A Practical Guide

Understanding and Selecting Ethernet Cable

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Computer Networking is all about sharing. It means sharing information or services between local devices such as other computers, printers, external hard drives and even video distribution. It also means sharing information or services with the rest of the world via the Internet.

The network highway can be wired or wireless creating enormous flexibility. In this discussion we're going to focus on the wired side, otherwise known as Ethernet cabling and connectivity.

Before we get started let's keep in mind that this is a practical guide. Many of the deeper details are omitted and more relevant to an engineering specification. So get ready, here comes the fine print…

Disclaimer: Nothing in this guide should be construed as specific advice or recommendation of any kind. Your application will ultimately determine the best possible solutions. Warehouse Cables is in no way responsible for any interpretation or results thereof from the information provided herein.

Bring In the Standards

Ok, so who came up with this Ethernet communications scheme? **The Institute of Electrical and Electronics Engineers (**IEEE) published the final **IEEE 802.3** standard in 1985 as a replacement for older wired LAN (local area network) technologies. The twisted pair cabling standard arrived around 1990 and has since evolved through the various "Categories" up to the present.

In addition, the **Telecommunications Industry Association and Electronic Industries Alliance** (**EIA/TIA**) developed their own standards, based on **IEEE 802.3** to serve the public interest by eliminating misunderstandings between manufacturers and purchasers, facilitating interchangeability and promoting the improvement of products. This widely referenced Standard can be found printed on the cable jacket as **EIA/TIA 568-B** indicating compliance.

Intertek's ETL mark is also an accepted proof that a cable product has been independently tested and safety certified. Intertek is one of the world's largest Testing, Inspection and Certification organizations providing electrical safety testing. The **ETL Verified** mark is also typically found printed on the cable jacket.

Underwriters Laboratories (**UL**) is perhaps the best known independent testing and certification organization. Most manufacturers periodically submit their cable products for testing in order to present the coveted "UL Approved" certification, also printed on the cable jacket as **UL Exxxxx** (file number).

It should be noted that the weight of the UL Mark had become so important that counterfeiting became an industry headache. To counter the problem, UL now issues a **holographic sticker** which can be found on the carton or cable reel. Due to the high cost of UL testing and inspection some companies are foregoing the UL certification altogether. Instead, they are relying only on the ETL mark as a means of industry compliance.

Canada has its own testing standards group known as **Canadian Standards Association** (**CSA**). Most cable products used in the US are also CSA approved as indicated on the carton and/or cable jacket.

Finally, there is the Restriction of Hazardous Substances Directive 2002/95/EC, otherwise known as **RoHS**. This directive was issued by the European Union (EU) and restricts the use of various hazardous materials in the manufacture of electrical and electronic equipment. It also sets standards for the collection, recycling and recovery targets for electrical goods and is part of a legislative initiative to solve the problem of huge amounts of toxic e-waste.

This directive is widely accepted and standardized in the US and abroad. Once again, the **RoHS** mark can be found printed on the cable jacket.

So What are Twisted Pairs?

An Ethernet or "Category" cable utilizes eight conductors separated into four separate pairs, each of which is twisted together. This plays a large part of the performance difference between Cat 5e, Cat 6, Cat 6a, etc... Each pair has a different rate of twist which helps prevent crosstalk interference between the pairs. In the case of Cat 6 cable, the pairs are further separated (usually) by a center "spline" which adds a physical separation of the pairs as well.

This is a good time to bring up the subject of termination. In order to attach the wires to an RJ45 connector or Keystone jack the pairs must be untwisted to a degree that allows insertion. However, untwisting the pairs excessively can introduce crosstalk interference so it's always best to maintain the twist of each pair as much as possible.

It's said that network performance is only as fast as its weakest link. This is often at the point of termination and as a cumulative effect through multiple connections.

Types of Conductors

The conductors which make up each of the four twisted pairs can be either Solid or Stranded. This means that each conductor will be either a single solid wire or a wire consisting of (typically) 7 individual strands.

A solid conductor cable is commonly used on runs through walls and ceilings. It is more robust for pulling and can form around obstacles with ease. Though flexible, it cannot withstand repeated bending without

the risk of fracture. However, it does provide maximum performance over distance when compared to stranded conductor. Note that a typical wall plate mounted "keystone jack" requires a solid conductor to "punch down" into the jack terminals. All this makes solid conductor cable best for an install-it-and-leave-it solution.
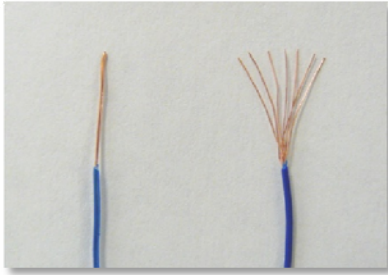
Solid vs Stranded

A stranded conductor cable is very flexible and can withstand frequent bending. This makes it ideal for use as "patch cables" for hardware inter-connectivity. While it can be used for longer runs, pulling on a length stranded cable runs the risk of breaking individual strands. Should this occur, there would be no visual indication and network performance would suffer.

Most all Ethernet cable conductors are made from pure copper. However, there has been an appearance of low-cost cable constructed from copper coated aluminum (CCA). The performance of such cable is questionable, particularly over distance. Also, the lower tensile strength of aluminum can cause the conductors to fracture easily. Most industry organizations advise against the use of CCA.

The Cable Jacket

The type of outer insulation of the cable (jacket) is an important consideration. From a building code standpoint the chemical makeup of the jacket plus where the cable is to be run within a construction is a matter of fire safety. Each type of jacket is tested and rated in terms of flame propagation. The "flame test" is conducted by UL (and others) and rated accordingly.

It should be noted that local building codes vary from town or region. For example, some regions require the use of plenum-rated cable regardless of installation type. Always check with the local building inspector for code compliance before installing any type of cabling.

Some of the various jacket types and purpose are:

Jacket Type	Designation	Application	Application
General Purpose	CM, CMX	General Purpose, UL-1581	Communications cable
Riser	CMR	Commercial, UL-1666	For use through walls and ceilings in non-plenum areas
Plenum	CMP	Commercial, UL-910	For use through a designated plenum space between floors
Outdoor	CMX	General Purpose, UL-1581	For above ground UV and water resistance
Direct Burial	CMX or HDPE	General Purpose, UL-1581	For below ground water and oil resistance

Be aware, there are some low-cost cables available with designations other than those listed above. In most cases these cables would not meet US building code standards and therefore not in compliance.

Interesting side note: *It's the resulting smoke rather than fire that causes catastrophic damage to building materials, particularly concrete. Water and PVC gases combine to produce hydrochloric acid. Anywhere a cable penetrates a fire-rated wall should be sealed with an approved "firestopping" material.*

What are my choices today for Ethernet Cable?

The approved Ethernet cable standards currently in use are:

Cable Type	Performance	Speed @ Distance	Speed @ Distance
Category 5e (enhanced)	100MHz	< 1 Gb/sec, 100 meters	1 Gb/sec, < 100 meters
Category 6	250MHz	1 Gb/sec, 100 meters	10 Gb/sec, < 55 meters
Category 6a (augmented)	500MHz	10 Gb/sec, 100 meters	> 10 Gb/sec, <100 meters

Each category represents an increase in performance at various maximum lengths. While all types utilize twisted pair conductors, the construction and performance characteristics of each vary. Also keep in mind that performance of the cable is only as good as its terminations and the hardware it's connected to.

A word about Cat 6a cable… Cat 6a is a somewhat different beast than regular Cat 5E or Cat 6. The wire gauge is a heavier 23 AWG and the jacket diameter is larger. This means that different RJ45 connectors, snagless boots and crimping tools are needed. Each of these is made specifically for 23 AWG, large diameter, Cat 6a cable. It's important to understand that to utilize the 10G capability of Cat 6a there must also be supporting 10G computer and network hardware.

Other classifications such as Category 6E, 7 and 7a have been offered by various manufacturers' outside of recognized EIA/TIA standards. It is up to the user to determine if such products are viable and appropriate for their application.

What's next? In 2016 EIA/TIA released an approved standard for Category 8 cable. Though not yet in production, it's expected to be the next step in performance above Cat 6a.

The Great MHz Mystery

People often ask for the MHz rating of a particular Category cable as a benchmark of performance. This rapidly becomes a point of confusion. The subject of rated bandwidth (MHz) must be viewed in two separate ways:

- TIA/EIA Published Standard
- Factory Tested Specification

For example, as a published standard, Cat 5e and 6 cables are rated at 100 and 250MHz respectively. However, most manufacturers will typically specify a rating of 350 and 550MHz respectively, implying superior performance. In fact, this is a "tested" rating by the manufacturer which has become something of a "pseudo" standard itself. Does this make a 350Mhz *tested* cable superior to 100Mhz *rated* cable? Not likely. All other factors must be weighed in equally which is difficult indeed without in-depth testing.

Simply put, when talking cable bandwidth, understand that "published" and "tested" are different numbers used to say essentially the same thing. If it meets the EIA/TIA published standard...then the cable is qualified.

Shielded vs. Unshielded Cable

Ethernet cables are available as shielded or unshielded. The shielded cable has its wire pairs surrounded by a common conductive layer. The shield layer may be composed of conductive Mylar film and/or braided strands of copper along with a ground (drain) wire. The individual twisted pairs may be shielded or the cable may utilize a single, overall shield or both. Shielded cables are usually thicker and more rigid than unshielded cables. As such, they also require a larger bend radius.

Unshielded Cable   *Shielded Cable*

When is Shielded Cable Required

The cable shield helps to mitigate electrical noise interference. EMI/RFI (electromagnetic/radio interference) is generated by an external source and can effect an electrical circuit through an electromagnetic coupling or induction. In an Ethernet cable, EMI disturbance can result in increased error rates, lowering performance or even to complete loss of data transfer. Common sources such as motors, generators, transformers and HID lighting can generate the electrical currents and voltages that cause EMI/RFI.

Alien crosstalk (AXT) is electromagnetic interference that can occur in a cable that runs alongside one or more other signal-carrying cables. The term "alien" arises from the fact that this form of crosstalk occurs between different cables in a group or bundle, rather than between individual wires within a single cable. Like EMI/RFI, alien crosstalk degrades the performance of data transfer by reducing the signal-to-noise ratio (S/N).

The shield serves three distinct purposes. First, to reduce electrical noise caused by nearby electrical equipment from affecting the signals passing through the cable. Second, to reduce electrical noise caused by the cable itself from effecting other adjacent cables and devices. Third, longer runs of cable have a greater potential for interference and shielding can help maintain performance.

Cables can be shielded using a number of different construction methods. The designating terminology has become much confused over the years. UTP and STP are often used as a general term to denote unshielded or shielded twisted pair cable.

Below is a comparison of some old and the most recent terminology according to **ISO/IEC 11801** standards**.**

Old name	New name	Cable Screening	Pair Shielding
UTP	U/UTP	none	none
STP	U/FTP	none	foil
FTP	F/UTP	foil	none
S-STP	S/FTP	braiding	foil
S-FTP	SF/UTP	foil, braiding	none
SFTP		foil	foil

U = unshielded
F = foil shielding
S = braided shielding
TP = twisted pair

The code before the slash designates the Screening or overall shielding of the cable, while the code after the slash determines the shielding for the individual pairs.

How to Ground Shielded Cable

The grounding of a shielded cable is widely misunderstood because of application differences between communications and other electrical cable types. In Ethernet cable, the ground consists of a separate bare "drain" wire which runs alongside the shield material inside the cable jacket. The ground connection is made in one of two ways:

1. Common Ground

Consider that all network cable runs have a starting point, typically from a patch panel, switch or router and moving to the point of use. As such, it is critical that the drain wire is grounded at one end only and that the ground points are common. This means that all the drain wires from all the cables come together as a common ground at the starting point. At the point of use, for example a keystone jack and wall plate, the drain wire is simply cut off.

Should the cable be grounded at both ends, an antenna is created which would both attract and radiate EMI/RFI interference. This is a bad thing. Even a shielded cable with no ground connection can potentially act as an antenna.

2. Ground Interconnection

Where cables are interconnected, the ground is passed from one end to the other through the connector terminations. These are specifically shielded RJ45 connectors that utilize a metal jacket to pass on the ground connection. The drain wire is typically wrapped around the cable at the connector crimp point to make contact with the metal jacket. When interconnecting cables the same common ground rule applies. The drain wires are ultimately grounded at one end only and all the ground points are common.

Important point: Since the ground connection is passed through the metal jacket of the RJ45 connector, one cannot assume the receiving end (hardware) does the same. In fact, most hardware connectors (female RJ45) such as computer network adapters, patch panels, switches and routers have a non-conducting plastic body. Hardware which is designated as "shielded" will have internal RJ45's with a metallic body which makes the ground connection coming from the cable.

As a work-around, it is possible to run the drain wire from the cable into the RJ45 connector and back out again as a "pigtail". A ground wire can then be attached and run to any convenient ground point that is not near an electrical panel. We suggest using the proper hardware instead.

Residential Application Note

Since EMI/RFI interference is not a common issue in residential applications there is no point to the extra cost and effort required to install shielded cable. Instead, following some general guidelines will insure maximum performance. Try to keep at least one foot away from power cables where possible. It's ok to cross a power cable if done at 90 degrees. Do not terminate Ethernet cable and power cable in the same outlet box.

For maximum cable performance over long distances or in environments where electrical noise is a serious issue, shielded cable is an ideal solution. Talk to our experienced professionals for tips on designing a network utilizing shielded components.

Is it a Quality Cable?

Specifications aside, the way a cable is manufactured does make a difference. Are the wire pairs inside the outer jacket too loose, firm or really tight? This will affect the bend radius and performance of the cable. Is the outer jacket too soft, firm or really hard? It may have an impact on installation in your application. These questions can be somewhat subjective but there really is a difference between Cable A and Cable B.

What about US vs. Off-shore Manufactured Cable?

Should you buy a Ford or a Toyota? Everyone has a passionate opinion towards both choices. Cable products manufactured in the US are generally consistent in terms of quality and performance. They can also cost considerably more than comparable off-shore alternatives.

Products manufactured off-shore can also be of excellent quality depending on the specific manufacturer. Because of low labor costs, these manufacturers can provide comparable products, often at a third of US prices.

When shopping for cables consider the reputation, expertise and experience of the Supplier. If in doubt, ask questions such as:

- Is the cable UL and/or ETL tested?
- Does the product have a holographic UL sticker?

- How long has the Supplier been working with the manufacturer?
- Are cable specifications and samples available?

As a general rule, when purchasing cable don't pay too much but don't pay too little. It doesn't need to be "Angus Beef" but remember, there are still no free lunches.

<u>In Summary</u>

Choosing the right cable along with proper installation will help insure that your network is providing maximum performance. "Good" advice is all over the internet and must be considered carefully. Installers are not always familiar with the issues surrounding Ethernet cable installation. Building codes can vary from county to county. Ask questions and when in doubt, talk to a professional.

What to Do Next

Got questions? Call us today to discuss your specific application and get expert advice. We want to help make your project a success!

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