibel) - A measurement of a gain or loss in signal strength in a communications circuit. Decibels are logarithmic, not linear.

Attenuation - Attenuation, measured in dB, denotes the change in transmission signal strength between two points. For copper wire, attenuation measurement is usually taken at a specified frequency or frequencies. For fiber, the measurement is taken at a specified wavelength.

Delay is the time it takes for a signal to propagate through the link. Cat-5e/6 specs require less than 548 nanoseconds propagation delay.

Delay Skew refers to the relative alignment between signals received at the far end. Cat-5e/6 specs require less than 45 nanoseconds skew.

Return loss measures the ratio of reflected signal strength to transmitted signal strength. For Cat-6, passing or failing the test for return loss can be affected by how much bend there is in the cable segment being tested. Return loss at higher data rates is a problem for RJ-45 connectors as well. Of course, everybody would like to continue to use RJ-45 connectors for backward compatibility. Don't count on it.

Crosstalk - The unwanted coupling of electromagnetic signals from one communications cable to another. Crosstalk can be measured from the near end of the transmitter (NEXT) or the end furthest away from the transmitter (FEXT).

NEXT (Near-end Crosstalk) measures crosstalk from a transmitting pair to an adjacent passive pair in the same cable at the near (transmission) end.

ELFEXT (Equal-level far-end crosstalk) is similar to NEXT but measures the effect at the far end of the cable.

PSNEXT (Power-sum NEXT) measures the crosstalk that three transmitting pairs induce on the fourth pair at the transmission end; **PSELFEXT** (power-sum ELFEXT) makes this measurement at the far end. Additional computations are used to produce attenuation-to-crosstalk ratios (ACR and PS-ACR) representing signal-to-noise measurements that show a safe operating margin.

ACR - Attenuation-to-Crosstalk-Ratio - The ratio of attenuation and crosstalk measured in dB at a given frequency. EIA/TIA gives specific levels for ACR (AKA Signal to noise ratio) for each category of cable. If this measurement is low, the receiving end will not hear the signal over the noise created on the line from other pairs.

Headroom (PS-ACR) - Power Sum Attenuation-to-Crosstalk Ratio - same as ACR except PSNEXT is used to calculate the ratio instead of NEXT. PS-ACR is used when comparing various cables to determine which cable is better. PS-ACR is the difference between Attenuation and PSNEXT. The result is referred to as "headroom". The more head room a cable or system has the more forgiving it will be with installation errors (apart from mis wiring).

Power Sum - A power sum is the summation of all possible combinations of interference from adjacent cable pairs. Power sum measurements are associated with various forms of cross talk, such as NEXT, FEXT, and ELFEXT. For transmission schemes that employ two pairs, the only measurement for crosstalk is made between the two pairs. In four pair, full duplex transmission schemes, all 4 pairs are energized. The crosstalk effect can arise from any combination of pairs, and the total (power sum) crosstalk applies. To obtain the Power Sum NEXT on pair 1, the dB loss on pairs 1-2, 1-3, and 1-4 must be added.

Bandwidth - The highest frequency up to which positive power sum ACR (Attenuation to Crosstalk Ratio) is greater than zero.

MHz vs. Mbps - The analog frequency of the carrier signal is expressed in MHz. The amount of data received per unit time is expressed as Mbps.

- Professional wire installers typically use a LAN Tester (Microtest, Agilent, Fluke, Wavetec, Datacom Textron) to check the effectiveness of an installation. While not as expensive as a high end LAN Analyzer ($25,000+), the typical $5000 price tag for this item is beyond the grasp of a DIYer installing his own home LAN. The good news is that most carefully installed home LANS will work good enough if the installer uses common sense.

Wirescope 350

Channel Link - every element required to carry data from the hub in the wiring closet to a desktop PC.

Permanent Link - the permanently installed horizontal wiring from the wiring-closet cross-connection to the work-area outlet.

Basic Link - the basic link adds patch cords to the Permanent link for testing purposes.

Cross-connect - the place where cables are terminated and are connected to a network device by patch cord

MC - Main Cross-connect

IC - Intermediate Cross-connect

HC - Horizontal Cross-connect

TO - Telecommunications Outlet (connector)

TP - Transition point - where flat undercarpet cable connects to round cable

balun - a balun isolates the transmission line and provides balanced output current.

Some comments on wiring standards:

Typically, wiring standards were proprietary standards created and maintained by private businesses like AT&T, Bell, DEC, and IBM. When other companies entered the market, a need for common standards among industry participants was recognized. There is no code similar to the National Electric Code (developed by the National Fire Protection Association) that exists for LAN wiring. Voluntary standards are developed and suggested by the merged Electronics Industries Association and the Telecommunications Industry Association (EIA/TIA.) It's the TR-42 group that makes the specs for User Premises Telecommunications Cabling Requirements including 568A, 568B and 570A. These standards are widely recognized because a large number of people specify them as a standard to be met when purchasing and installing equipment. And if your equipment doesn't meet this spec, I ain't buying it.

Punch-down Order:

- Pair 1 (Pin 1, 2): white-blue/blue
- Pair 2 (Pin 3, 4): white-orange/orange
- Pair 3 (Pin 5, 6): white-green/green
- Pair 4 (Pin 7, 8): white-brown/brown

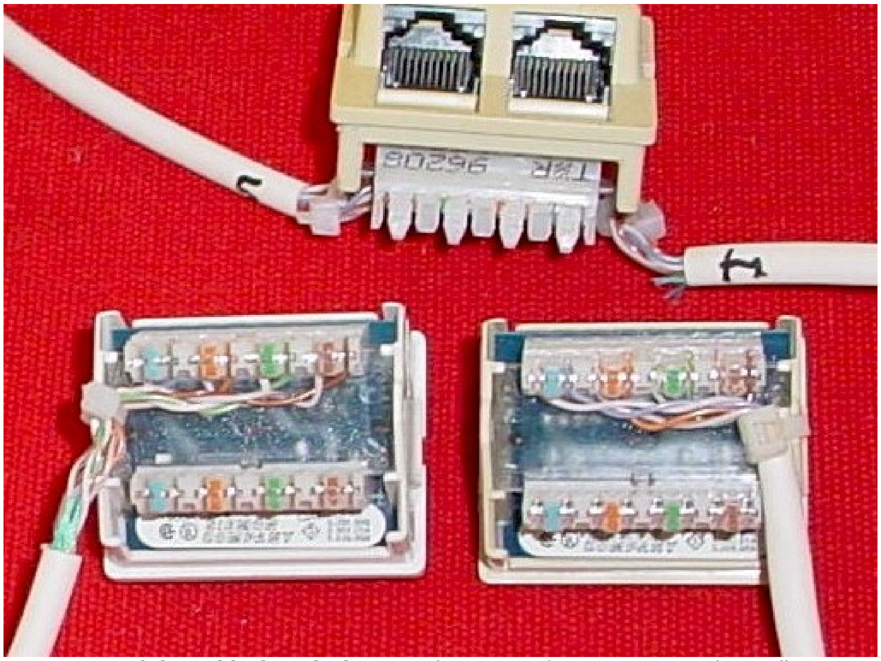
Punch-down order follows the order of white-color first followed by (solid) color. The ascending color order is remembered by the (mnemonic) word, **BLOG** - **BL**ue, **O**range, **G**reen, and Brown is left over (last.) This is **not** the order for modular plug connectors. This is the order for punch-down blocks. If the punch-down block interfaces to a keystone jack, the block should be labeled either EIA/TIA 568A or EIA/TIA 568B according to the wiring standard being followed by use of that device.

Punchdown block on jacks (Residential - Leviton - Home Depot)

IIn the illustrations, these el-cheapo residential keystone jacks from Leviton (and acquired from Home Depot) have color markings that are consistent with modular plug order -- NOT with the standard punch-down order described above. The configuration of the "punch-down block" on this keystone jack is not particularly easy to work with while maintaining the twist ratio of the pairs. The consideration for this design is space and clearance given where the jack will be inserted. Cheap equipment, however, makes it difficult to make good connections. That said, I have used these jacks to make good dependable connections for 100Base-T, but I've lost a lot of religion while doing it and I wouldn't count on challenging the assembly with anything at higher bandwidth. It is possible to produce a cable segment that doesn't talk if you are not careful about where stuff gets punched down. Fortunately, the pins are also numbered. Not shown are a number of devices that will hold this jack including wall plates, surface boxes, patch panels, and others.

Also note that these keystone jacks are rated as CAT-5 and not CAT-5e. If you use these with CAT-5e wire, you get a CAT-5 installation (which is good enough for most home LANs.)

Using a cable tester to test end-to-end cable installation (with whatever patch cords in place -- a basic link) is not a bad idea when you think you are finished. Obviously, you will have tested the patch cords first. Testing could save you a lot of grief when you get the network devices hooked up. Do the test after you make your first cable run because if you punch-down that one wrong, you are likely to punch-down the next three runs wrong also. (Fluke sponsored Cable Testing Website.)



Punchdown block on jacks (Commercial - Siemens - Patch Panel)

These patch panel jacks follow the standard punch-down block convention. The label (though you can't read it in the picture) states that this jack is configured for EIA/TIA 568A wiring spec. We have here a wiring job on the left that works and a wiring job on the right that works after being wired by a professional cable installer paying attention to details. Note that even though the cable on the left is stripped a bit far back (not a particularly neat and fastidious job -- ok, it's ugly (I didn't do it)), the twist pattern for each pair is maintained to a point as close to punch-down as possible. People that have to wire 400 - 500 of these at a pop are likely to be satisfied with "good enough." This is a real world example that does meet CAT-5 spec in spite of the sloppy strip back of the jacket, and the patch panel operated without any problems. At home with a half-dozen such connections to make this year, you could take some time and make the job neat. Keeping the cable sheath around the pairs for as long as possible is a good idea as is maintaining the twist ratio for each pair -- this to avoid near-end cross-talk.

Here both the wire and the jack are rated for CAT-5. CAT-5e has replaced CAT-5, but if you can score some CAT-5 equipment cheap, there's nothing wrong with using it at home for 10Base-T or 100Base-T equipment. The higher the category number, the less likely you will get away with sloppy workmanship.

UTP cables used for standard Ethernet are typically terminated with standard modular connectors, jacks or punch-downs. The jack or plug is typically referred to as an RJ-45, but RJ-45 actually refers to a telco spec for a modular 8 pin connector that terminates a USOC connection (pin-out) used for telephone systems. Everybody calls them RJ-45 connectors anyway. A plug is the male connector on a cable and a jack is a female receptacle. Wall outlets (receptacles) are typically called jacks. Don't trust the color coding on wall plate jacks unless you have proven they are correct. You might want to ring out the conductors to make sure. The color coding for the punch-down block on the back of a jack may follow the pair order for EIA/TIA 568A or EIA/TIA 568B (instead of the standard punch-down order described above). Wire pairs should not be untwisted any more than necessary. The typical maximum specification is 1/2 inch but most consider that a lot. 1/4 inch is preferred.

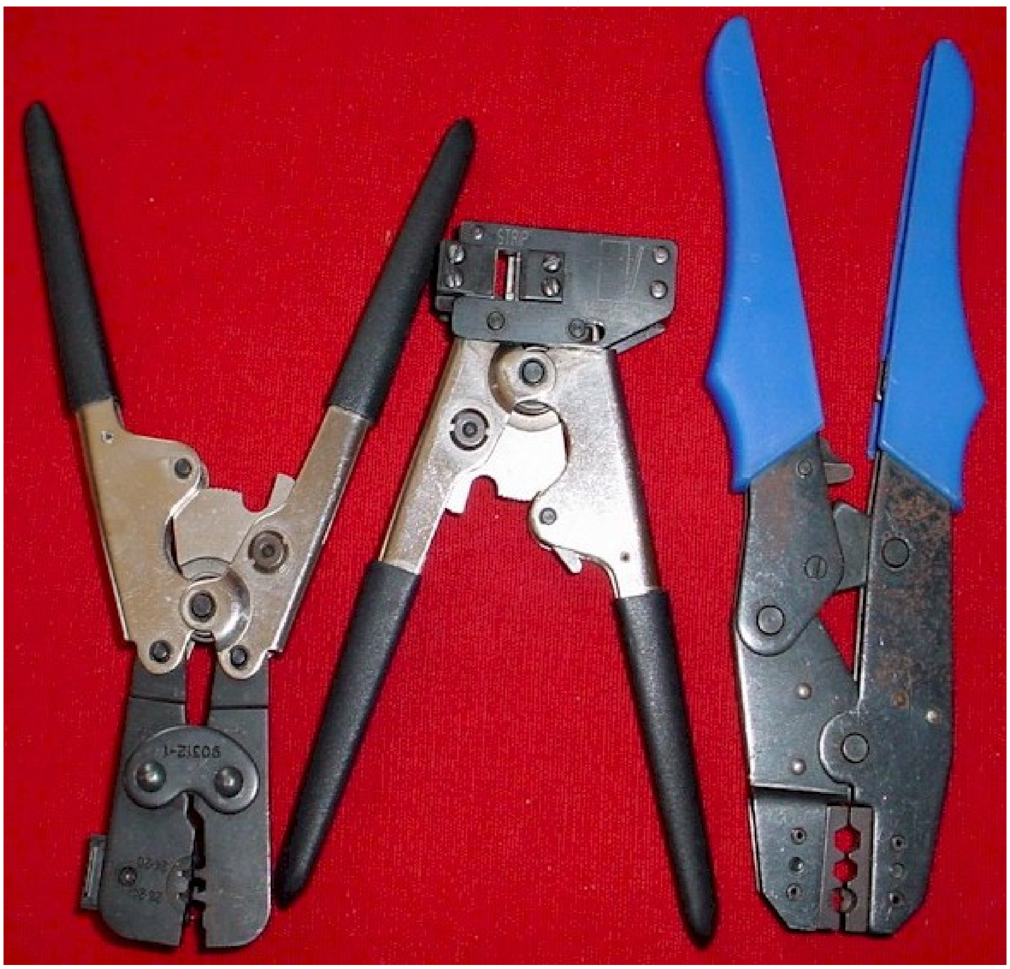
Punch down blocks come in 110, 66, and "other" varieties. Telco equipment generally employs 66 blocks and LAN equipment generally employs 110 blocks. The "other" varieties are rare and/or proprietary and/or in use for sites outside the USA. The punchdowns found on LAN devices are generally 110 unless you have something wierd.

You need a punch-down tool to make punch-down connections. The tools for 110 and 66 are different to accommodate the different terminals.

Punchdown Tools

If you purchase a keystone jack(s) from some place like Home Depot, the box may include a little plastic 110 punch-down tool (that would be the blue thingy at the top of the illustration). This document will not explain the difference between hydrocarbon polymers and tool steel. The yellow punch-down (Harris / impact) tool handle shown is what people who are serious about making a good connection use (It ain't cheap.) There are two punch-down tools illustrated, the black (blued) one for a 110 block in the handle and the SS one at the bottom used for 66 blocks. The two tools can interchange in the handle with a simple twist to lock or unlock the tool. The tool will reverse in the handle with one side being for punch-down only and the other side being for simultaneous punch-down and cutting of the wire on one side of the terminal. The tool aligns in the handle so that the cutting edge is on the yellow side that is marked "cut". People who do this job with a screwdriver will get what they get--that is, the likelihood of good integrity and a minimum of noise is much less probable using a screwdriver for the job while the likelihood of shorts becomes quite high.

A crimping tool for RJ-45 male connectors (plugs) can come in handy, if you already own one. Since the commercial cable makers have brought the price of patch cables down, however, it's just about not worth the effort -- buy your patch cables. If you only need a couple of patch cables for home, it would take a long time to cover the cost of a good crimping tool -- even if you get one with dies that will convert the tool for various RJ specs, and even if you don't have to ruin about 20 connectors to figure out some technique that really works.



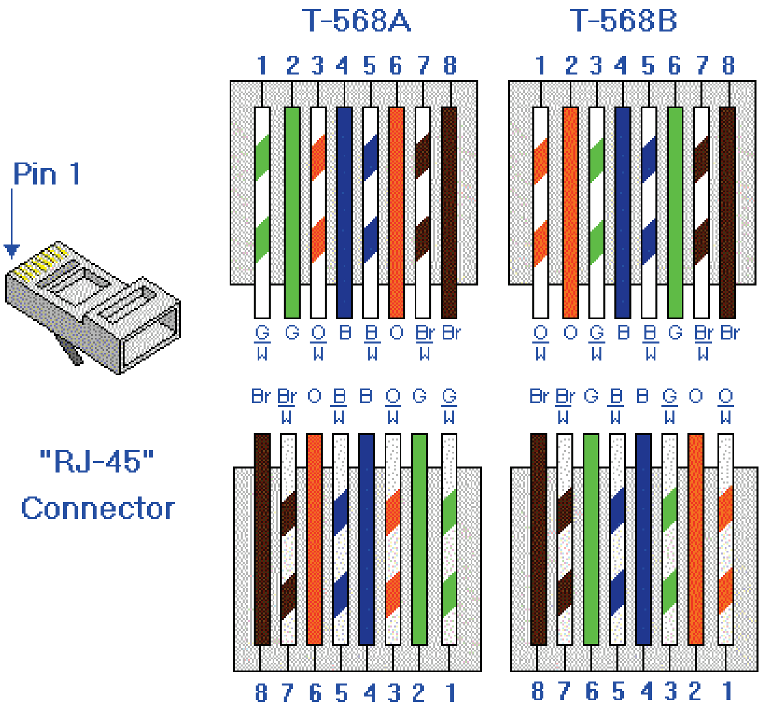
Serious crimping tools for people who put connectors on cables.

People who are serious about making their own cables (also people who want to get the job done fast) will want a specialized CAT-5 cable stripper as well. Just remember, pre-fabricated patch cables get installed really fast.

Cable Order

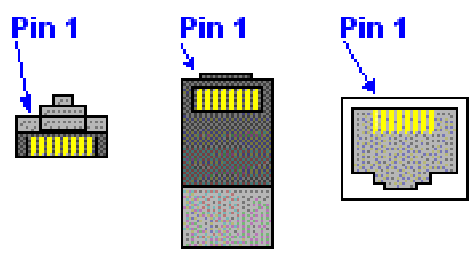
A CAT-5 data cable with 8 conductors should have each conductor identified by the color of the insulation on the wire. Each of the 4 pairs consists of a solid color wire as well as a white and color striped wire. Each of the pairs are twisted together. To maintain reliability of communication, do not untwist the pairs any more than is necessary (about 1/4 inch).

10BaseT Ethernet employs the orange and green pairs. The brown and blue pairs are unused. So, it can be seen from the illustration of the two EIA/TIA 568 wiring specifications in the illustration below that the difference matters. The difference between the two specifications is only pin order. The function of the numbered pairs is the same in both specifications.



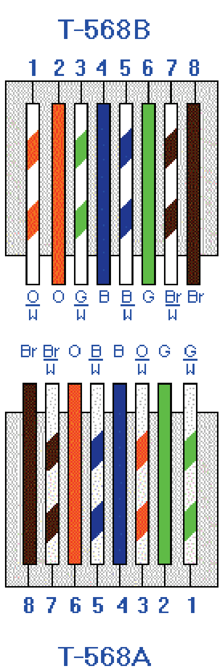
Straight-through EIA/TIA 568A and EIA/TIA 568B

When you hold the contacts of an "RJ-45" male connector (plug) so that they face your eyes and are up (the cable would trail from the bottom), pin 1 is on the left Pin 1 is always a white and colored wire. Solids and stripes alternate. Even number pins always have solid colors. The blue pair is always pins 4 and 5. The brown pair is always pins 7 and 8. Pins 1 and 2 always carry a pair of the same color. The "A" specification starts with (white/) Green at pin 1 while the "B" specification starts with (white/) Orange at pin 1 -- those are alphabetical. The pair numbers (regardless of whether "A" or "B") follow the same order as for punchdown blocks (BLOG).



Pair Order:

- Pair 1: white-blue/blue
- Pair 2: white-orange/orange
- Pair 3: white-green/green
- Pair 4: white-brown/brown



Cross-over Cable, 10/100Base-T

For a single segment connecting only two computers (or two network distribution devices) you can provide the signal crossover by building a crossover cable, with the transmit pins on the eight-pin plug at one end of the cable wired to the receive data pins on the eight-pin plug at the other end of the crossover cable and vice versa. It turns out that, if you do this, one end of the cable will look like T-568B and the other end will look like T-568A.

Remember, for 10BaseT, only the orange and green pairs are used. It doesn't much matter what happens with the other two pair. This works for 100BaseT as well.

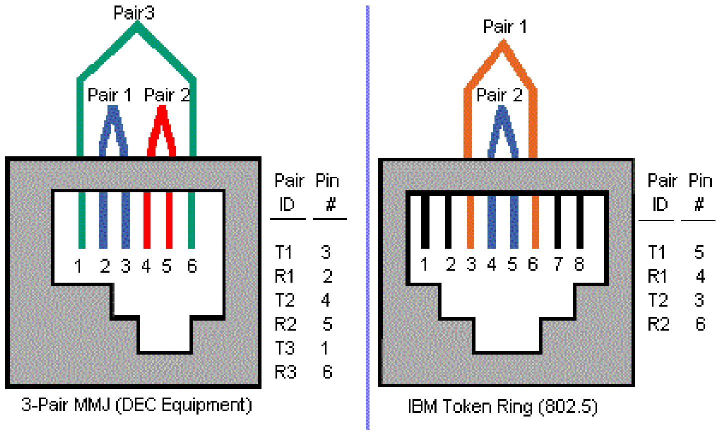
On the great value of crossover cables: Er, I have this el-cheapo hub I carry around in my laptop bag. All my hubs/switches have a switch or extra jack with an "X" on them. I haven't needed a cross-over cable in 4 years.

In my travels, I've also seen a crossover cable spec that supposedly will work for 1000BaseT. Uh, I'm wondering if there is a reason for this cable. Anyway, in addition to the cross for orange and green pairs, this cable has a parallel cross for blue and brown pairs. If you run across a need for this, you should be able to figure it out from that.

Other connector standards (for lagniappe):

The pair designations for other connector standards do NOT conform to BLOG order.

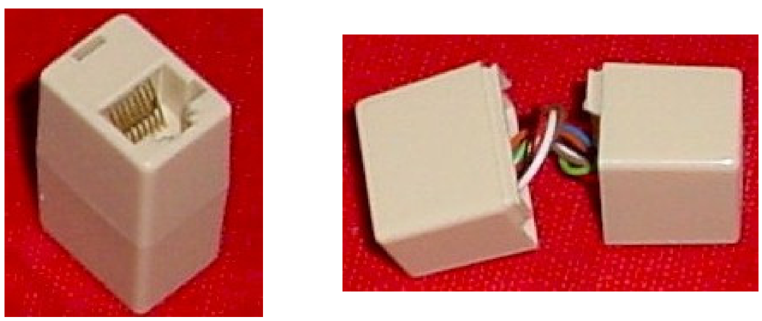
Other Connectors



Both ATM and ANSI X3T9.5 use the two outer pairs (pins 1 & 2 and 7 & 8) of an 8 position RJ-45 connection.

Faster and/or easier:

Stay away from RJ-45 butt connectors. If you get away with it, good for you, but the reason why you are so advised can be seen in the picture, on the right, below.



RJ-45 Butt Connector (Unrated)

That's cross-talk heaven inside the plastic. Get the right size patch cable and reduce the possibilities for noise.

Most of the equipment to be found in a home network still employs cable and is advertised as 10/100 Mbps. While wireless is rapidly gaining in popularity, it clearly has some cons to go along with the pros. In its favor, it promises to be a painless installation--no unsightly cables to run. Holding it back is lower bandwidth (slower speed), lackluster security (WEP), and equipment cost. Some people will gladly tolerate slower speed (if they notice much) and trade the cost of a neat cable installation (wire pulling, drywall repairs, labor) for dollars tied up in equipment. A copper installation, however, will have less security considerations, more robust operation, more bandwidth now, and the promise of even more bandwidth without changing the cable plant in the future. For some the choice is easy; some decide to do both; some have a hard time getting the job done at all.

Nobody lives up to the named bandwidth--doesn't matter if it is a cable or wireless installation. When it's all said and done, we don't care about advertised bandwidth; what we care about is day-to-day, real-life throughput. Neither cabled nor wireless installations deliver 100 percent. Throughput seldom lives up to nominal speed for lots of reasons. Cable plant integrity, NIC efficiency, network device latency, and other factors often reduce throughput. Most operators of home LANs don't care because the network, typically (at any speed), is plenty fast for their use. Most wouldn't know how to measure bandwidth.

The following tests were conducted using cheap 10/100 NICs, a cheap 10/100 switch, Cat-5e patch cables, and software loaded on the receiving stations. Obviously, these are not optimum conditions. Copying a large file from one PC to another shows a throughput of 55 Mbps. Simultaneously copying a large file from one PC to two other PCs shows a combined throughput of 72 Mbps. Simultaneously copying files from two PCs to two PCs shows a combined throughput of 76 Mbps. Default or autosense settings were accepted for all devices, and these readings were not taken with isolated professional level network bandwidth analyzers.

The more the cable is disturbed in the form of tight bends, stretched segments, too many over-tightened cable ties, too much pressure applied to the cable, and other mortal installation sins, the worse the performance of the cable gets. Don't preserve the intended twist rate at the el-cheapo terminals, and introduce fluorescent light ballasts and other noise inducers, and you can have real trouble. One spec for cable bend radius calls for a bend of radius no less than 8 times cable O.D. (with no load) -- 10 times to be safe. Some industry white papers indicate that using CAT-6 equipment with CAT-5e equipment could result in less than CAT-5 performance (Ideal Industries - "Compatibility Concerns..." -- Also Ortronics - "Center Tuned Category 6 Connectivity").

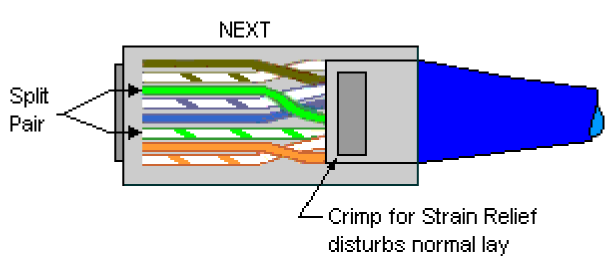
Performance reduction is cumulative. A poor installation wrecks high-speed links.

A Quick Comparison of Category 5, 5e, and 6 Standards

As of **6/18/2002**	**TIA Cat 5** TIA-568-A Oct-95 (Obsolete)	**TIA Cat 5e** TIA-568-B Final May-01	**TIA Cat 6** TIA-568-B.2 Final Jun-02
Maximum Test Frequency	100 MHz	100 MHz	250 MHz
Values @ 100 MHz			
	(dB)	(dB)	(dB)
Insertion Loss (AKA Attenuation - the lower the number, the better solution)			
Cable	22	22	19.8
Connector	0.4	0.4	0.2
Channel	24	24	21.3
NEXT (the higher the number, the better solution)			
Cable	not specified	35.3	44.3
Connector	not specified	43.0	54.0
Channel	not specified	30.1	39.9
ELFEXT (the higher the number, the better solution)			
Cable	not specified	23.8	27.8
Connector	not specified	35.1	43.1
Channel	not specified	17.4	23.3
Return Loss (the higher the number, the better solution)			
Cable	16.0 (SRL)	20.1	20.1
Connector	14.0	20.0	24.0
Channel	8.0	10.0	12.0

While I'd say any intelligent DIYer could make a workable Cat-5 installation at home, if you think you are going to make a Category 6 installation at home, think about it a lot and prepare to be possibly disappointed. First, it is less than likely that you will have the equipment to test a Cat-6 installation to make sure that it meets spec. Next, the techniques required differ according to the manufacturer of the equipment, and professional cable installers typically need training by the manufacturer (at a price) to achieve a good installation (the object of the standard, however, is to change this situation.) In the CAT-6 world, manufacturers don't feel the least bit uncomfortable not certifying performance levels if the equipment of other manufacturers is used (beyond their normal reluctance.) Manufacturers disagree on how an installation should be tested for spec, and sometimes specify the *EXACT* testing equipment (Mfg. and model) to be used with their product. The difference between category 5e and category 6 is transmission performance. Cat-6 extends available bandwidth from 100 MHz (Cat-5e) to 200-250 MHz and includes better insertion loss, near end crosstalk (NEXT), return loss, and equal level far end crosstalk (ELFEXT). Meeting the spec for these parameters requires tight tolerances be maintained by the manufacturer, and the fastidious installer must pay minute attention to detail. The result of the specification is a higher signal-to-noise ratio allowing higher data rates in the future. Unless you have the inside track, because you have a Cat-6 installation and resources where you work, don't count on being able to effectively use Cat-6 cable the same way you might use CAT-5 cable. Home Depot carries CAT-5e wire and CAT-5 equipment; they do not carry CAT-6 equipment. Not that Home Depot is where you should go, necessarily, for your supplies, but the fact that they do not carry CAT-6 supplies is telling.

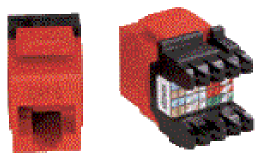
If you are lucky, you have a quality cable and device supplier near you. If you don't, you can find them on the internet. You can use Home Depot too (I have on occasion), but just be aware of the level of quality that you are buying.



The difficulties associated with producing high quality patch cords, manually, dictates that more attention be paid to the purchase and use of patch cords, modular plugs, and modular jacks, particularly for Category 6. The weakest link in a modular cable assembly is the modular plug. Modular plugs used in patch cords makes patch cords more susceptible to cross-talk at this point because of the design.&nb sp; The large contact blades positioned in parallel at the business end of the plug act as capacitive plates and can be a significant source of signal coupling. The way cable lays, through the whole length of the plug, demands that the individual pairs are untwisted and split. This alteration of natural cable lay defeats the cable's ability to remain immune to cross-talk. The split pair at pins 3 and 6 requires conductors to cross over one another, a weak point that can contribute to cross-talk.   The strain relief crimp can crush the wires together resulting in deformed wire and conductor pair invasion resulting in both cross-talk and return loss. Even some commercially available pre-fabricated cables use this technique. A factory produced quality patch cord may employ insert molding for strain relief, leaving the interior of the cable undisturbed.

Amp, for example, has a modular plug design, detailed in document 114-13035, that separates the split pair from the other conductors in the plug. This document also shows a tool (Read the caveats!) for manually installing crimp-on CAT-6 cable ends! {*Don't do this at home, boys and girls.*}

As you might expect, the design requirements for punch-down blocks and jacks are just as demanding as for modular connector plugs. Design considerations may call for staggered contacts, a strain relief design that doesn't crush the cable, unique cable routing, extra internal contacts, an incorporated small printed circuit board that allows pairs to remain twisted, and others.



Leviton Category-6 Extreme Jack

Compare the Leviton Cat-6 keystone shown here with the Cat-5 example in the illustration for the "Punch-down" section of this page, above.

Quote from the Cat-6 FAQ at TIAonline

> **What is meant by the term "Electrically Balanced"?**
>
> *A simple open wire circuit consisting of two wires is considered to be a uniform, balanced transmission line. A uniform transmission line is one which has substantially identical electrical properties throughout its length, while a balanced transmission line is one whose two conductors are electrically alike and symmetrical with respect to ground and other nearby conductors.**
>
> *"Electrically balanced" relates to the physical geometry and the dielectric properties of a twisted pair of conductors. If two insulated conductors are physically identical to one another in diameter, concentricity, dielectric material and are uniformly twisted with equal length of conductor, then the pair is electrically balanced with respect to its surroundings. The degree of electrical balance depends on the design and manufacturing process. Category 6 cable requires a greater degree of precision in the manufacturing process. Likewise,* ***a category 6 connector requires a more balanced circuit design****.*
>
> *For balanced transmission, an equal voltage of opposite polarity is applied on each conductor of a pair. The electromagnetic fields created by one conductor cancel out the electromagnetic fields created by its "balanced" companion conductor, leading to very little radiation from the balanced twisted pair transmission line. The same concept applies to external noise that is induced on each conductor of a twisted pair. A noise signal from an external source, such as radiation from a radio transmitter antenna generates an equal voltage of the same polarity, or "common mode voltage," on each conductor of a pair. The difference in voltage between conductors of a pair from this radiated signal, the "differential voltage," is effectively zero. Since the desired signal on the pair is the differential signal, the interference does not affect balanced transmission.*
>
> *The degree of electrical balance is determined by measuring the "differential voltage" and comparing it to the "common mode voltage" expressed in decibels (dB). This measurement is called Longitudinal Conversion Loss "LCL" in the Category 6 standard.*
>
> ** The ABC's of the telephone Vol. 7*