

Module 4 - Copper Cabling, Bandwidth & Configurations



This module looks at the principles of the cable, the different constructions and why we use them. We cover the basics of transmission and how remote powering or PoE is provided simultaneously as the communications signal. We also start to look at why the way the cable is installed can have an impact - more detail will be covered in Module 6. Finally we will cover the different categories and classes and the bandwidth throughput each one can achieve.

- ≡ Principles of Cable
- ≡ Cable Constructions
- ≡ Categories and Classes
- ≡ Topologies
- ≡ Single Pair Ethernet

Principles of Cable

Dielectric Path

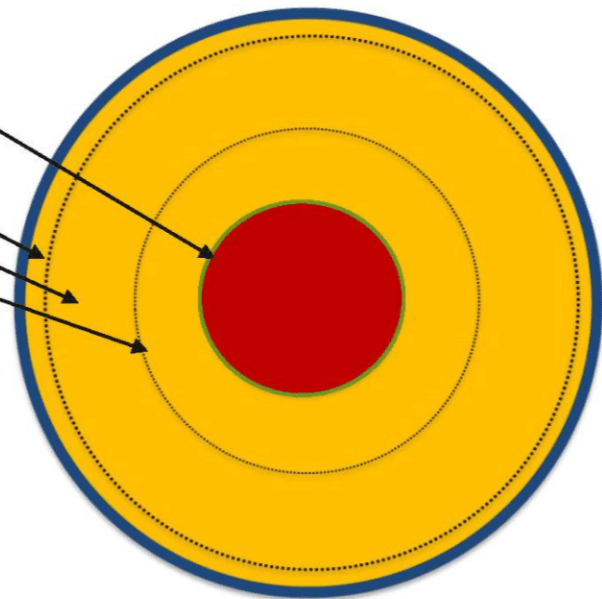
- 50Hz 32.2VDC - IEEE 802.3af PoE+
- 100 MHz Class D - 32.5MHz application requirement
- 250 MHz Class E - 200 MHz application requirement
- 500 MHz Class Ea - 400MHz application requirement

IEEE 802.3bt 4PPoE

100 MHz Class D

250 MHz Class E

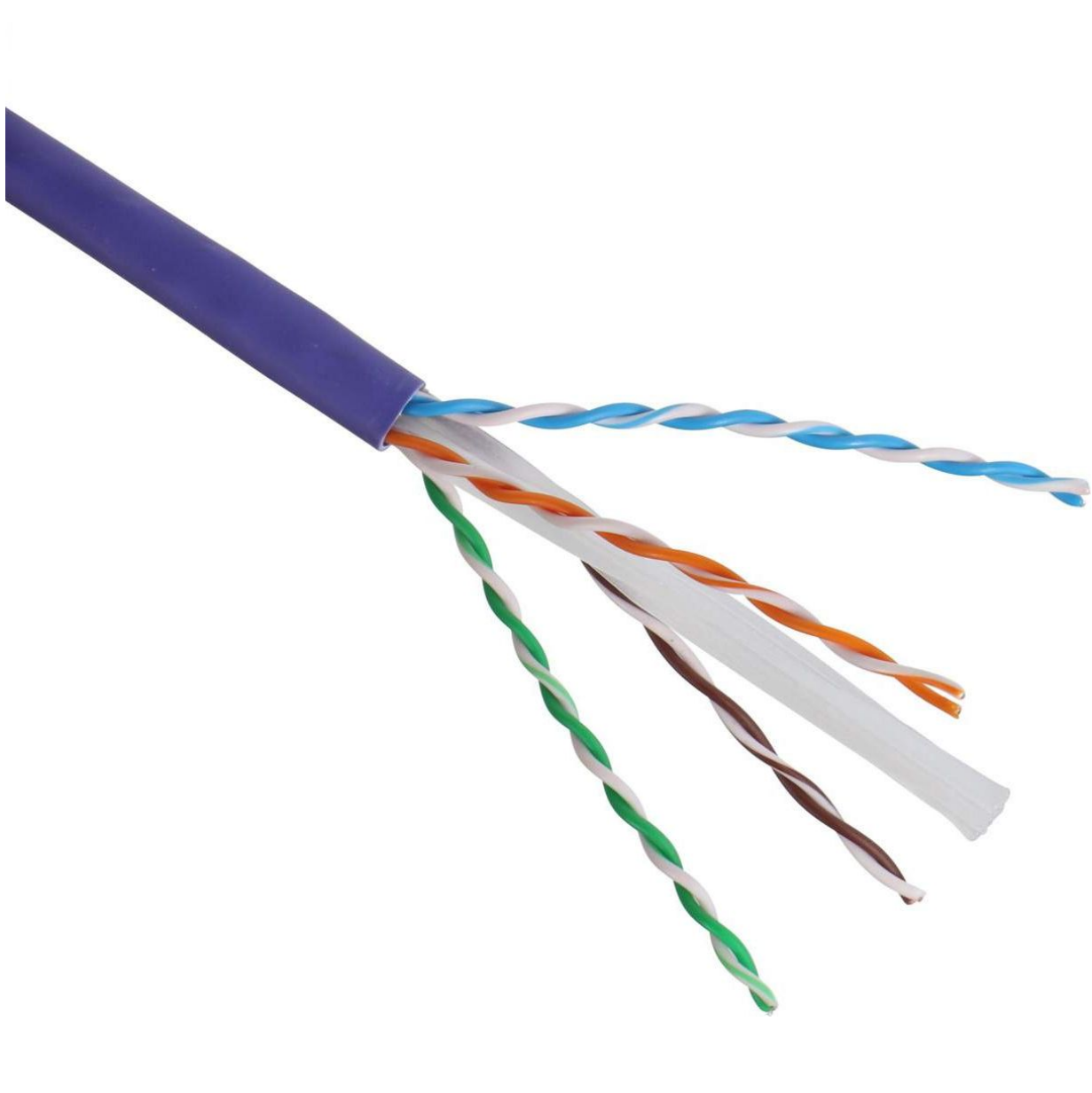
500 MHz Class Ea



Balanced Twisted Pair Cables

- 4 twisted pairs of wires

- Plastic jacket contains the four pairs
- 22-24 AWG
- Twisted pair cables known as 'Balanced' cables
- All 4 pair cables have a Characteristic Impedance of 100 Ohms



They are known as **balanced twisted pairs** because the signal is balanced. Each pair has a send and receive conductor. The twist rate of each pair is different to help reduce 'Crosstalk'. There are no

standards that define the ratio between the pairs, however, in some cables the difference between the shortest and longest pairs, in a 90m run, can be as much as 4-5m. Characteristic Impedance is a complex calculation involving: Resistance, Inductance, Conductance and Capacitance. You do not need to understand how it is carried out, however, for a 4 pair balanced cable it needs to be 100 Ohms, regardless of Category. Localised changes to this value caused by damage (for example) can have an impact on performance.

Not only is each pair twisted, but all 4 pairs are twisted together and that is required to maintain the specified performance. If there is a cross filler present, that also helps maintain the both the geometry of the twist and the separation of the pairs and thereby reduces the potential impact of 'Crosstalk'

The plastic jacket (whether that is LSOH, CMP, PVC) only has one function when dealing with internal cables - **to maintain the geometry of the cable and ensure the relationship between each pair is maintained.**

The jacket is **NOT** a waterproof membrane and is not to provide protection against poor installation.

Cable Constructions

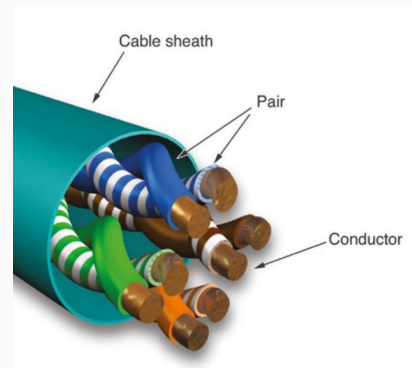
Screened versus Unscreened

The acronym used in all standards is in two parts:

1. The first part describes the outer screening method inside the sheath
2. The second part describes screening around each pair

U/UTP

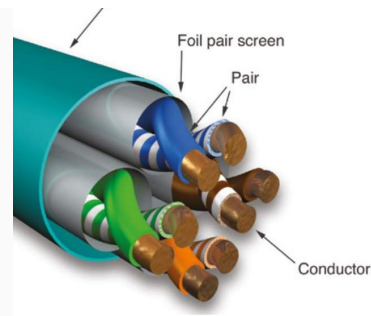
Unscreened outer with
unscreened twisted pairs



Cable sheath

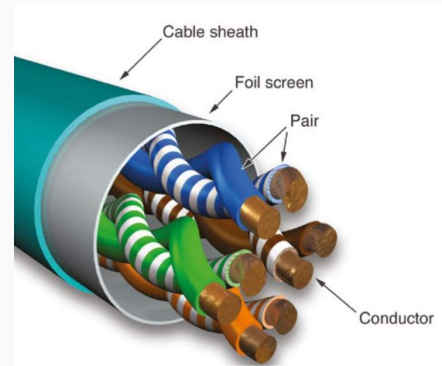
U/FTP

Unscreened outer with
individual screened foil
twisted pairs



F/UTP

Screened foil outer with
unscreened twisted pairs



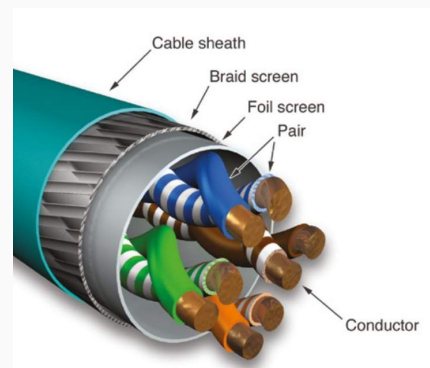
- All screened cables also contain a drain wire.
- In the case of this second part of the acronym for a screened cable, the screening is always an aluminium foil with a mylar coating on one side.

Braid Screening

S/FTP and SF/UTP offers an additional layer of protection with a braid coupled with foil screen either as an overall foil or wrapped around the individual twisted wires. Of the two types shown, S/FTP is the most prevalent. Again this can protect against EMI/RFI and crosstalk. SF/UTP is not as efficient against crosstalk. Rather than having a single layer to penetrate in the case of the foil which acts uni-directionally, the 'Faraday Cage' style of screen provided by the braid has a disrupting effect by reflecting the interference in multiple directions. This provides the ultimate protection to mitigate against Alien Crosstalk. Having the two types of screening also has the benefit when considering the segregation between power and data. These constructions according to EN 50174-2 fall under 'Segregation Classification "d"', which means the distance between power and data can be halved.

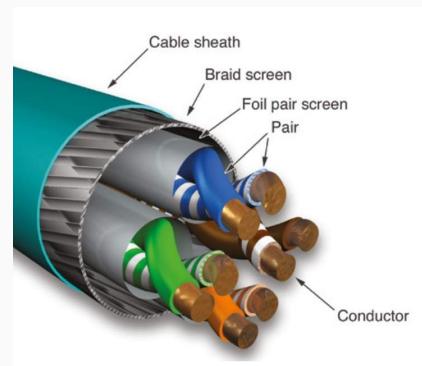
SF/UTP

Screened braid and foil
outer with unscreened
twisted pairs



S/FTP

Screened braid outer with
individual screened foil
twisted pairs



Categories and Classes

ISO and Cenelec

Both ISO and Cenelec use Application Classes to define the Permanent Link and Channel. The Performance Limits are exactly the same, although they are different to EIA/TIA. Each Class is made up using Categories of Components, as follows:

Class	Frequency	Bandwidth
Class C	16 MHz (Category 3)	10 Mbps
Class D	100 MHz (Category 5e)	1 Gbps
Class E	250 MHz (Category 6)	1 Gbps
Class EA	500 MHz (Category 6A)	10 Gbps
Class F	600 MHz (Category 7)	10 Gbps
Class FA	1 GHz (Category 7A)	10 Gbps
Class I	1.6 GHz (Category 8.1)	25/40 Gbps
Class II	2.0 GHz (Category 8.2)	25/40 Gbps



A Class defines a link by design where components performance can be manipulated to serve a higher applicational requirement. Category relates the the construction of the components therefore a category of link is only as good as its lowest component.

- Class I & II (they are defined this way in the standards and not as 1 & 2) are only for 'Top of Rack, End of Row' applications within a Data Centre and not for commercial office installations.
- Also, remember the clause listed in the latest revision of ISO 11801 outlined in Module 2: A minimum of Class E should be used and Class EA if more than 1Gbps is to be supported. The only standard that mentions Category 5e anymore is Part 4 – Homes.
- Classes F and FA are included for historic reasons. There have never been any real applications that have ever required a 4 pair balanced cable operating at 600MHz or above to date. Germany was already using a 600MHz cable called PiMF (pairs in metal foil) well before 10Gbps came along for an implementation called 'sheath sharing' where they would pull one cable to a position and split it into 2 x 2 pairs to be terminated on outlets. You only require 2 pairs to support 100Mbps.
- They are also not used by TIA/EIA which will also prove a barrier to their use.

TIA and EIA

Class	Frequency	Bandwidth
Category 3	16 MHz	10Mbps/4MbTR
Category 4	20 MHz	10Mbps/16MbTR
Category 5	100 MHz	100 GbpsM

Class	Frequency	Bandwidth
Category 5e	100 MHz	1 Gbps
Category 6	250 MHz	1 Gbps
Category 6A	500 MHz	10 Gbps
Category 7	N/A	Not Used
Category 7A	N/A	Not Used
Category 8	2.0 GHz	25/40 Gbps

- There are certain Categories that are left in for historic reasons.
- Category 4 came about in an effort to support 16Mb Token Ring which was a very good application that came from IBM. Category 3 could support 10Mb Ethernet and 4Mb Token Ring, when IBM launched the 16Mb TR, the only cabling that could support it was a very heavy and proprietary cabling system from IBM called Type 1 which used large conductors and wasn't a generic twisted pair cable that could support multiple applications.
- This Category lasted for less than a year when the IEEE ratified and published the standard for 100Base-T otherwise known as Fast Ethernet. Which required improvements in the cable and component standard to support it. This resulted in Category 5.
- In the mid 1990s IEEE produced 1000Base-T which required additional improvements in the cabling performance on values such as Attenuation and Return Loss. This resulted in the cabling Category 5e (e = enhanced). Category 6 came about as the cabling standards tried to anticipate what the next bandwidth requirement might be. However, when the IEEE ratified 10GBase-T in 2006 they changed the encoding technique (the way the packet of information is compiled) which meant that not only was Category 6 bypassed, the requirement for the higher frequencies of Category 7 and 7A was made effectively redundant. A 5 fold increase in frequency produces a 10 fold increase in bandwidth.
- Therefore Category 6A (augmented) was born.

- Some may question "Why Category 6"? The benefits for using this as the minimum will be covered in subsequent modules, but in short the higher frequency is better for IPTV and larger conductor and cable works better for PoE.



The difference in performance between ISO/Cenelec and TIA/EIA can be as much as 2.5dB at the higher frequencies.

Topologies

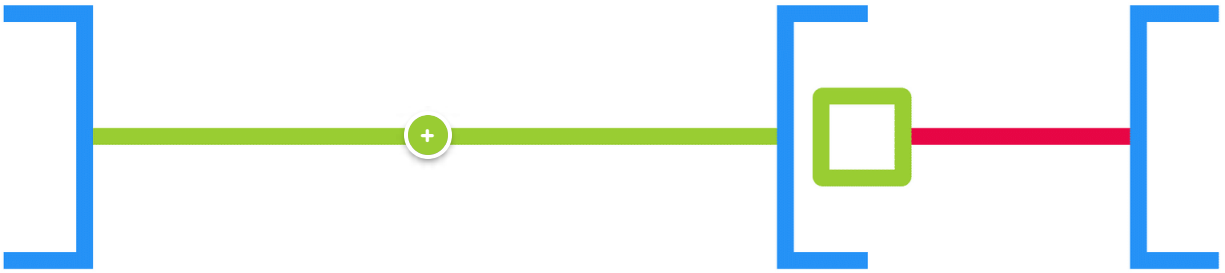
Permanent Link

- For a system to be a given class, all components must be of the same Category
E.g. *Class E*, requires all panels, cables and outlets to be Category 6
- Maximum length 90m

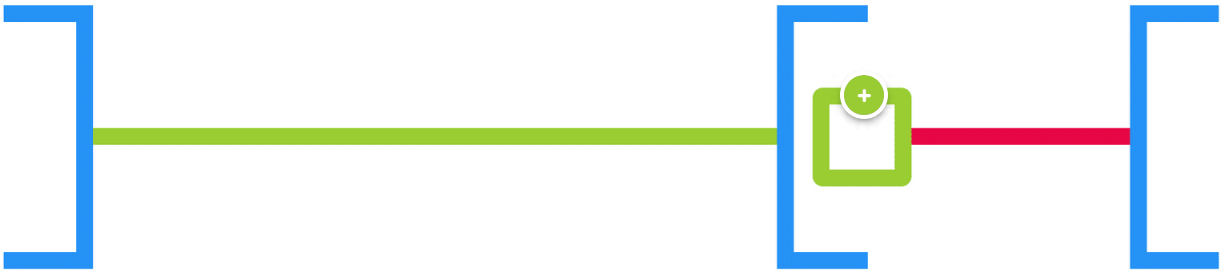




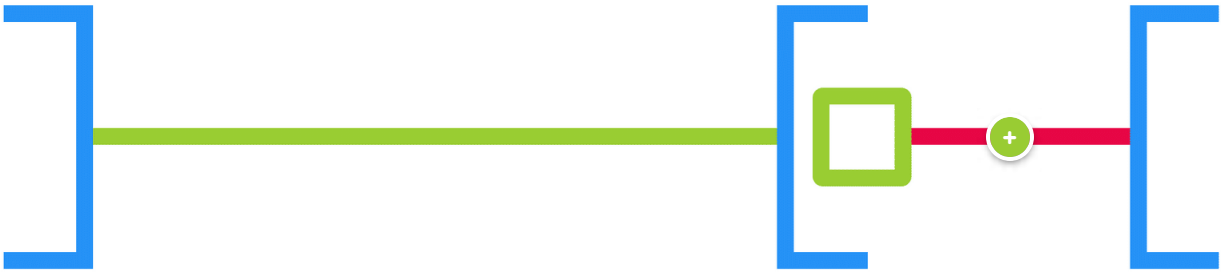
Patch Panel



Horizontal Cable



Consolidation Point (optional)



CP Cable

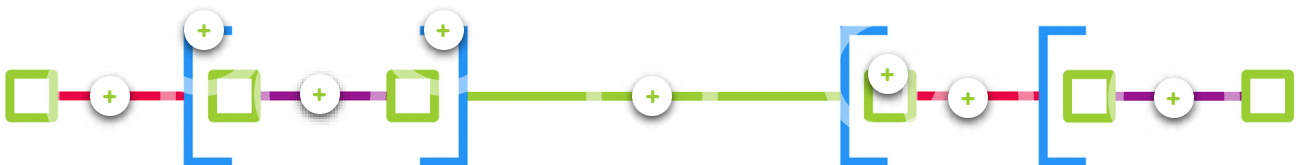


Telecom Outlet

 A Consolidation Point cannot be closer than 15m to the Patch Panel.

Channel

- The Channel below shows a Crossconnect Model
- All components must be of the same Category including patch leads and harness/switch links
- Maximum length 100m





Switch Lead



Patch Panel



Patch Lead



Patch Panel



Horizontal Cable



Consolidation Point



CP Cable



User Lead

There are two main Channel Models:

- **Interconnect** is where the equipment in the main Equipment room is connected to the Permanent Link using a Patch Cord
- **Crossconnect** is when the switch/equipment is hardwired to a patch panel by way of a switch or harness link made up of the same solid core cable used for the Horizontal Cable.

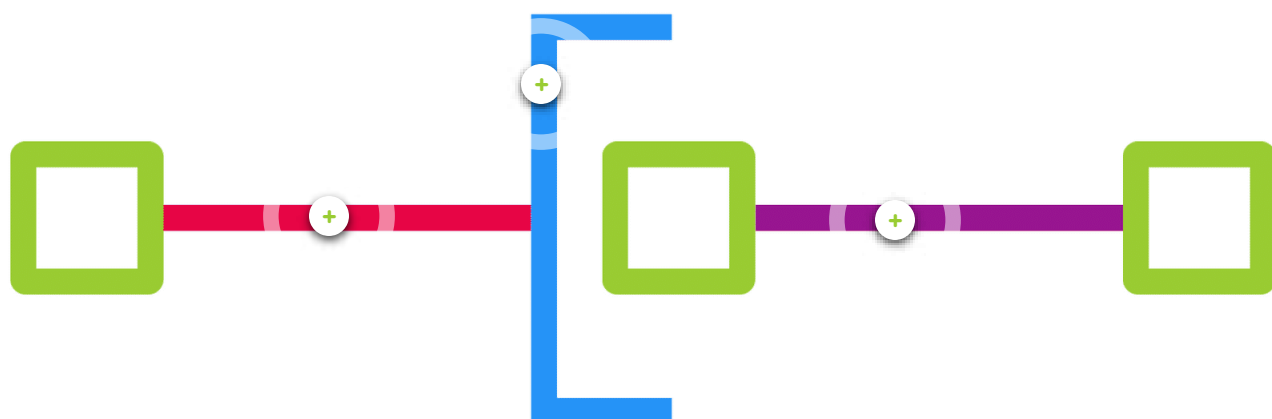
The two patch panels are connected by way of a patch lead to create a 'Patching Field'.

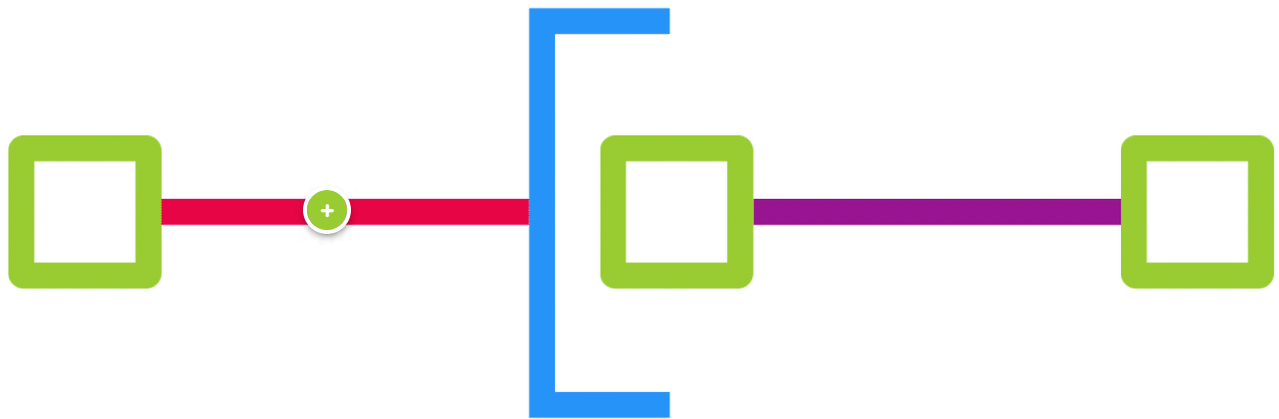
There are no limitations in the number of connectors that can be in a channel - Excel have a 6-Connector model certified.

Category 8.1

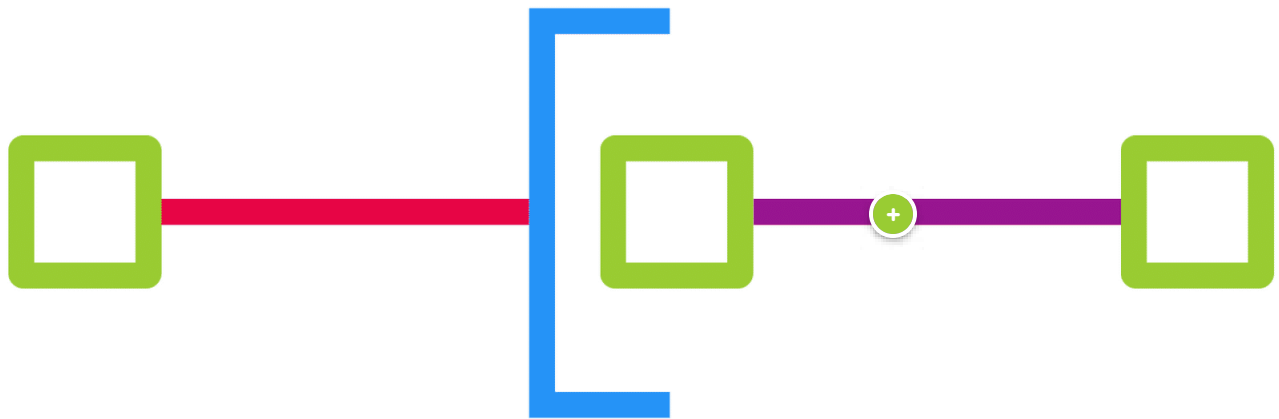
This is a hybrid model based on the Crossconnect model. A switch or harness link is connected between the switch and the patch panel and a patch lead is used to connect to the equipment.

- Top of Rack, End of Row applications within a Data Centre
- One connection or less 15m
- Connection relates to a mated plug and outlet, the plugs connecting to the equipment are ignored
- Given distance mainly used for the ToR

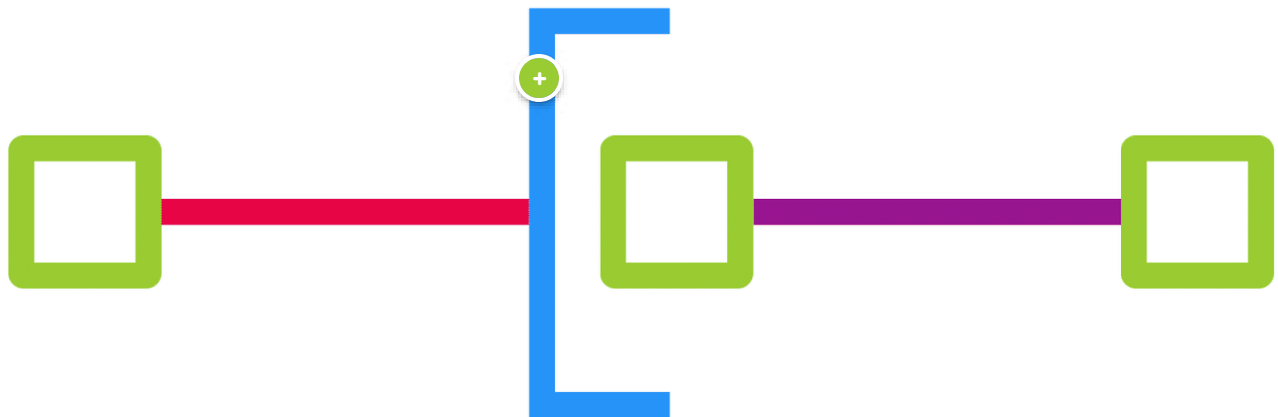




Switch Lead



Patch Lead

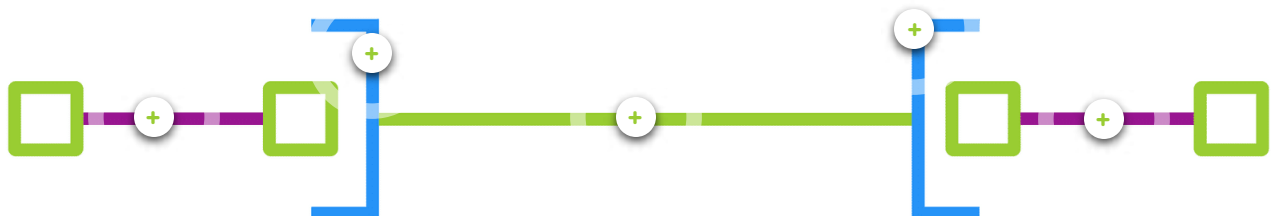


Patch Panel

Category 8.2

This is a very simple Interconnect model, but with a Patch Panel to Patch Panel link and two patch leads to connect to the equipmentTop of Rack, End of Row applications within the Data Centre.

- Two connections or less up to 32m
- Distance and number of connections make it more suitable to EoR





Patch Lead



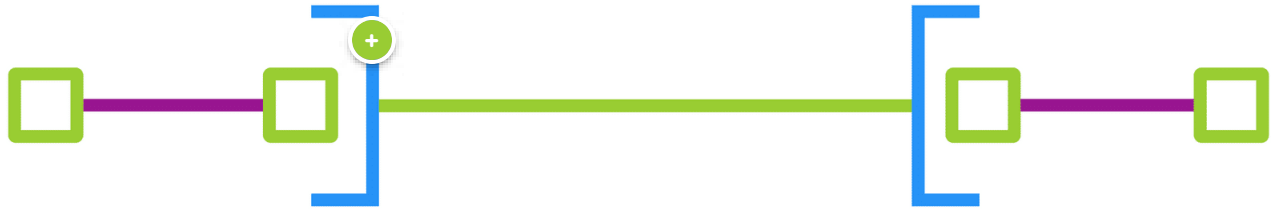
Patch Lead



Patch Panel



Horizontal Cable



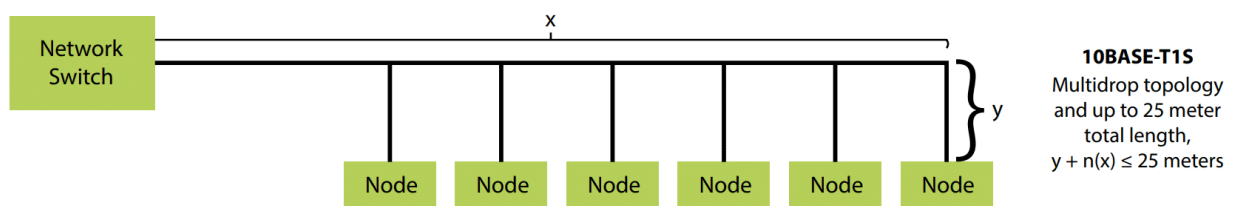
Patch Panel

Single Pair Ethernet

At the time of writing this course (April 2021), there are no systems currently available. However, during the period this course is in use, systems will become available and installed. Single Pair Ethernet will not replace 4 pair cabling. The main markets will be Building and Industrial Automation. Channel models will be different. Lengths and number of connections will also differ.

- IEEE published the first standards for the Automotive sectors in 2015 and 2016. This was followed by 802.3cg in 2019 for the automation and control markets.
- Connectivity and Cable types approved and available.
- Cables will mainly be of a screened construction.
- The only missing part is the Electronics but they are close to being made available.

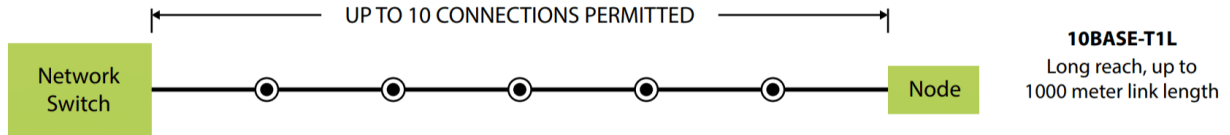
10BASE-T1S – Mixing segment (multidrop), 8 nodes, 25m reach



10BASE-T1S – Link segment (point-to-point), 4 connections, 15m reach, PoDL power

- PoDL power (pronounced 'Poodle') is similar to PoE in the way it works
- Predominately it is limited to 10Mbps however, a key difference is the number of connections that can be included within as standard channel

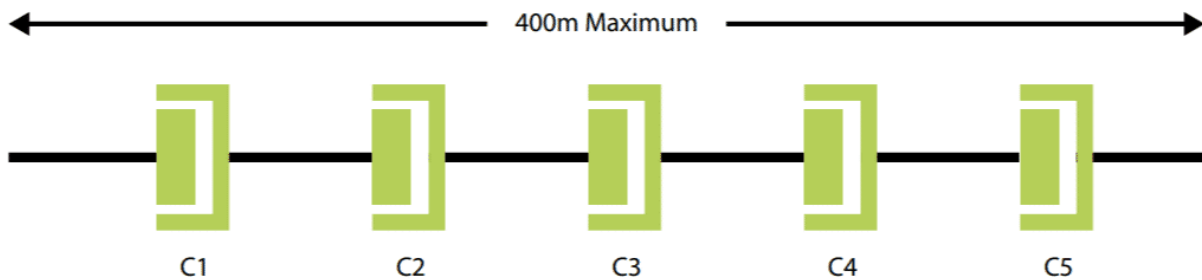
- It also allows for multi-drop connectivity



10BASE-T1L – Link segment (point-to-point), 10 connections, 1000m reach, PoDL power

- The long reach version can be up to 10 connections, transmitting 10Mbps up to 1Km

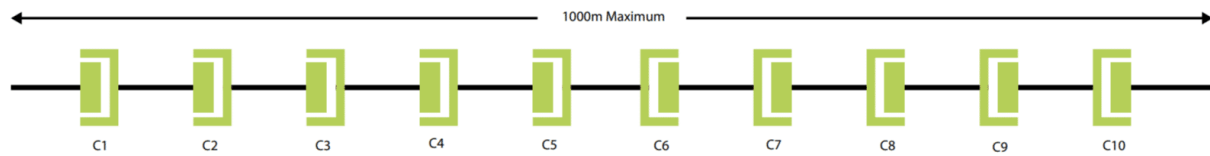
SP1-400 Channel (23 AWG)



IEEE 802.3da – 10 Mb/s Multidrop Enhancements Mixing segment (multidrop), 16 nodes, 50m reach, PoDL power

- A further version 802.3da allows for multiple nodes in a short distance over 23AWG cables, this conductor size is common in Category 6 and 6A cables currently so will be easy to develop

SP1-1000 Channel (18 AWG)



IEEE 802.3da – 10 Mb/s Multidrop Enhancements

Mixing segment (multidrop), 16 nodes, 50m reach, PoDL power

- The longer channel version will require much larger conductor sizes. They will be approx. twice the size of 23 AWG having a diameter 1.024mm compared to 0.57mm and an area that is over 3 times at 0.823 mm² compared 0.259 mm²