Demystifying Ethernet Category Types

White paper

Introduction

Ethernet represents the plumbing pipes of the Internet. Many network installers and system integrators are familiar with Cat5e and Cat6 cables with RJ45 connectors. But the term “Ethernet”, encompasses an entire range of twisted pair and fibre cables that are constantly being upgraded and standardized by the Institute of Electrical and Electronics Engineers known as IEEE. Each new iteration of Ethernet, or category, supports increasingly faster bandwidth speeds and improves upon noise cancelation.

Ethernet cables often referred to as a wired connection to the Internet. An Ethernet cable can be any of several common network cables used to access the web. Local area networks, referred to as LANs, need Ethernet cables to connect to personal computers and routers. Ethernet cables support Category 5 (CAT5), Category 6 (CAT6) or Category 6A (CAT6A) industry standards.

All Ethernet cables serve the same basic purpose to connect devices to networks, like the internet. Not all Ethernet cables are exactly the same. However, if you’ve ever found yourself in need of an Ethernet cable without any idea which one you should pick, then this paper will help you. Ethernet designations, like many things in today’s world of modern technology, can be difficult to interpret and understand. This white paper explores find out which cable is right for you and your situation.

Ethernet cables are grouped into sequentially numbered categories (“cat”) based on different specifications; sometimes the category is updated with further clarification or testing standards (e.g. 5e, 6a). These categories are how we can easily know what type of cable we need for a specific application. Manufacturers are required to adhere to the standards, which makes lives easier.

Balanced Twisted-Pair Cables

Metallic conductor cables commonly use balanced twisted-pair construction. Production of small cables of this type involves twisting individual pairs and grouping those twisted pairs to form either a cable or a unit for larger cable.

The main reason for twisting pairs of conductors is to minimize crosstalk and noise by decreasing capacitance unbalance and mutual inductance coupling between pairs. Twisting conductors also improves the balance (physical symmetry) between conductors of a pair and reduces noise coupling from external noise sources.

Pair-to-pair capacitance unbalance is a measure of the electrical field coupling between two pairs if a differential voltage is applied on one pair and a differential noise voltage is
measured on another pair in close proximity. Mutual inductance is a measure of the magnetic field coupling between two pairs if a differential current is applied on one pair and a differential noise current is measured on another pair in close proximity.

The conditions under which crosstalk is measured include both capacitance unbalance and mutual inductance coupling effects.

Pair Twists - Both mutual inductance and capacitance unbalance are affected by the relative length and uniformity of pair twists. To minimize crosstalk.

Tight Twisting – All copper LAN cables employ tight twisting for optimum transmission performance. Tight twists tend to preserve their shape better in a cable. Longer twists tend to nest together as they are packed in a cable—shorter, tighter twists are less likely to deform.

The twisting of each pair of wires provides a cancellation effect that helps neutralize noise and null out interference. Interference such as EMI and RFI tends to be cancelled out. They are limited in distance, bandwidth and data rate due to problems with attenuation, interference and noise. The issue to be cross-talk due to interference from other signals. Shielding with metallic braid or sheathing helps reducing this interference. Twisting also reduces low-frequency interference and crosstalk.

Twisted pair became the basis for all Ethernet cables to eliminate interference between internal and external wires.

What does “Cat” mean?

The cables are nearly always classified as “CAT5,” “CAT6e,” or something similar thereof. “Cat” simply stands for “Category,” and the following number indicates the specifications to which the cable was manufactured. A general thumb is that higher numbers represent faster speeds and higher frequencies, measured in Mhz. As is the case with most technologies, newer cables tend to support higher bandwidths, and therefore increased download speeds and faster connections.

Keep in mind that longer Ethernet cables will result in slower transmission speeds, though cables bought for personal use rarely exceed 100 metres, where speed drop-off typically begins to occur.

Different Ethernet Classes and Categories

Ethernet cabling differences can be invisible to the casual observer. However, each new generation introduces copper pairs with tighter twists and more complex sheathing. Many earlier Ethernet generation cables have become obsolete.

Category is the term used to distinguish the grades of twisted-pair cables, patch panels, communication outlets. Class is the specification for system application on full channel. Below is the application classification for the respective ISO classes:

ISO Classes	Frequency Characteristics
Class A	For applications up to 100KHz Voice Telephony
Class B	For applications up to 1MHz Voice and medium speed data rates such as IBM 3270 Terminals
Class C	For applications up to 16MHz Token Ring
Class D	For applications up to 100MHz High speed data such as 10Base and 100 Base Ethernet.
Class E	For applications up to proposed 250MHz Fast Ethernet 1000 Base
Class E_A	For applications up to proposed 500MHz
Class F	For applications up to 600MHz
Class F_A	For applications up to 1000MHz
Optical Class	For applications above 10 MHz Very high bit rate where bandwidth is not a limiting factor

The differences in cable specifications is not as easy to see as physical changes. So, let’s look at what each category does and does not support. Below is a chart for reference when picking cable for your application based on the standards for that category:

Category Cable Comparison

	Frequency Supported *	Ethernet Signal Supported	Shielded	Connector	Conductor Pairs	Applications
Cat 5	1-100MHz	10/100Base T	Optional	8p8c RJ45	4	Small office, home office, schools
Cat5e	1-100MHz	10/100Base T Gigabit Ethernet	Optional	8p8c RJ45	4	
Cat6	1-250MHz	10/100Base T Gigabit Ethernet	Optional	8p8c RJ45	4	Large enterprise, university campuses, high speed applications
Cat6a	1-500MHz	10/100Base T Gigabit Ethernet 10Gig Ethernet	Optional	8p8c RJ45	4	
Cat7	1-600MHz	10/100Base T Gigabit Ethernet 10Gig Ethernet	Individual Pair & Overall Cable Shield	GG45 TERA	4	Data center backbone, high speed and bandwidth intensive applications
Cat7a	1-1000MHz	10/100Base T Gigabit Ethernet 10Gig Ethernet	Individual Pair & Overall Cable Shield	GG45 TERA	4	

Category 3

Cat3 cable is an earlier generation of Ethernet but can still be seen in older deployments. With the ability to support a maximum frequency of 16 MHz, this type of Ethernet can still be used for two-line telephone systems and 10BASE-T networks. CAT3 cable can also be used for alarm system installation or similar applications. CAT3 cable can have 2, 3, or 4 copper pairs (though uncommon). Category 5e cable however, has become the default Ethernet category of choice with the ability to support faster speeds and frequencies.

Category 5

Cat5 Ethernet, introduced 10/100 Mbps Ethernet, also known as Fast Ethernet. Even though some older deployments still use CAT5 cable, it is now considered obsolete and has since been replaced by Cat5e.

Category 5e

Cat 5e (the “e” indicates “enhanced”), is a version of Cat 5 designed to decrease crosstalk, enabling speeds of up to 1000 Mbps – or “Gigabit Ethernet” as it’s more commonly known. Though Cat5 and Cat5e cables are physically similar, Category 5e Ethernet adheres to more stringent IEEE standards. Cat5e is the most common type of cabling used for deployments due to its ability to support Gigabit speeds at a cost-effective price.

Even though both Cat5 and Cat5e support a maximum frequency of up to 100MHz, Cat5e has completely replaced its predecessor. Gigabit Ethernet utilizes 4 data pairs in comparison to Fast Ethernet which utilizes 2 data pairs.

Category 6

Cat 6 cables support much higher bandwidths than Cat 5 and Cat 5e cables, though they're also more expensive. Cat6 wiring can support up to 10 Gbps and frequencies of up to 250 MHz. While Cat5e cable features 1.5-2 twists per cm, Cat6 cables are more tightly wound and feature 2 or more twists per cm. (The amount of twists per cm varies upon each cable manufacturer). Cat6 cables also sport thicker sheaths in comparison to Cat5e. It is completely compatible with existing Cat 5e and Cat 5 devices. Though standard Ethernet supports distances of up to 100 metres, CAT6 cable only supports 37-55 metres (depending on crosstalk) when transmitting 10Gbps speeds. Its thicker sheath protects against Near End Crosstalk (NEXT) and Alien Crosstalk (AXT). Even though Cat6 and Cat6a cabling offers higher performance rates, many LANs still opt for CAT5e due to its cost-effectiveness and ability to support Gigabit speeds.

Physically, Cat 6 cabling has more twists in each pair, and has a plastic separator spine running through the centre, reducing crosstalk and enabling the higher speeds. Cat 6a is a new standard designed to support 10 Gbps over the full 100-metre length.

Category 6A

The "a" in Cat 6a stands for "Augmented." In comparison to the regular Cat 6 cables, 6a cables support twice the maximum bandwidth, and are capable of maintaining higher transmission speeds over longer cable lengths. Cat 6a cables are always shielded, and their sheathing which is thick enough to eliminate crosstalk completely makes for a much denser, less flexible cable than Cat 6.

Cat6A can support bandwidth frequencies of up to 500 MHz, twice the amount of Cat6 cable, and can also support 10Gbps like its predecessor. However, unlike Cat6 cabling, Cat6a can support 10 Gigabit Ethernet at 100 meters. Cat6 cabling on the other hand, can transmit the same speeds at up to 37 meters.

Cat6a also features more robust sheathing which eliminates alien crosstalk (AXT) and improves upon the signal-to-noise ratio (SNR). The stronger sheathing makes Cat6a cabling considerable thicker than Cat6.

Category 7

Cat 7 cables utilize the newest widely-available Ethernet technology, and support higher bandwidths and significantly faster transmission speeds than Cat 6 cables. They're proportionally more expensive than other Ethernet cables, though their performance reflects their premium price tag. Cat 7 cables are capable of reaching up to 100 Gbps at a range of 15 meters, making them an excellent choice for connecting modems or routers directly to your devices. The cabling can support frequencies of up to 600 Mhz.

Cat7 offers extensive shielding to reduce signal attenuation and is relatively stiff in comparison to previous generations of cabling. The shielding needs to be grounded and Cat7 also requires special GigaGate45 (CG45) connectors. Currently, this category is not recognised by TIA/EIA.

Category 8

Cat8 cable is still in the development stage. We can expect them to hit the market relatively soon, however, with faster maximum speeds and higher maximum bandwidths than Cat 7 cables. According to the 2015 Ethernet Alliance Roadmap, it will be able to support 25GB and 40Gb Ethernet. Cat8 will be able to support even faster transmission rates at distances of up to 30 meters.

How to choose the right cable?

- The easiest way to select a cable is to pick the one with the range and performance you need.
- Start with the speed of your home Internet connection. If you have Gigabit Internet, an old Ethernet cable will hold you back. But if you have a slow connection, say 10 or 20 megabits per second, you're good with anything Cat 5 or newer.
- Next, consider the speed you need for your network. This is frankly irrelevant for most home users. But if you move big files between computers frequently, or you stream extremely high-bandwidth video content, a better Ethernet cable can make a difference.

- Finally, consider your router. So, cheap routers only support Ethernet up to 100 megabits per second, so it's going to bottleneck anything newer than Cat 5. Even the best home routers rarely support better than Gigabit Ethernet, so Cat 6a and Cat 7 are of questionable use.

With all of the above consider, a Cat 6 cable is the most you'll likely need, and most homes can get away with Cat 5e.

It's What's on the Inside That Counts: Shielded Vs. Unshielded

Twisted pair copper comes in shielded and unshielded forms. Shielded copper cable includes protective conductive coating such as braided strands of copper, copper tape or conductive polymer to reduce noise interference. Shielded Twisted Pair (STP) cables have an extra layer of protection that will help to reduce cross talk and other interference. Typically, the twisted cables have a layer of foil surrounding them inside the PVC, LSZH or PE jacket.

Unshielded Twisted Pair (UTP) cable, includes no shielding and is ideal for most common LAN environments. The wires are bundled inside a rubber sleeve with no other protection. Since STP cables are thicker, they don't offer the same flexibility that UTP cables do. If you need a more flexible cable and won't have too many cables in close proximity to one another than UTP would be best.

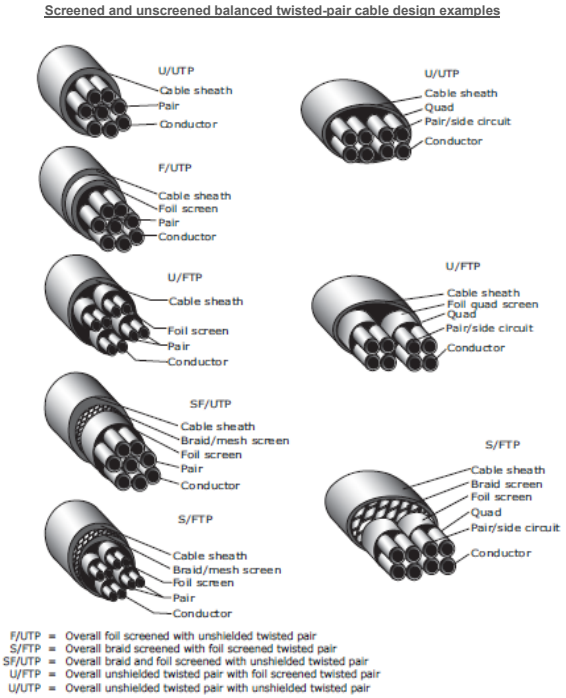
Shielded twisted copper pairs, are reserved for networking environments with higher frequencies. If you think that your cabling will be affected by high interference or you want them to be run inside walls or outdoors than STP will be the right choice. There are many types of shielded copper pairs. Sheathing can also envelop all four data pairs. Sheathing can wrap around twisted pairs. STP is more expensive, but the signal doesn't degrade as much over longer distances – it's commonly used in areas with heavy machinery or other interference.
TP: Twisted Pairs. This terminology refers to the way that the wires inside the cable are twisted together. Twisted Pair has been an industry standard for years, and is only inferior to fibre optic cabling in terms of maximum length and speed drop-off.
From basic unshielded, UTP to braid and foil shielding options there is a cable design for every application.

U/UTP: Unshielded Twisted Pair
Cables designated UTP won't have foil or braided shielding, which makes the cable cheaper to produce and more flexible, but you'll sacrifice signal quality and increase vulnerability for crosstalk. The UTP cable consists of pairs of wires twisted together. This is one of the most basic methods used to help prevent electromagnetic interference.

STP/FTP: Shielded Twisted or Foiled Pair
STP and FTP offer an additional layer of protection with shielding (also called screening) wrapped around the individual twisted wires. This protects against EMI/FRI and crosstalk.
Shielding reduces noise and, therefore, improves connection quality.

S/UTP & F/UTP: Shielded/Screened or Foiled Unshielded Twisted Pair
This has an overall foil or braid screen encasing the 4 pairs of unshielded twisted pairs

S/FTP: Shielded and Foiled Twisted Pair
A combination of the two above, with foil shielding around the individual twisted wires and an overall screen which can sometimes be a flexible braid. This provides the maximum level of protection from interference and is found in the highest performance cables.



Solid vs. Stranded Ethernet

Solid and stranded Ethernet cables refer to the actual copper conductor in the pairs.

Solid cable uses a single piece of copper for the electrical conductor while stranded uses a series of copper cables twisted together.

There are many different applications for each type of conductor, but there are two main applications for each type you should know about.

Stranded copper cables comprise of several thin copper cables. Stranded cable is more flexible and should be used at your desk or anywhere you may be moving the cable around often. Solid cable is not as flexible but it is also more durable which makes it ideal for permanent installations as well as outdoor and in walls.

Conclusion

Whether you are a consultant designing a new cabling infrastructure for a new costumer or an IT manager who is tasked with designing a new datacentre, choosing the best cabling system for a premise LAN or a datacentre can be a daunting task. Fortunately, there are industry standards and best practises to help select and deploy the right cabling system. Therefore, it is very important for making an informed decision to select the right copper cabling system for your next premise LAN or datacentre project. The differences between the categories and how to know when to use unshielded, shielded, stranded, or solid cable is known.

In today's economy, IT managers are more concerned with project budgets, material costs, and installation time than ever before. It's more critical than ever to choose the right type of structured cabling system for every project. Structured cabling solutions should be chosen based on the required Ethernet protocol. The TIA, ISO, and IEEE standards bodies specifically designed in sufficient headroom and bandwidth to provide reliable transmission performance for the required Ethernet protocol. Consider going with Cat6 if you are not under budget constraints, but want Cat 6's added headroom to compensate for potential poor installation practise. However, please keep in mind that proper installation should not be an issue if you are buying an end-to-end cabling system that's being installed by a certified installer and is being backed by an extended warranty. Choose Cat6A if you are looking for a cost-effective alternate to fibre in the datacentre or you want to future proof your cabling infrastructure. Finally, don't contemplate Cat 8 until the TIA and ISO standards for this cabling system are ratified. Even then, it's likely that Cat8 will only be suitable for the datacentre or for users who require ultra-high data transmission. Please do your homework, plan for the long run, and look at the big picture. These tired but true clichés will ensure long-term performance of your Ethernet copper cabling system.

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