# Basic understanding of Structured Ethernet Cabling

*Version: 2023-05-29*

## Basic considerations

These are some of the primary considerations to keep in mind when deciding what kind of cabling to use in your network.

- Network equipment and the required bandwidth.
- Anticipated changes and upgrades in equipment and applications.
- The maximum distance between devices on the network, including switches, routers, PCs, and other network hardware.
- Available space for adding new cable runs and equipment.
- EMI/RFI levels where cables and equipment are installed.
- Existing cable installations — will they support future upgrades and, if not, can they be re-used for applications that don't require better performance or more bandwidth.
- The costs for fibre optic cable, components, and hardware is steadily decreasing. Installation costs for fibre optic are higher than copper because of the skill needed for terminations. Fibre optic typically costs less to maintain, has much less downtime, and requires less networking hardware.

**Copper cables**
The need for increased bandwidth never ceases. Applications keep getting more complex, and it won't be long before you need to increase your network's speed.
Doing so may mean upgrading your cable. Twisted-Pair copper cable is the most common networking cable. Let's take a look at the choices you have to make to select the right high-performance Twisted-Pair cable.

1. CAT5e, CAT6, CAT6a and more
   Depending on your needs for quality and speed of your data communication you need to choose between the different possible standards. As a rule of thumb, always use the same or better cable grade as in your fixed cabling.

2. Basic, moulded or snagless
   Moulded boots prevent cable kinks in crowded patch panels, Snagless boots also protect the locking strip. Basic connectors give you reliable performance at reduced prices.

3. Shielded versus Unshielded
   The environment determines whether cable should be shielded or unshielded. Shielding is the sheath surrounding and protecting the cable wires from electromagnetic leakage and interference.

4. Straight-pinned versus Crossover
   Straight-pinned cable has the most common type of pinning. The send and receive pairs are wired straight-through on either end of the cable.
   Crossover cable is generally used for peer-to-peer connections. The send and receive pairs are crossed between Connector A to Connector B on either end of the cable. See page 6 for a graphical explanation.

5. Solid versus stranded conductor cables
   Solid conductor cables, designed for horizontal! and backbone cable runs, should not be flexed, bent or twisted repeatedly. Our patch cables with stranded conductors are excellent for applications that call for repeated flexing without damaging the cable.

## Difference between Cat5, Cat5e, Cat 6, and Cat7

Ethernet represents the plumbing pipes of the Internet. Many network installers and system integrators are familiar with the ethernet types: Cat5e and Cat6 cables with RJ45 connectors. But the term "Ethernet", co-invented by Robert Metcalfe, encompasses an entire range of twisted pair and fiber 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.

### Different Ethernet 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.

| | Cat 5 | Cat 5e | Cat 6 | Cat 6a | Cat 7 |
|---|---|---|---|---|---|
| Cable Type | UTP | UTP or FTP | UTP or STP | STP | S/FTP |
| Max Speed | 10/100 Mbps | 10/100/1000 Mbps | 10/100/1000 Mbps | 10 Gbps | 10 Gbps |
| Max Bandwidth | 100 MHz | 100 MHz | 250 MHz | 500 MHz | 600 MHz |
| Max length @ Max Speed | 100 m @ 100 Mbps | 100 m @ 1000 Mbps | 100 m @ 1000 Mbps | 100 m @ 10 Gbps | 100 m @ 10 Gbps |
| Max Speed @ Max Length | 100 Mbps @ 100 m | 1000 Mbps @ 100 m | 10 Gbps @ 55 m | 10 Gbps @ 100 m | 10 Gbps @ 100 m<br>40 Gbps @ 50 m<br>100 Gbps @ 15 m |
| Attenuation (min. @ 100 MHz) | 22dB | 22dB | 19.8dB | - | 20.8dB |
| Characteristic Impedance | 100 ohms + 15% | 100 ohms + 15% | 100 ohms + 15% | - | 100 ohms + 15% |
| NEXT (min. @ 100 MHz) | 32.3 dB | 35.3 dB | 44.3 dB | 27.9 dB | 62.1 dB |
| PS-NEXT (min. @ 100 MHz) | - | 32.3 dB | 42.3 dB | - | 59.1 dB |
| ELFEXT (min. @ 100 MHz) | - | 23.8 dB | 27.8 dB | 9.3 dB | - |
| PS-ELFEXT (min. @ 100 MHz) | - | 20.8 dB | 24.8 dB | - | - |
| PS-ANEXT (min. @ 500 MHz) | - | - | - | 49.5 dB | - |
| PS-AELFEXT (min. @ 500 MHz) | 16.0 dB | 20.1 dB | 20.1 dB | 23.0 dB | 14.1 dB |
| Return Loss (min. @ 100 MHz) | 16.0 dB | 20.1 dB | 20.1 dB | 8.0 dB | 14.1 dB |
| Delay Skew (max. per 100m) | - | 45ns | 45ns | - | 20ns |

***Category 5***
Cat5 Ethernet introduced 10/100 Mbps Ethernet over distances of up to 100 meters, 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***
Though Cat5 and Cat5e cables are physically similar, Category 5e Ethernet adheres to more stringent IEEE standards. "e" is for enhanced, meaning a lower-noise version where the potential for crosstalk is reduced. Crosstalk is interference that transfers from adjacent wires. 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 all 4 data pairs in comparison to Fast Ethernet which utilizes only 2 data pairs. Further, Cat 5e supports speeds of up to 1000 Mbps. It's flexible enough for small space installations like residences, though it is still used in commercial spaces. Of all the current cabling options, Cat5e is your least expensive option.

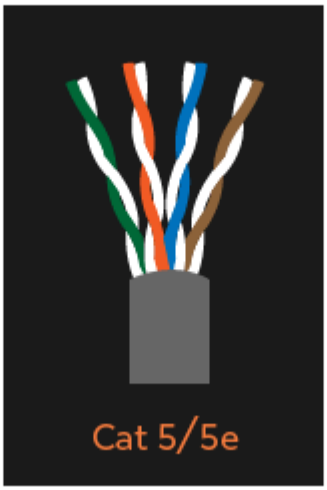
Category Se (CATSe) is designed to enable cabling to support full-duplex Fast Ethernet operation and Gigabit Ethernet. You can expect problem-free full-duplex, 4-pair Ethernet transmissions over your CAT5e UTP, sweep tested and characterized to 350 MHz. We advise you to use CAT5e instead of older standards.

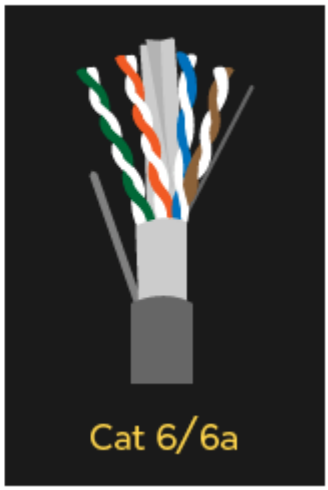
***Category 6***
Cat6 wiring can support up to 10 Gbps and frequencies of up to 250 MHz. While Cat5e cable features 1.5-2 twists per cm, Cat6 cables are more tightly wound and feature 2 or more twists per cm. Note that the amount of twists per cm varies upon each cable manufacturer.
Cat6 cables also sport thicker sheaths in comparison to Cat5e. Though standard Ethernet supports distances of up to 100 meters, CAT6 cable only supports 37-55 meters, depending on crosstalk, when transmitting 10 Gbps speeds. Its thicker sheath protects against Near End Crosstalk (NEXT) and Alien Crosstalk (AXT).
Even though Cat6 and Cat6a cabling offer higher performance rates, many LANs still opt for CAT5e due to its cost-effectiveness and ability to support Gigabit speeds.

CAT6 cables for all your high-performance applications - CAT6 provides a much higher performance than CAT5e and features more stringent specifications for crosstalk and system noise. The quality of the data transmission depends on the performance of the components of the channel.

***Category 6a***
Cat6a supports 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 Gbps at 100 meters.
Cat6a also features more robust sheathing which eliminates alien crosstalk (AXT) and improves upon the signal-to-noise ratio (SNR). "A" = augmented. The stronger sheathing makes Cat6a cabling considerably thicker than Cat6, also making it less flexible to work with, and therefore, better suited for industrial environments at a lower price point.

Cable designed for 10/100/1000BASE-T applications - CAT6a is a 10-Gigabit Ethernet over copper proposal to the CAT6 standard. Available as PVC or LSZH




***Category 7***

Cat7 can also support 10 Gbps, but laboratory testing has successfully shown its ability to transmit up to 40 Gbps at 50 meters and even 100 Gbps at 15 meters. The newer "Class F" cabling can support frequencies of up to 600 Mhz. That said, Cat7 has not been approved as a cable standard for telecommunications.

Cat7 offers extensive shielding to reduce signal attenuation and is relatively stiff in comparison to previous generations of cabling. Both individual pairs are shielded, with an additional layer of shielding over the entire cable. The shielding needs to be grounded and Cat7 also requires special GigaGate45 (GG45) connectors to take full advantage of higher performance features. All in all, Cat6a can perform just about the same as Cat7 but at a lower price point. Most of our AV and IP surveillance customers opt for Cat6a STP or Cat6a FTP. Both offer shielding from alien crosstalk and interference around high voltage lines.

Cat7 is suited for use in datacenters and large enterprise networks.

***Category 8***

Cat8 cable is still in the development stage and not yet ratified. According to the 2016 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.

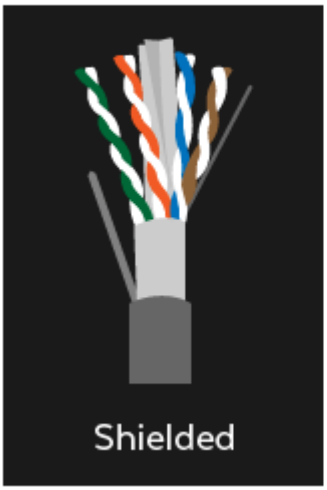
**How to know what types of ethernet cabling to buy once deciding on a CAT type**
Answer the following questions to narrow down to your requirements:

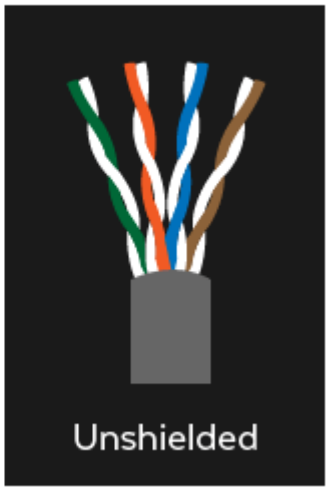
- Will the cables be within 6 inches alongside power lines, lights or other RF radiating devices?
- Are you looking for burial cables with UV protection?
- Will the cables be in walls?
- Is flame resistance cabling required for the installation?

Each cable category has various types of insulation or shielding that installers need to take into consideration before purchasing. There's no one answer to all questions but the answers to these questions should help the reader decide based on their project.

**Why are copper pairs twisted?**
When telephone lines were first deployed alongside power lines, Alexander Graham Bell, popularly known as the inventor of the telephones, was the first person to twist copper pairs to reduce crosstalk between the lines. Twisting the copper cable every 3-4 utility poles allowed for the reduction of electromagnetic interference and an increase in range. Ethernet copper cables adopted the same technique to reduce crosstalk between internal wires (NEXT = Near End Cross Talk, FEXT = Far End Cross Talk) and external wires (AXT – Alien Cross Talk).

**Shielded (FTP) vs. Unshielded (UTP)**
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. Unshielded Twisted Pair, or UTP, includes no shielding and is ideal for most common LAN environments. Shielded twisted copper pairs, are reserved for networking environments with higher frequencies.




There are many types of shielded copper pairs. Sheathing can also envelop all four data pairs. Sheathing can wrap around twisted pairs. There are two sections to a shielded "code". The first letter signifies the type of shield used to enclose all four twisted pairs of an Ethernet cable. An Unshielded cable is marked with a (U), a cable with Foil Shielding is marked with an (F), and a cable with Braided Shielding is marked with an (S). The second portion of the code, describes if a twisted pair is foiled (F) or Unfoiled (U). TP stands for Twisted Pair.

The environment determines whether cable should be shielded or unshielded. Shielding is the sheath surrounding and protecting the cable wires from electromagnetic leakage and interference.
Sources of this electromagnetic activity (EMI) - commonly referred to as noise - include elevator motors, fluorescent lights, generators, air conditioners and photocopiers.

To protect data in areas with high EMI, choose a shielded cable. Shielding also protects cables from rodent damage. Foil is the most basic cable shield, but a copperbraid shield provides more protection.
Use a foil-shielded cable in busy office or retail environments. For industrial environments, you might want to choose a copperbraid shield.
For quiet office environments, choose unshielded cable

**Shielding Code:**

U : Unshielded
F : Foil Shielding
S : Braided Shielding
TP : Twisted Pair

**Types of Shielded Ethernet Cables**

- **F/UTP**– Foiled/Unshielded Twisted Pair
  Common in Fast Ethernet deployments, this cable will have a foil shield that wraps around unshielded twisted pairs.

- **S/UTP**– Braided Shielding/ Unshielded Twisted Pair
  This cable will wrap a braided shield around unshielded twisted pairs.

- **SF/UTP**– Braided Shielding+Foil/Unshielded Twisted Pairs
  This cable braids a shield around a foil wrap to enclose unshielded twisted pairs.

- **S/FTP**– Braided Shielding/Foiled Twisted Pair
  This cable wraps a braided shield around all four copper pairs. Additionally, each twisted pair is enveloped in foil.

- **F/FTP**-Foiled/Foiled Twisted Pair
  This cable encloses all copper pairs in foil. Additionally, each twisted pair is enveloped in foil.

- **U/FTP**-Unshielded/Foiled Twisted Pairs
  This cable only envelopes the twisted pairs in foil.

- **U/UTP**-Unshielded/UnshieldedTwisted Pair
  No sheathing is used. Standard Cat5e cable are examples of U/UTP cables.

**Solid vs. Stranded Ethernet**
These terms refer to Ethernet conductors. Stranded copper cables comprise of several thin copper cables. Solid cable conductors comprise of a single, thick copper cable conductor.

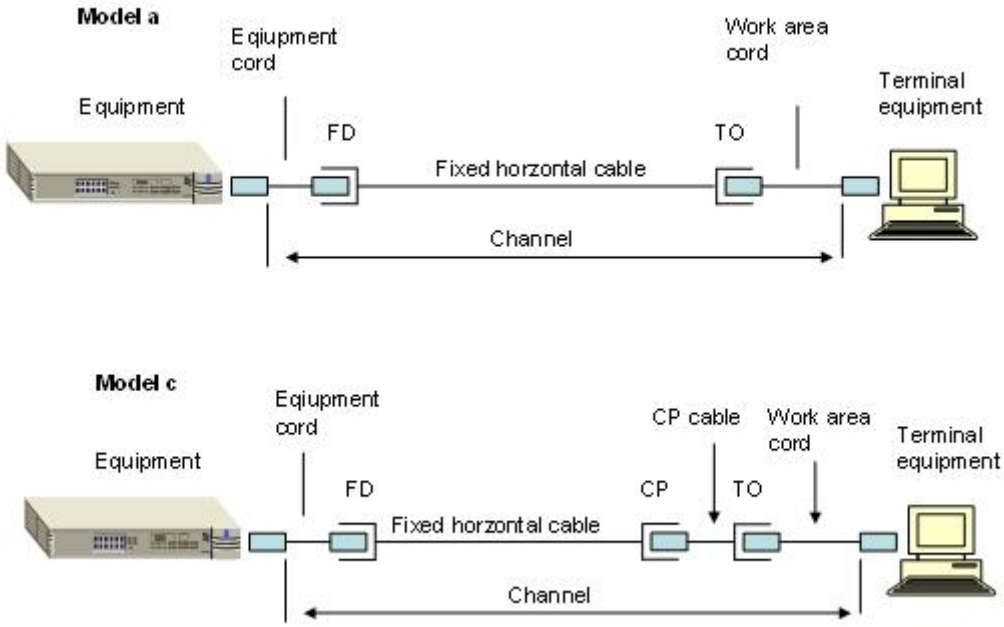
**LSZH = Low Smoke Zero Halogen**
The European market is demanding that cables used in LANs, WANs, etc. meet this specification. The IEC 60332-1 governs the Flame Retardant Grade specifications in already reference to LSZH cables.

Essentially, the compound used in manufacturing cables meeting the above specification reduces the amount of dangerous/poisonous gases in case of fire. The main difference in specifications between IEC 60332-1 versus UL® 1581, UL 1666 and UL910 is that the cable under the IEC spec can continue to burn while still emitting very low gases. The UL specs demand that the flame be extinguished, but it can still emit dangerous/poisonous gases.

Today virtually all medium and large installations in Europe must meet the IEC specification. Many public authorities are demanding that new installations must meet IEC 60332-3 which is a more demanding flammability specification for LSZH.

Physically, PVC and LSZH are very different. PVC patch cords are very soft; LSZH patch cords are more rigid because they contain the flame retardant compound, and they are aesthetically more pleasing.

## Calculus of standard horizontal network cabling




CD : Campus distributor
BD : Building distributor
FD : Floor distributor
CP : Consolidation point
TO : Telecommunications outlet

The basic principle is that:

In the model a of figure, the fixed horizontal cabling is continuous from the patch panel of the floor distributor to the telecommunications outlet.
In model c, the consolidation point (CP) is included and the fixed horizontal cabling extends only to the consolidation point. From consolidation point the cabling runs as the CP cable to the telecommunications outlet.
In the both models the channel also includes the equipment cord in the floor distributor and the work area cord in the work area.

The equations shown below can be used to determine the lengths of different cabling sections for models a and c, when the performance of the cables, cords and connecting hardware are known. The equations are based on the following assumptions:

- The cables used in equipment and work area cords are flexible cables, which have maximum 50% greater attenuation than the fixed horizontal cable.
- The cables used in equipment and work area cords have the same attenuation per length unit.
- The cable used in the CP cable may of the same type as the fixed horizontal cable or it may be a flexible cable. The attenuation of CP cable may differ from that of both the fixed horizontal cable and the flexible cables.

| Model | Length equation for the channel | | |
|---|---|---|---|
| | **Class D = Cat 5** | **Class E = Cat 6** | **Class F = Cat 7** |
| a | H = 109 – FX | H = 104 – FX | H = 105 – FX |
| c | H = 107 – FX – CY | H = 103 – FX – CY | H = 103 – FX – CY |
| H = maximum length of fixed horizontal cable in meter<br>F = combined length of equipment cord and work area cord in meter<br>C = length of CP cable in meter<br>X = ratio of flexible cable attenuation (dB/m) to fixed horizontal cable attenuation (dB/m)<br>Y = ratio of CP cable attenuation (dB/m) to fixed horizontal cable attenuation (dB/m) | | | |

In addition to table the following restrictions apply:

1. The physical length of the channel shall not exceed 100 m.
2. The physical length of the fixed horizontal cable shall not exceed 90 m.
3. When a multi-user telecommunications outlet assembly is used, the length of the work area cord should not exceed 20 m.
4. When a consolidation point is used, it should be located at least 15 m from the floor distributor.
5. The physical length of the equipment cord shall not exceed 6 m.
6. The physical length of the work area cord shall not exceed 3 m.

*Example:*

- We will ue Cat 6 cabling = Class E with consolidation point
- Combined length of equipment cord (3 m) and work area cord (2 m) is F = 5 m
- Length of CP cable C = 6 m
- Attenuation of equipment cord and work area cord is 50 % greater than that of fixed horizontal cable so X = 1.5
- Attenuation of CP cable is same as that of fixed horizontal cable so Y = 1

So, what is maximum length of fixed horizontal cable (FD-CP)?

Maximum length of fixed horizontal cable:

H = 103 – FX – CY = 103 – (5 * 1.5) – (6 * 1) = 89.5 m

Checking restrictions:

1. Channel length = 5 + 6 + 89.5 = 100.5 m which is greater than 100 m so the max fixed horizontal cable length can be 89 m and not 89.5 m.
2. Fixed horizontal cable length = 89 m is smaller than 90 m and hence OK
3. Length work area cord is 2 m which is smaller than 20 m so OK.
4. We use a consolidation point which is max located at 89 + 6 = 95 m which much bigger than 15 m so OK.
5. The physical length of the equipment cord is 3 m and does not not exceed 6 m so OK.
6. The physical length of the work area cord is 2 m and does not exceed 3 m so OK.