How to Make Cat5 Twisted-Pair Network Cables

by KeithParsons

Introduction

The purpose of this article is to show you how to make the two kinds of cables, which can be used to network two or more computers together to form local area networks (LANs). These instructions are also the same for making patch cables for networks with more complex infrastructure wiring.

The two most common unshielded twisted-pair (UTP) network standards are the10 Mhz 10BASE-T Ethernet and the 100Mhz 100BASE-TX Fast Ethernet. The 100BASE-TX standard is quickly becoming the predominant LAN stand-ard. If you are starting from scratch, to build a small home or office network, this is clearly the standard you should choose. The same cables work for both types of Ethernet networks.

What is a LAN?

A LAN can be as simple as two computers, each having a network interface card (NIC) or network adapter and running network software, connected together with a *crossover* cable.

CROSSOVER CABLE

The next step up would be a network consisting of three or more computers and a hub. Each of the computers is plugged into the hub with a *straight-thru* cable (the crossover function is performed by the hub).

HUB
STRAIGHT-THRU CABLES
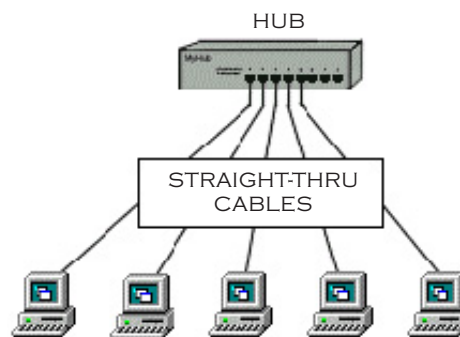
Network Cable and Connectors

There are several classifications of cable used for twisted-pair networks. I use and recommend only Category 5 (or CAT 5) cable for all new installations. Likewise, there are several fire code classifications for the outer insulation of CAT 5 cable. I use CMR cable, or "riser cable," for most of the wiring I do. You should also be aware of CMP or plenum cable (a plenum is used to distribute air in a building). You may be required by local, state or national codes to use the more expensive plenum-jacketed cable if it runs through suspended ceilings, ducts, or other areas, if they are used to circulate air or act as an air passage from one room to another. If in doubt, use

plenum. CMR cable is generally acceptable for all applications not requiring plenum cable.

CAT 5 wire is available in reel-in-box packaging. This is very handy for pulling the wire without putting twists in it.

Stranded wire patch cables are often specified for cable segments running from a wall jack to a PC and for patch panels. They are more flexible than solid core wire. However, the rational for using it is that the constant flexing of patch cables may wear-out solid core cable—break it.

Most of the wiring I do simply connects computers directly to other computers or hubs. Solid core cable is quite suitable for this purpose and for many home and small business networks. I find it also quite acceptable for use as patch cables. You might consider stranded wire patch cables if you have a notebook computer you are constantly moving around.

CAT 5 cable has four twisted pairs of wire for a total of eight individually insulated wires. Each pair is color coded with one wire having a solid color (blue, orange, green, or brown) twisted around a second wire with a white background and a stripe of the same color. The solid colors may have a white stripe in some cables. Cable colors are commonly described using the background color followed by the color of the stripe; e.g., white-orange is a cable with a white background and an orange stripe.

Connectors
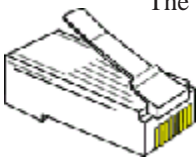
The straight through and cross-over patch cables are terminated with CAT 5 RJ-45 modular plugs. RJ-45 plugs are similar to those you'll see on the end of your telephone cable except they have eight versus four or six contacts on the end of the plug and they are about twice as big. Make sure they are rated for CAT 5 wiring. (RJ means "Registered Jack"). Also, there are RJ-45 plugs designed for both solid core wire and stranded wire. Others are designed specifically for one kind of wire or the other. Be sure you buy plugs appropriate for the wire you are going to use.

Network Cable Tools

• **Modular Plug Crimp Tool**

You will need a modular crimp tool. This one is very similar to the one I have been using for many years for all kinds of telephone cable work and it works just fine for Ethernet cables. You don't need a lot of bells and whistles, just a tool that will securely crimp RJ-45 connectors.

• **Diagonal Cutters**

It is easier to use diagonal cutters ("diags" or "dikes") to cut the cable off at the reel and to fine tune the cable ends during assembly. Also, if you don't have a stripper, you can strip the cable by using a small knife.

• **Cable Tester**

It is much better to test the cables upon completion, than to try each cable on a 'known-good' network. Inexpensive cable testers are available to examine continuity, much more expensive options allow for crosstalk and Cat 5 compatibility.

A Little Theory

The 10BASE-T and 100BASE-TX Ethernets consist of two transmission lines. Each transmission line is a pair of twisted wires. One pair receives data signals and the other pair transmits data signals. A balanced line driver or transmit-

ter is at one end of one of these lines and a line receiver is at the other end. A simplified schematic for one of these lines and its transmitter and receiver follow:
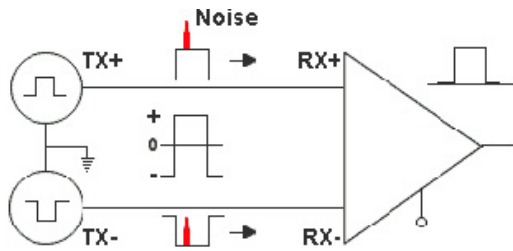
Pulses of energy travel down the transmission line near the speed of light (186,000 miles/second). The principal components of one of these pulses of energy are the voltage potential between wires and current flowing near the surface of the wires.

One concern is the transient magnetic fields which surrounds the wires and the magnetic fields generated externally by the other transmission lines in the cable, other network cables, electric motors, fluorescent lights, telephone and electric lines, lightning, etc. This is known as noise.

Magnetic fields induce their own pulses in a transmission line, which may literally override the Ethernet pulses, the conduit of the information being sent down the line.

Twisted-pair Ethernet employs two principle means for combating noise. The first is the use of balanced transmitters and receivers. A signal pulse actually consists of two simultaneous pulses relative to ground: a negative pulse on one line and a positive pulse on the other. The receiver detects the total difference between these two pulses. The magnetic field surrounding one wire from a signal pulse is a mirror of the one on the other wire. At a very short distance from the two wires the magnetic fields are opposite and have a tendency to cancel the effect of each other out. This reduces the line's impact on the other pair of wires and the rest of the world.

The second and the primary means of reducing crosstalk—the term crosstalk came from the

ability to hear conversations on other lines on your phone—between the pairs in the cable, is the double helix configuration produced by twisting the wires together. This configuration produces symmetrical (identical) noise signals in each wire. Ideally, their difference, as detected at the receiver, is zero.

Color-Code Standards

Here are simple pin-out diagrams of the two types of UTP Ethernet cables:
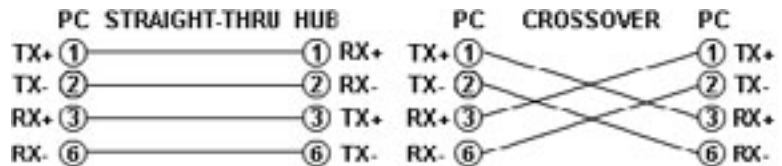
Note that the TX (transmitter) pins are connected to corresponding RX (receiver) pins, plus to plus and minus to minus. You must use a crossover cable to connect units with identical interfaces. If you use a straight-through cable, one of the two units must, in effect, perform the crossover function.

Two wire color-code standards apply: EIA/TIA 568A and EIA/TIA 568B. The codes are commonly depicted with RJ-45 jacks as follows:
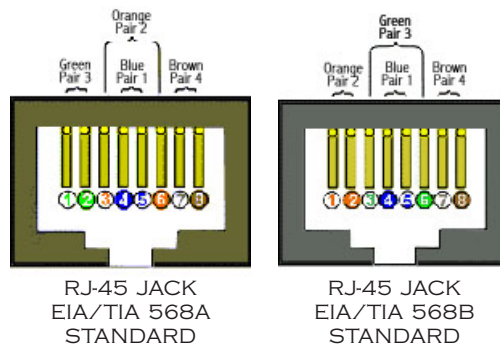
Note that pPins 4, 5, 7, and 8 and the blue and brown pairs are not used in either standard. These pins and wires are not used or required to implement 100BASE-TX duplexing—they are just plain wasted. Some people use want to 'save' these wasted wires and attempt to use them to carry voice or other data.

This is a recipe for network disaster. The additional crosstalk these other signals induce cause the initial network to fail.

You cannot use an flat-untwisted telephone cable for a network cable. Furthermore, you must use a pair of twisted wires to connect a set of transmitter pins to their corresponding receiver pins. You cannot use a wire from one pair and another wire from a different pair.

Let's Make It Simpler

There are only two unique cable ends in the preceding diagrams. They correspond to the 568A and 568B RJ-45 jacks.

568A CABLE END

568B CABLE END

Again, the wires with colored backgrounds may have white stripes and may be drawn that way in diagrams found elsewhere. For example, the green wire may be labeled Green-White. The background color is always specified first.

Now, all you need to remember, to properly configure the cables, are the diagrams for the two cable ends and the following rules:

• A straight-thru cable has identical ends

• A crossover cable has different ends

It makes no functional difference which standard you use for a straight-thru cable. You can start a crossover cable with either standard as long as the other end is the other standard. It makes no functional difference which end is which. Despite what you may have read elsewhere, a

568A patch cable will work in a network with 568B wiring and 568B patch cable will work in a 568A network. The electrons could care less what color cable they are on.

My preference is to use the 568B standard for straight-thru cables and to start crossover cables with a 568B end. That way all I have to remember is the diagram for the 568B end, that a straight-thru cable has two of them, and that the green and orange pairs are swapped at the other end of a crossover cable.

Let's Make Some Cables

• Pull the cable off the reel to the desired length and cut. The total length of wire segments between a PC and a hub or between two PC's cannot exceed 100 Meters (328 feet or about the length of a football field) for 100BASE-TX and 300 Meters for 10BASE-T.

• Strip one end of the cable with the stripper or a knife and diags. Using a knife and diags, carefully slit the cable for about an inch or so and neatly trim around the circumference of the cable with diags to remove the jacket.
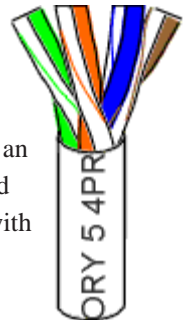
• Inspect the wires for nicks. Cut off the end and start over if you see any. Cable diameters and jacket thickness vary.
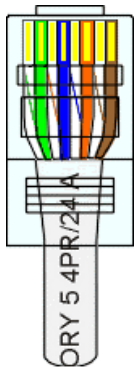
• Spread and arrange the pairs roughly in the order of the desired cable end.

• Untwist the pairs and arrange the wires in the order of the desired cable end. Flatten the end between your thumb and forefinger. After the ends are in the correct order you can trim the ends of the wires so they are even with one another. It is very important that the unstripped (untwisted) end be slightly less than 1/2" long. If it is
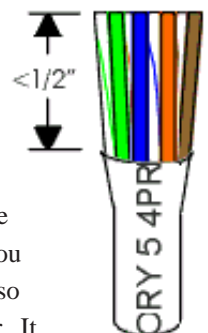
longer than 1/2" it will be out-of-spec and susceptible to crosstalk. If it less than slightly less than 1/2" it will not be properly clinched when RJ-45 plug is crimped on. Flatten again. There should be little or no space between the wires.

• Hold the RJ-45 plug with the clip facing down or away from you. Push the wire firmly into the plug. Now, inspect the darn thing. . .before crimping and wasting the plug! Looking through the bottom of the plug, the wire on the far left side will have a white back-ground. The wires should alternate light and dark from left to right. The furthest right wire is brown. The wires should all end evenly at the front of the plug. The jacket should end just about where you see it in the diagram—right on the line. Aren't you glad you didn't crimp the plug?

All About Crimping

• Hold the wire near the RJ-45 plug with the clip down and firmly push it into the left side of the front of the crimper (it will only go in one way).

Hold the wire in place squeeze the crimper handles quite firmly. The crimper pushes two plungers down on the RJ-45 plug. One forces what amounts to a cleverly designed plastic plug/
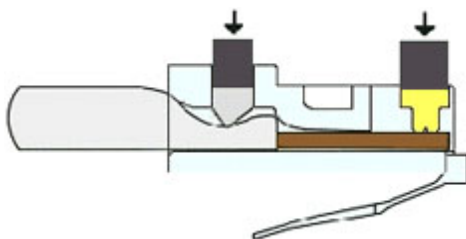
wedge onto the cable jacket and very firmly clinches it. The other seats the "pins," each with two teeth at its end, through the insulation and into the conductors of their respective wires.

• Test the crimp... If done properly an average person will not be able to pull the plug off the cable with his or her bare hands. And that quite simply, besides lower cost, is the primary advantage of twisted-pair cables over the older thin net, coaxial cables. In fact, I would say the RJ-45 and ease of its installation is the main reason coaxial cable is no longer widely used for small Ethernets. Look at the side of the plug and see if it looks like the diagram and to make sure it is crimped well.

• Prepare the other end of the cable so it has the desired end and crimp.

• If both ends of the cable are within reach, hold them next to each other and with RJ-45 clips facing away. Look through the bottom of the plugs. If the plugs are wired correctly, and they are identical, it is a straight-thru cable. If they are wired correctly and they are different, it is a crossover cable.
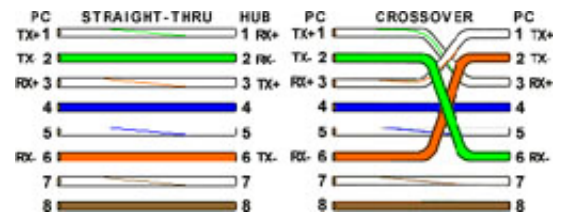
• If you have an operational network, test the cable. I normally use a cable tester to confirm continuity on all lines first.

• If the cable doesn't work, inspect the ends again and make sure you have the right cable and that it is plugged into the correct units for the type of cable.

• If you have many straight-thru cables and a crossover cable in your system, you should consider labeling the crossover cable or using a different colored cable for the crossover cable so you don't mix them up.

CABLING RULES

Try to avoid running cables parallel to power cables.

Do not bend cables to less than four times the diameter of the cable.

If you bundle a group of cables together with cable ties (zip ties), do not over-cinch them. It's okay to snug them together firmly; but don't tighten them so much that you deform the cables.

Keep cables away from devices that may introduce noise into them. Here's a short list:

- electric heaters
- speakers
- printers
- TV sets
- fluorescent lights

- copy machines
- copiers
- welding machines
- microwave ovens
- telephones

- elevator motors
- electric ovens
- dryers, fans
- washing machines
- shop equipment

Avoid stretching UTP cables (the force should not exceed 25 LBS).

Do not run UTP cable outside of a building. It presents a very dangerous lightning hazard!

Do not use a stapler to secure UTP cables. Use telephone wire hangers which are available at most hardware stores.

Tips and Tricks

Quickly Changing Printer Settings

If you frequently print documents using different printer settings, such as black and white drafts versus color documents, you're probably getting tired of changing these settings each time you print. You can avoid this busywork by tricking Windows into thinking you have two different printers. "Install" the same printer twice, then set the Properties for each to match your most commonly used settings. From then on, the only setting change you'll have to make is selecting the printer you want to use.

To "install" your printer again, select Start, Settings, Printers and click Add Printer. Follow along with the installation instructions and, when asked, opt to keep the existing driver. Also, be sure to give this "second" printer an appropriate name, such as *Color Docs*.

When the installation is complete, you'll see two different printer icons in the Printers window. To adjust their Properties, one at a time, right-click an icon, select Properties, and then make the changes you'd like. The next time you want to print a document, use the native application's Print command, select a printer in the resulting dialog box, and click OK.

Audible Caps Lock Key

Do you want your Caps Lock and Num. Lock keys to play a sound when you press them, so you don't find yourself typING IN ALL CAPS or typing numbers instead of paging up and down? Then call upon ToggleKeys.

Open the Control Panel and double-click Accessibility Options. On the Keyboard tab, select Use ToggleKeys, then click OK. From now on, pressing Caps Lock or Num. Lock (or Scroll Lock) plays one of two sounds (depending on whether you're turning the button on or off).

(Note: If you don't see Accessibility Options in your Control Panel, you need to install it using your Windows 98 installation disk. Inside the Control Panel, double-click Add/Remove Programs. Click the Windows Setup tab and, under Components, select Accessibility. Click the Details button, select Accessibility Tools, click OK twice, and so on.)