PDHonline Course E449 (10 PDH)

Cabling Network, Wireless & Fiber Optics Installation Standards

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CABLING NETWORK, WIRELESS & FIBER OPTICS INSTALLATION STANDARDS

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OBS.: This is a very didactic and professional work. It´s highly recommended downloading and printing the course content for your study, before answering the quiz questions.

I. INTRODUCTION:

Network, according to Thesaurus Dictionary "is *any complex, interlocking system*". According to the Dictionary web, for radio and television, "*is a group of tramsmitting stations linked by wire or microwaves so that the same program can be broadcast*", and for electricity, "*is an arrangement of conducting elements, as resistors,capacitors, or inductors, connected by conducting wire*".

In telecommunications, **network** is a system containing any combination of computers, printers, terminals, audio, visual display devices and telephones, interconnected by cables to transmit or receive information. A network can **consist** of two computers, or millions of computers connected with cables or optical fibers, that are spread over a large geographical area, such as telephone lines, active equipment, radio, television and all visual or communication devices. Internet is an example of a very large network.

Cabling network **standards** are used internationally, published by ISO/IEC, NEC, CENELEC, NEMA, and the Telecommunications Industry Association (TIA). BICSI (Building Industry Consulting Service International) is a recognized independent trainer of computer structured cabling installers, with best practice documents and independent manufacturers, design and installation, also plays a major role with industry leaders in developing and designing US standards.

The **main focus** here is **cabling installation standards, fiber optics and wireless systems**, that is, the use of various standard cable systems for operating **equipment**, such as computers, instruments, machinery, flow processes, and other applications including electric power cables and automation. However, automation systems are achieved by various means including mechanical, hydraulic, pneumatic, electrical, electronic and computers, and usually in a whole combination.

Today extensive **automation** is practiced in practically every type of manufacturing and assembly process. Some of the larger processes include electrical power generation, oil refining, chemicals, steel mills, plastics, cement plants, fertilizer plants, pulp and paper mills, automobile and truck assembly, aircraft production, glass manufacturing, natural gas separation plants, food and beverage processing, canning and bottling and manufacture of various kinds of parts.

Robots are especially useful in **hazardous** applications like automobile spray painting. Robots are also used to assemble electronic circuit boards. Automotive welding is done with robots and automatic welders are used in applications like pipelines. The result has been a rapidly expanding range of applications and human activities.

A computer-aided technology (CAx) is used to **create** complex systems, including Computer-aided design (CAD software) and Computer-aided manufacturing (CAM software). Programmable Logic Controllers (PLCs) are used to synchronize the flow of inputs from sensors and the flow of outputs to actuators and machinery. Human-machine interfaces (HMIs) are usually employed to commucate with PLCs and other computers.

The International Society of Automation (ISA), founded in 1945, is a leading, global, nonprofit organization, which sets the standard for automation, certifies industry professionals, provides education and training, publishes books and technical articles, and hosts conferences and exhibitions for automation professionals. ISA is also the founding sponsor of the Automation Federation (www. automationfederation.org).

II. ELECTRIC TRANSMISSION LINES:

Electric-power transmission is the bulk transfer of **electrical** energy, from generating power plants to electrical substations located near demand centers. In 1882, generation was with *direct current* (DC), which could not easily be increased in voltage for long-distance transmission. Other classes of loads (for example, lighting, fixed motors, and traction/railway systems) required different voltages, and so used different generators and circuits.

Early DC generating plants needed to be within about 1.5 miles (2.4 km) of the farthest customer to avoid excessively large and expensive conductors. The competition between the direct current (DC) and alternating current (AC) by Thomas Edison and George Westinghouse respectively, in the late **1880s**, was known as the War of Currents. At the conclusion of their campaigning, in the late **1890s**, AC became the dominant form of transmission of power.

In **1886**, in Great Barrington, Massachusetts, a 1 kV *alternating current* (AC) distribution system was installed. That same year, AC power at 2 kV was installed at Cerchi, Italy, transmitted 30 km. In USA, at an meeting on 1888, **Nikola Tesla** delivered a lecture entitled "*A New System of Alternating Current Motors and Transformers*", describing the efficient generation and use of polyphase alternating currents. The ownership of the Tesla patents, then, was the Westinghouse Company, which entered to offer a complete alternating current power system for both lighting and power.

In Germany, the first transmission of **three-phase** alternating current using high voltage took place in **1891** during the international electricity exhibition in Frankfurt. A **25 kV** transmission line, approximately **175 km** long, connected Lauffen on the Neckar and Frankfurt. Voltages used for electric power transmission increased through the 20th century. By **1914**, fifty-five transmission systems, each operating with more than **70 kV**, were in service. The highest voltage then used was 150 kV.

The rapid industrialization in 20th century made electrical transmission lines and **grids** a critical infrastructure item in most industrialized nations. The interconnection of local generation plants and small distribution networks, was greatly spread due the requirements of World War I, with large electrical generating plants built by governments, to provide power to munitions factories. Later these generating plants were connected to supply civil loads through long-distance transmission.

Electrical Transmission Grid: Is a huge **network** of power stations and transmission lines, which use components, such as power lines, cables, circuit breakers, switches and transformers. The electric energy is usually transmitted within a grid with ***three-phase AC***. Single-phase AC is used only for distribution to end users since it is not usable for large polyphase induction motors.

In the 19th century, the **two-phase** transmission became used, but required either four wires or three wires with unequal currents. That time, the system started using transformers to step-up voltage to **high-voltage** transmission lines, and then to step-down voltage to local distribution circuits or industrial customers. Most transmission lines were high-voltage three-phase alternating current (AC), although single phase AC was sometimes used in railway electrification systems.

Today, electricity is transmitted at **high voltages** (138 kV or above) to reduce the energy losses in long-distance transmission. Underground power transmission has a significantly higher cost and greater operational limitations but is sometimes used in urban areas or sensitive locations. Lower voltages, such as **69 kV** and **26 kV**, are usually considered sub-transmission voltages, but are occasionally used on long lines, with light loads. Voltages less than **33 kV** are usually used for distribution. Voltages above **230 kV** are considered extra high voltage and require different designs compared to equipment used at lower voltages.

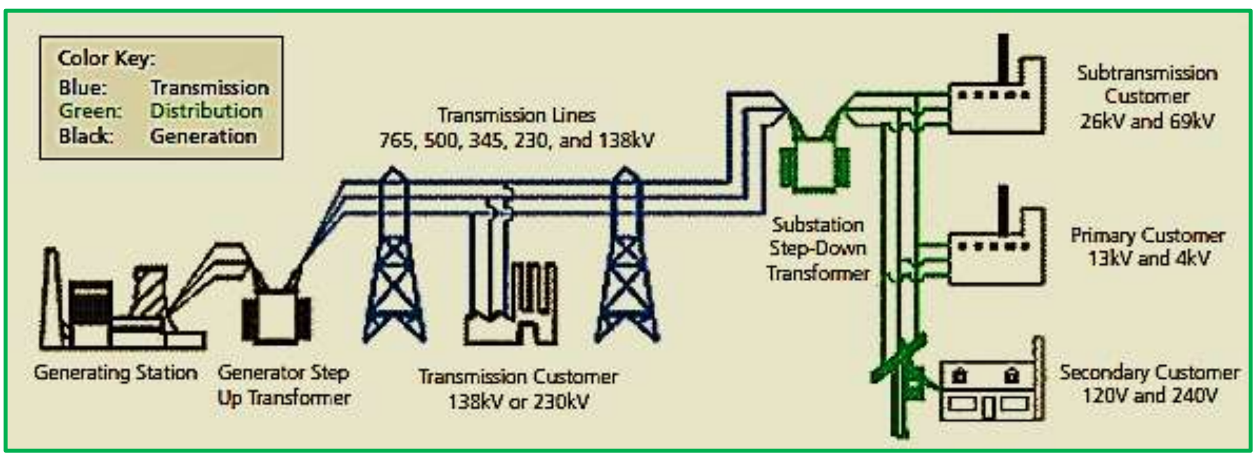


Diagram of an electric power system; transmission system is in blue

Since overhead transmission wires depend on **air** for insulation, the design of these lines requires minimum **clearances** to be observed to maintain **safety**. Adverse weather conditions, such as high wind and low temperatures, can lead to power outages. Wind speeds as low as **23 knots** (43 km/h) can permit conductors to achieve operating clearances, resulting in a loss of supply. The oscillatory motion of the physical line can be termed gallop or flutter depending on the **frequency** and amplitude of oscillation.

Electric power can also be transmitted by **underground** power cables instead of overhead power lines. Underground cables take up **less** right-of-way than overhead lines, have lower visibility, and are less affected by bad weather. Long underground AC cables have significant capacitance, which may reduce their ability to provide useful power to loads beyond 50 miles. Rotary converters and later mercury-arc valves and other rectifier equipment, also allows DC using different frequencies to be interconnected.

Sub-transmission: Is part of an electric power transmission system that runs at relatively **lower** voltages. Typically, only larger substations connect with high voltage. At the substations, transformers reduce the voltage to a lower level for distribution to commercial and residential users. Then, voltage is stepped down and sent to smaller substations in towns and neighborhoods. Voltages of 69 kV, 115 kV and 138 kV are **often** used for sub-transmission in North America.

High-voltage Direct Current (HVDC): This technology is used with great efficiency at very **long** distances (typically hundreds of miles or kilometers), using submarine power cables longer than 30 miles (50 km), where AC cannot be supplied. HVDC systems are often used to **connect** the electricity grids of islands and difficult places, for example, between Great Britain and mainland Europe, between Great Britain and Ireland. Submarine cable connections up to 600 kilometers (370 mi) in length are presently in use.

High-temperature Superconductors (HTS): Is a power distribution that provides lossless transmission of electrical power. The development of **superconductors** with transition temperatures higher than the boiling point of liquid nitrogen has made the concept of superconducting power lines commercially feasible, at least for high-load applications, since the refrigeration consumes about half the power by the elimination of the resistive losses.

Some companies such as Consolidated Edison and American Superconductor have already begun commercial production of such systems. In one hypothetical future system called a SuperGrid, the cost of **cooling** would be eliminated by coupling the transmission line with a liquid hydrogen pipeline. Superconductor cables will be particularly suited to high load density areas, such as the business district of large cities, where purchase of cables would be very costly.

Wireless Power Laser Transmission: In the late 1800s and early 1900s, both Nikola Tesla and Hidetsugu Yagi attempted to install **wireless** power transmission for large scale systems, with no commercial success. In 2009, Laser Motive won the NASA 2009 Power Beaming Challenge, by powering a cable climber **1 km** vertically, using a ground-based laser transmitter. The system produced up to **1 kW** of power at the receiver end.

In 2010, NASA contracted private companies to pursue the design of **laser** power beaming systems to power low earth orbit satellites and to launch **rockets** using laser power beams. Wireless power transmission has been studied for transmission of power from solar power satellites to the earth. A proposed military application is to power *drone reconnaissance aircraft,* with microwaves beamed from the ground, allowing them to stay aloft for long periods.

Rectenna: A rectenna or **rectifying** antenna is a **wireless** transmission system that transmits **power** by radio waves, used to **convert microwave** energy into direct electricity. Similar devices, scaled down are also used in *nanotechnology*, and to *convert light into electricity*, what is currently possible only with *solar cells*. This type of converter device is called ***optical rectenna*** or nantenna. Major engineering and economic challenges face a new solar power satellite project.

Transmission Lines Distribution: An electric power distribution system is the final stage in the delivery of electric power; it carries electricity from the transmission system to individual consumers. Distribution **substations**, are connected to the transmission system source and **lower** the transmission voltage to a medium voltage ranging between **2 kV and 35 kV** using transformers. This primary distribution lines carry this medium voltage power to all distribution transformers located near the final users.

Next, distribution transformers **lower** the voltage to the utilization voltage of **appliances** and feed several users through **secondary** distribution lines at this voltage. Commercial and residential final users are then, connected to the secondary distribution lines through service drops. When users need to demand a much higher high voltage load, may be connected directly at the **primary** distribution level or the sub-transmission level.

Electric power is normally generated at **11 - 25 kV** in a power station. To transmit power over long distances, it is then stepped-up to higher voltages: 400 kV, 330 kV, 275 kV, 220 kV, 132 kV, 110 kV and 66 kV are common in UK, Ireland, Australia and New Zealand, while 765 kV, 500 kV, 345 kV, 230 kV, 138 kV, 115 kV and 69 kV are common in North America.

This **grid** is then connected to load cities through a sub-transmission network of lines at voltages from **33 kV** up to **230 kV** or more. These lines terminate at substations, where the voltage is further stepped-down to **25 kV** or less, for power distribution to general users, through a distribution network of local lines at these lower voltages.

Distribution Networks: Are typically of **two types**, radial or interconnected. A **radial** network leaves the station and passes through the network area with no normal connection to other supply. This is typical of long **rural** lines with isolated load areas. An **interconnected** network is geneerally found in more **urban** areas and will have multiple connections to other points. The benefit is that in the event of a fault or required maintenance, a small area of network can be iso- lated, and the remainder kept on supply.

Distribution Feeders: Tipically originate from a substation, generally controlled by a **circuit breaker**, which opens when a **fault** is detected. Automatic circuits may be installed to further segregate the **feeders**, minimizing the impact of faults. Long feeders voltage drops require capacitors or voltage **regulators**. Characteristics of the supply given to customers are generally mandated by a contract between the supplier and the user. Variables of the supply include:

- AC or DC - Virtually all public electricity supplies, are AC today;
- DC power as some electric railways, telephone or special industrial processes, such as aluminium smelting, usually operated by their own DC power or use rectifiers from the public AC supply;
- Nominal voltage, and tolerance (for example, +/- 5 per cent);
- Frequency, commonly 50 or 60 Hz, 16.7 Hz and 25 Hz for some railways and, in a few older industrial and mining locations, 25 Hz;
- Phase configuration (single-phase, polyphase including two-phase and three-phase);
- Maximum demand (some energy providers measure as the largest mean power delivered within a 15 or 30 minute period during a billing period);

- Load factor, expressed as a ratio of average load to peak load over a period of time. Load factor indicates the degree of effective utilization of equipment of distribution line or system;
- Power factor of connected load, earthing systems - TT, TN-S, TN-C-S or TN-C.

III. WIRES AND CABLES:

Wires and cables are **rated** by the circuit voltage, temperature rating, and environmental conditions (moisture, sunlight, oil, chemicals) in which they can be used. A wire or cable has a voltage (to neutral) and a maximum conductor surface temperature rating. The amount of current a cable or wire can safely carry depends on the installation conditions.

Heavy industries have more demanding wiring requirements, such as very large currents and higher voltages, frequent changes of equipment layout, corrosive, or wet or explosive atmospheres. In facilities that handle **flammable** gases or liquids, special rules may govern the installation and wiring of electrical equipment in hazardous areas.

Building wiring is the electrical wiring and associated devices such as switches, meters and light fittings used in buildings or other structures. Wiring **safety codes** vary by country and the International Electrotechnical Commission (IEC) is attempting to standardize wiring amongst member countries. Wires and cables are rated by the circuit voltage, temperature, and environmental conditions (moisture, sunlight, oil, chemicals) in which they can be used. **Colour** codes are used to distinguish line, neutral and ground (earth) wires.

Electrical codes arose in the late **1880s**, with the commercial introduction of electrical power. The first electrical codes in USA were originated in New York in 1881 to regulate installations of electric lighting for buildings. Since 1897 the US National Fire Protection Association, a private non-profit association formed by insurance companies, has published the *National Electrical Code* (NEC).

The earliest standardized method of wiring in buildings, in common use in North America from about 1880 to the 1930s, was ***knob and tube*** (K&T) wiring: single conductors were run through cavities between the structural members in walls and ceilings, with ceramic tubes forming protective channels, through joists and ceramic knobs attached to the structural members, to provide air between the wire and the lumber and to support the wires.

In **1927**, the Canadian Standards Association (CSA) produced the Canadian *Safety Standard for Electrical Installations*, which is the basis for provincial electrical codes. The CSA also emitted the Canadian Electrical Code. The 2006 edition referenced by the IEC 60364 (*Electrical Installations for Buildings*) states the **code** addresses and the fundamental principles of electrical protections.

The international **standard** wire sizes are given in the **IEC 60228** standard of the International Electrotechnical Commission. In North America, the *American Wire Gauge* standard for **wire** and thin **plates** sizes is used. The Canadian code reprints Chapter 13 of IEC 60364, but there are no numerical criteria listed in that chapter to assess the adequacy of any electrical installation.

In European countries, an attempt has been made to **harmonize** national wiring standards in an IEC standard, IEC 60364 *Electrical Installations for Buildings*. Hence national standards follow an identical system of sections and chapters. However, this standard is not written in such language that it can readily be adopted as a national wiring code.

Metal-sheathed Wires: In the United Kingdom, a form of **insulated** cable was introduced in 1896 and consisted of two impregnated-paper-insulated conductors in an overall lead **sheath**. These cables were similar to **underground** telegraph and telephone cables of the time. A system later invented in the UK in 1908 employed vulcanized-rubber insulated wire enclosed in a strip metal sheath. The **metal sheath** was bonded to each metal wiring device to ensure earthing continuity.

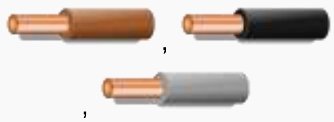
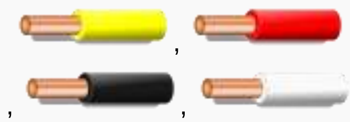
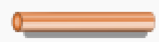
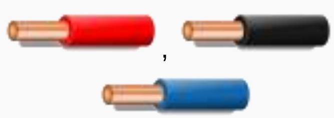
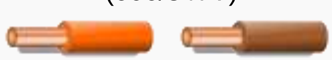
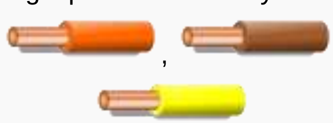
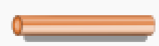
A system developed in Germany called "*Kuhlo wire*" used two or three **rubber-insulated** wires in a brass or lead-coated iron sheet tube, with a crimped seam. Special outlet and junction boxes were made for **lamps** and switches, made either of **porcelain** or sheet steel. The crimped seam was not considered as watertight as the *Stannos* wire used in England, with a soldered sheath.

A similar system called "*concentric wiring*" was introduced in the United States around 1905. In this system, an **insulated** electrical wire was *wrapped with copper* tape, soldered, forming the grounded (return) conductor of the wiring system. While companies, such as General Electric manufactured **fittings** for the system, it was never adopted into the US National Electrical Code.

Color Standards: To enable wires to be easily and **safely** identified, all common wiring safety codes mandate a **colour** scheme for the insulation on power conductors. In a typical electrical code, some colour-coding is mandatory, while some may be optional. Nevertheless, many local rules and exceptions exist. Older installations **vary** in colour codes, and may shift with insulation exposure to heat, light, and ageing.

Many electrical **codes** now recognize (or even require) the use of wire covered with green insulation, additionally marked with a prominent yellow stripe, for safety earthing (grounding) connections. This growing international **standard** was adopted for its distinctive appearance, to reduce the likelihood of dangerous confusion of safety earthing (grounding) wires with other electrical functions, especially by persons affected by red-green colour **blindness**.

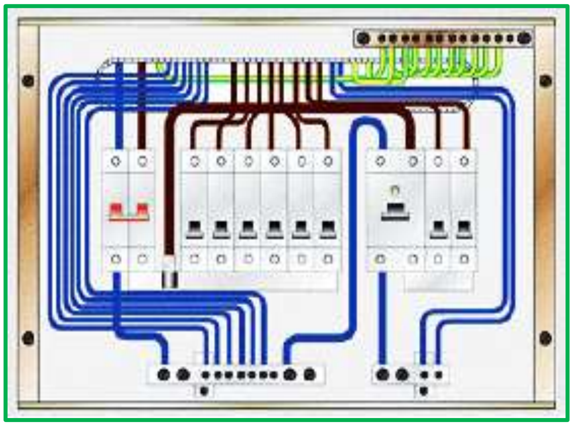
Standard Wire Colors for Flexible Cables:			
Region or Country	**Phases**	**Neutral**	**Protective earth/ground**
European Union (EU), Argentina, Australia, South Africa (IEC 60446)			
Brazil	 , 		

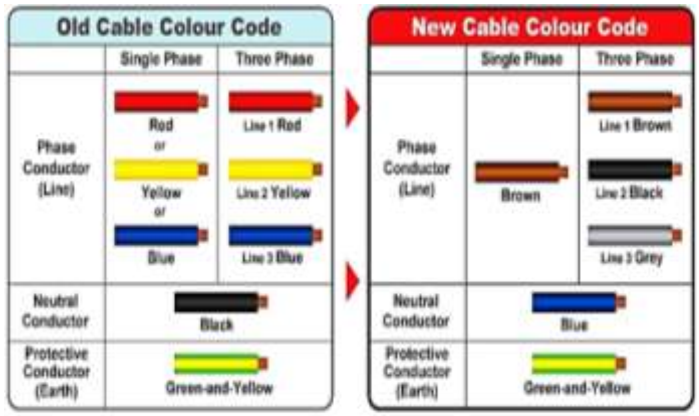
United States, Canada	 (black or *brass*)	 (white or *silver*)	 (*green*)
Standard wire colours for fixed cable - (In-, On-, or Behind-the-wall wiring cables):			
Region or Country	**Phases**	**Neutral**	**Protective earth/ground**
European Union (EU) (IEC 60446) including UK from 31 March 2004 (BS 7671)			
Brazil			
United States	 (120/208/240V) - (black or brass)  (277/480V) 	 (120/208/240V)-(white or *silver*)  (277/480V)	 (*green*)  bar conductor  (ground or isolated)
Canada	 (120/208/240V)  (600/347V)  (single phase isolated systems)  (three phase isolated systems)	 (120/208/240V)  (600/347V)	 (*green*)  bar conductor  (isolated ground)

Notes:

- Parenthesized colours in *italics* are used on metallic terminals. "*Green/yellow*" means green with yellow stripe. The colours in this table represent the most common and preferred standard colours for wiring; however others may be in use, especially in older installations.
- Australian and New Zealand wiring standards allow both European and Australian colour codes. Australian-standard phase colours conflict with IEC 60446 colours, where *neutral* colour (blue), is an allowed *phase* colour. Care must be taken when determining system used in existing wiring.

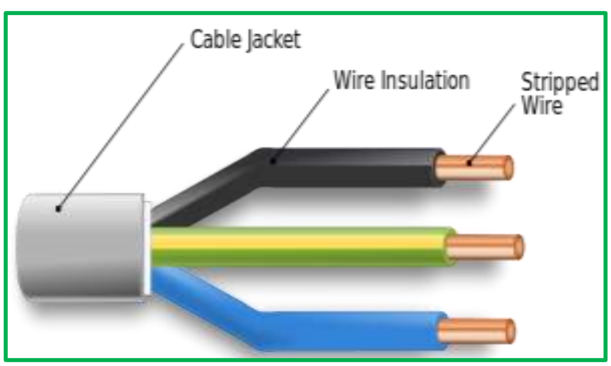
The **old** cable colour code, (red, yellow and blue for phase and black for neutral conductors), are to be **replaced** by the **new** one, (brown, black and grey for phase and blue for the neutral conductors), as shown below. For a **single** phase installation, only the brown colour should be used to identify a phase conductor, irrespective of whether it is connected to the L1, L2 or L3 phase. For a room / flat /unit taking **single** phase electricity supply from a multi-phase power supply source, only brown (phase) and blue (neutral) coloured cables should be used.

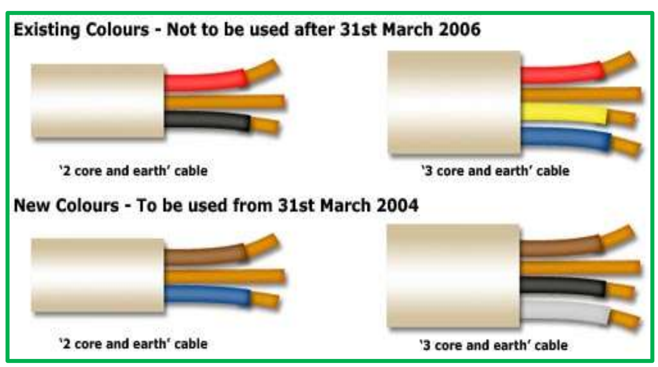




It was agreed that existing cables must not be used after 31st March 2006).
New cable colours should be used from 31st May 2004.

Rubber-Insulated Cables: Armoured cables with **two** rubber-insulated conductors in a flexible metal sheath were used as early as **1906**, and were considered at the time a better method than open **knob-and-tube** wiring, although much more expensive. Over time, become **brittle** because of exposure to atmospheric oxygen, then, must be handled with care and usually replaced during renovations. Rubber insulation was hard to **strip** from bare copper, so copper was tinned, causing slightly more electrical resistance. Rubber insulation is **no longer** used for permanent wiring installations, but may still be used for replaceable **temporary** cables where flexibility is important, such as electrical extension cords.





Simple electrical cables have three insulated conductors.

Polymer-Insulated Cables: The first **polymer-insulated** cables for building wiring were introduced in 1922. These were two or more solid copper electrical wires with rubber insulation, plus woven cotton cloth for protection of the insulation with an overall woven jacket, usually impregnated with tar as a protection from moisture. Waxed paper was used as a filler and separator.

PVC-Insulation and Jackets: About 1950, **PVC-insulation** and jackets were introduced, especially for residential wiring. About the same time, single conductors with a thinner PVC insulation and a thin **nylon** jacket (Type THN, THHN, etc.) became common. The simplest form of cable has two in- sulated conductors twisted together to form a unit; such unjacketed cables with two or three conductors, are used for low-voltage signal and control applications, such as doorbell wiring.

Copper Conductors: Electrical devices often contain **copper** conductors because of their multiple beneficial properties, including their high electrical conductivity, tensile strength, ductility, creep resistance, corrosion resistance, thermal conductivity, coefficient of thermal expansion, solderability, resistance to electrical overloads, compatibility with electrical insulators, and ease of installation.

Aluminum Conductors: Was common in North American residential wiring from the late 1960s to mid-1970s due to the rising cost of copper. Because of its greater resistivity, **aluminium** wiring requires larger conductors than copper. For instance, instead of 14 AWG (American wire gauge) for most lighting circuits, aluminium wiring would be 12 AWG on a typical 15 ampere circuit, though local building codes may vary.

Copper Aluminum Revised (CO/ALR): Due improper design and installation, some junctions to wiring devices **overheat** under heavy current load, and cause **fires**. Revised standards for wiring devices, such as the CO/ALR "*copper-aluminium-revised*" designation, were developed to reduce these problems. Aluminium conductor are still used for bulk power distribution and large feeder circuits, because it costs and weighs less than copper wiring, especially in the large sizes needed for heavy current loads.

Modern Wiring Materials: Modern **non-metallic** sheathed cables, such as types NMB and NMC (US and Canada), consist of *two to four wires covered with* ***thermoplastic*** *insulation*, plus a *bare wire for grounding* (bonding), surrounded by a flexible plastic jacket. Some versions wrap the individual conductors in paper before the plastic jacket is applied.

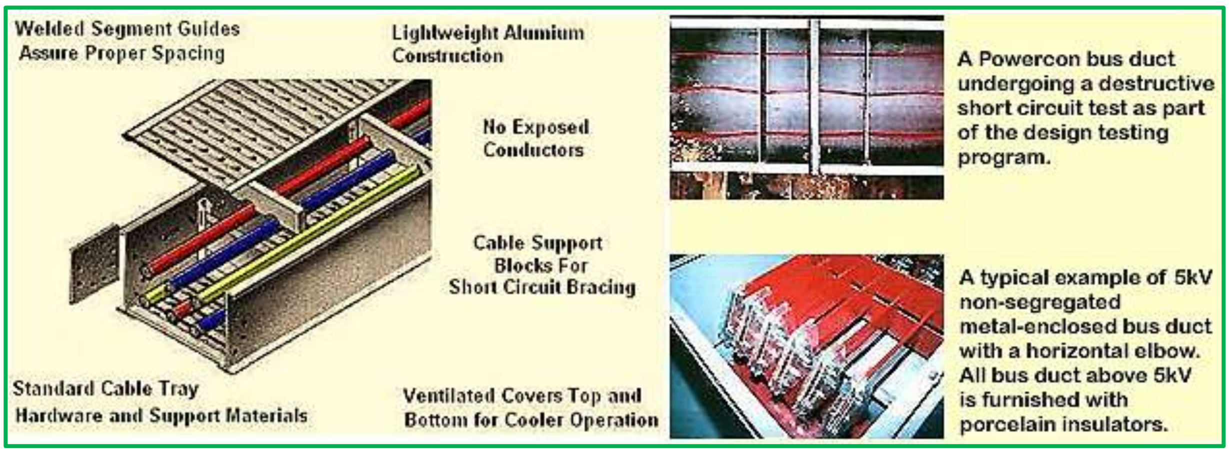
Bundle Conductors: Are used at **high** voltages to reduce energy loss caused by ***corona*** *discharge (*an electrical discharge due the ionization of a fluid surrounding a conductor that is electrically energized). Conductor sizes range from **12 mm^2** (No. 6 American Wire Gauge) to **750 mm^2**, with varying resistance and current-carrying capacity. Because of this current limitation, **multiple** parallel cables (called bundle conductors) are used when higher capacities are needed.

Special & Instrumentation Sheathed Cables: Are designed for direct **underground** burial (often with separate mechanical protection) or exterior use, where exposure to ultra-violet radiation (UV) is possible. Rubber-like **synthetic** polymer insulation is *installed underground* because of its superior moisture resistance. Common cables for **instrumentation** may be PVC-sheathed or special types as, halogen-free, flame retardant (LSZH-sheathed), fire-resisting, and polyethylene-sheathed with an additional polyamide covering.

High-Temperature Cables: These cables have a certified **fire** resistance rating, but are more costly than **non-fire** rated cables. Some industrial uses in **steel mills** and similar hot environments, as no organic materials give satisfactory service. Cables insulated with compressed **mica** flakes are sometimes used. Another form of high-temperature cables more commonly used are the *mineral insulated cables*, with individual conductors placed within a **copper** tube, and the space filled with **magnesium** oxide powder.

Bus Bars, Bus Ducts and Cable Bus: The term "*bus*" is a contraction of the Latin ***"omnibus"*** meaning "*for all*", consisting of a *rigid piece of copper or aluminium*, usually in **flat** bars (sometimes as tubing or other shapes). Conductor bars with insulators and grounded enclosures, known as **bus duct** or **bus way**, are used for connections to large **switchgears** or for *the main power feed into a building*. A form of bus duct known as "*plug-in bus*" is used to distribute **power** through the length of a building and to allow **tap-off** switches or motor controllers to be installed along the bus.

Bus ducts may have all **phase** conductors in the **same** enclosure (non-isolated bus), or may have each conductor separated by a grounded **barrier** from the adjacent phases (segregated bus). Isolated-phase bus is used for very large currents in generating stations or substations, where it is difficult to provide circuit protection. This type of **bus** can be rated up to **50,000 amperes** and up to hundreds of **kilovolts** (during normal service, not just for faults), but is not used for building wiring in the conventional sense.



Standard Cables & Wire Sizes: The IEC 60228 is the International Electrotechnical Commission's international **standard** on conductors of insulated cables. In the United States, **wire sizes** are commonly measured in **American Wire Gauge** (AWG). Increasing **AWG** gives decreasing cross sectional areas (the smallest AWG size being 50 and the largest 0000). Among other things, it also defines a set of standard **wire cross-sections**:

This means that in American Wire Gage, for every **6 gauge decrease**, **doubles** the wire diameter, (e.g., 2 AWG is about **twice** the diameter of 8 AWG), and for every 3 gauge decrease, doubles the wire cross sectional area, (e.g., Two **14 AWG** wires have about the **same** cross-sectional area as a single **11 AWG** wire), similar to dB in signal and power levels.

American Wire Gauge (AWG): Also known as the **Brown & Sharpe** wire gauge is a standardized wire **gauge** system used since **1857** predominantly in North America for the **diameters** of round, solid, nonferrous, electrically conducting wires. The cross-sectional area of each gauge is an important factor for determining its current-carrying capacity. In the American Wire Gauge (AWG), diameters can be calculated by applying the formula **D(AWG)** $=.005 \cdot 92^{((36-AWG)/39)}$ inch. The table below shows various data including both the resistance of the various **wire gauges** and the allowable current (ampacity) based on plastic insulation. The diameter information in the table also applies to solid wires. The **stranded** wires are calculated by the equivalent **cross section** of the copper area. The **fusing** current (melting wire) is estimated based on **25°C** ambient temperature.

When installing any electrical wire, the **proper wire size** for the application is needed and installation of **conductors** may depend on a few factors. The gauge of the wire, wire capacity, and what the wire will **feed** should all be considered. This table below assumes **DC**, or **AC** frequencies equal to or less than **60 Hz**, and does not take **skin** effect into account. Turns of wire are an upper limit for wire **without** insulation.

AWG gauge	Conductor Diameter Inches	Conductor Diameter mm	Ohms per 1000 ft.	Ohms per km	Maximum amps for chassis wiring	Maximum amps for power transmission	Area	
							(kcmil)	(mm^2)
0000 (4/0)	0.4600	11.684	0.04901	0.1608	250	230	212	107
000 (3/0)	0.4096	10.405	0.06180	0.2028	250	200	168	85.0
00 (2/0)	0.3648	9.266	0.07793	0.2557	250	175	133	67.4
0 1/0	0.3249	8.25246	0.0983	0.322424	245	150	212	107
1	0.2893	7.34822	0.1239	0.406392	211	119	168	85.0
2	0.2576	6.54304	0.1563	0.512664	181	94	133	67.4
3	0.2294	5.82676	0.197	0.64616	158	75	106	53.5
4	0.2043	5.18922	0.2485	0.81508	135	60	83.7	42.4
5	0.1819	4.62026	0.3133	1.027624	118	47	66.4	33.6
6	0.162	4.1148	0.3951	1.295928	101	37	52.6	26.7
7	0.1443	3.66522	0.4982	1.634096	89	30	41.7	21.2
8	0.1285	3.2639	0.6282	2.060496	73	24	33.1	16.8
9	0.1144	2.90576	0.7921	2.598088	64	19	26.3	13.3
10	0.1019	2.58826	0.9989	3.276392	55	15	20.8	10.5
11	0.0907	2.30378	1.26	4.1328	47	12	16.5	8.37
12	0.0808	2.05232	1.588	5.20864	41	9.3	13.1	6.63
13	0.072	1.8288	2.003	6.56984	35	7.4	10.4	5.26
14	0.0641	1.62814	2.525	8.282	32	5.9	8.23	4.17
15	0.0571	1.45034	3.184	10.44352	28	4.7	6.53	3.31
16	0.0508	1.29032	4.016	13.17248	22	3.7	5.18	2.62
17	0.0453	1.15062	5.064	16.60992	19	2.9	4.11	2.08
18	0.0403	1.02362	6.385	20.9428	16	2.3	3.26	1.65
19	0.0359	0.91186	8.051	26.40728	14	1.8	2.58	1.31
20	0.032	0.8128	10.15	33.292	11	1.5	2.05	1.04
21	0.0285	0.7239	12.8	41.984	9	1.2	1.62	0.823

22	0.0254	0.64516	16.14	52.9392	7	0.92	1.29	0.653
23	0.0226	0.57404	20.36	66.7808	4.7	0.729	1.02	0.518
24	0.0201	0.51054	25.67	84.1976	3.5	0.577	0.810	0.410
25	0.0179	0.45466	32.37	106.1736	2.7	0.457	0.642	0.326
26	0.0159	0.40386	40.81	133.8568	2.2	0.361	0.509	0.258
27	0.0142	0.36068	51.47	168.8216	1.7	0.288	0.404	0.205
28	0.0126	0.32004	64.9	212.872	1.4	0.226	0.320	0.162
29	0.0113	0.28702	81.83	268.4024	1.2	0.182	0.254	0.129
30	0.01	0.254	103.2	338.496	0.86	0.142	0.202	0.102

Note: In the North American electrical industry, conductors **larger** than **4/0 AWG** are generally identified by the **area** in thousands of **circular mils** (kcmil), where **1 kcmil** = **0.5067 mm²**. A circular mil is the area of a wire one mil in diameter. One million circular mils is the area of a circle with **1000 mil** = **1 inch diameter**.

Voltage Drops: Since all wires have **resistance**, the longer the wire, the greater the resistance. All conductors and cables (except super conductors) have some amount of resistance. This resistance is directly **proportional** to the length and inversely proportional to the diameter of conductor **R ∝ L/a** [Laws of resistance R = ρ (L/a)].

This means that for **longer** wiring runs is necessary to use a **larger** wire to compensate resistance, whose phenomenon is often referred to as *"voltage drop".* For **lower** voltage automotive systems, the loss of **2V** or even **1V** can be significant. There are specific voltage drop calculations that depend on the wire **size** in use, the length of the wire, the load applied, and the voltage in use.

Whenever **current** flows through a conductor, a voltage drop occurs in that conductor. Generally, *"voltage drop"* may be neglected for low length conductors but, for long length conductors, it cannot be neglected. According to IEEE rule B-23, at any point between power supply terminal and installation, Voltage **drop** should not increase above **2.5%** of provided (supply) voltage.

Example: If the supply voltage is **220V**, then the value of allowable voltage **drop** should be: Allowable Voltage Drop = 220 x (2.5/100) = **5.5V**.

In electrical wiring circuits, voltage drops also occur from the distribution board to the different sub-circuit and final sub-circuits, but for sub circuits and final sub circuits, the value of voltage drop should be half of that allowable voltage drops (i.e. 2.75V of 5.5V in the above case). In SI (System international or metric system) voltage drop is described by **ampere per meter** (A/m). In FPS (foot pound system) voltage drop is described in **100 feet**.

Determining the **size of cable** for a given load, take into account the following **rules**. For a given **load**, there should be **20%** extra scope of current for additional, future or emergency needs. From the **energy meter** to distribution board, the voltage drop should be **1.25%** and for final sub circuit, voltage drop should **not** exceed **2.5%** of the supply voltage.

Example: Electrical wiring installation in a building. Total load is **4.5 kW** and total length of cable from energy meter to sub circuit distribution board is **35 feet**. Supply voltages are **220V**. Find the most suitable size of cable from energy meter to sub circuit if wiring is installed in conduits.

Solution:

Total Load = 4.5kW = 4.5 x1000W = **4500W** - 20% additional load = 4500 x (20/100) = **900W**
Total Load = 4500W + 900W = **5400W**
Total Current = I = P/V = 5400W /220V = **24.5A**

Obs.: Always select the **next size** of cable for load current (taken from a standard Table), thus **AWG 10** = 7/0.0385 (30 Amperes).

Temperature: Beyond the load factor when finding the size of cable, it´s also necessary to consider the change in temperature, using the temperature **factors** (see NEC tables). When determining the cable size also consider the wiring system, even when temperature is low, considering that in conduit wiring, temperature increases due to the absence of air.

Conductors Sizing and Ampacity Chart: Ampacity is defined as the maximum **amount** of electrical **current** a conductor or device can carry, also described as **current rating** or current-carrying capacity. Amperage (A) is a measure of the electrical current flowing through a circuit. Current is measured in amperes (A) or "*amps*". Always use the correct size wires for the amperage requirements of the circuit to prevent overheating and fire.

The number and type of electrical **devices** connected to a circuit determine the amperage requirement of the circuit. Usually, a general purpose house circuit is designed for **20 A** (or amps). Lighting circuits may be designed for only **15 A**. To calculate the amperage for a circuit, first add up all powers or *wattage of all the electrical devices* that will be on the circuit. Then, **divide** the total *wattage* (W) by the *voltage (V) of the system*, **110 or 220**, and that will give you the expected current or **amps**. The main standardized conductors and the amperage requirements are:

Copper Conductors				Aluminium Conductors		
Wire Gage Size	60°C (140°F) TW, UF	75°C (167°F) RHW, THW, THWN, THHW, XHHW, USE	90°C (194°F) RHH, RHW-2, XHHW, XHHW-2 XHH, THHW, THWN-2, THW-2, THHN, USE-2	60°C (140°F) TW, UF	75°C (167°F) RHW, THW, THWN, THHW, XHHW, USE	90°C (194°F) RHH, RHW-2, XHHW, XHHW-2 XHH, THHW, THWN-2, THW-2, THHN, USE-2
14	20	20	25		---	---
12	25	25	30	20	20	25
10	30	35	40	25	30	35
8	40	50	55	30	40	45
6	55	65	75	40	50	60
4	70	85	95	55	65	75
3	85	100	110	65	75	85

2	95	115	130	75	90	100
1	110	130	150	85	100	115
1/0	125	150	170	100	120	135
2/0	145	175	195	115	135	150
3/0	165	200	225	130	155	175
4/0	195	230	260	150	180	205
250	215	255	290	170	205	230
300	300	285	320	190	230	255
350	260	310	350	210	250	280
400	280	335	380	225	270	305
500	320	380	430	260	310	350
600	355	420	475	285	340	385
700	385	460	520	310	375	420
750	385	475	535	320	385	435
800	410	490	555	330	395	450
900	435	520	585	355	425	480
1000	455	545	615	375	445	500
1250	495	590	665	405	485	545
1500	520	625	705	435	520	585
1750	545	650	735	455	545	615
2000	560	665	750	470	560	630

Note: One common wire size used in the NEC has a cross-section of **250,000 circular mils**, written as ***250 kcmil or 250 mcm***, which is the **first** size larger than 0000 AWG used within the NEC. In the Metric Gauge scale, the gauge is 10 times the diameter in millimeters, so a 50 gauge metric wire would be **5 mm** in diameter. In AWG the diameter goes up as the gauge goes down, but for metric gauges it is the opposite. Because of this confusion, most of the time metric sized wire is specified in **millimeters** rather than metric gauges.

Metric Standard Wire Sizes (IEC 60228)					
0.5 mm²	0.75 mm²	1 mm²	1.5 mm²	2.5 mm²	4 mm²
mm²	10 mm²	16 mm²	25 mm²	35 mm²	50 mm²
70 mm²	95 mm²	120 mm²	150 mm²	185 mm²	240 mm²
300 mm²	400 mm²	500 mm²	630 mm²	800 mm²	1000 mm²

Metric AWG Conversion:						
Cross Sectional Area	Wire Size		Number strands/diameter per strand		Approximate overall diameter	
mm²	Awg	Circ. Mils	inch	mm	inch	mm
0.5		987	1/0.032	1/0.813	0.032	0.81
	20	1020	7/0.0121	7/0.307	0.036	0.91

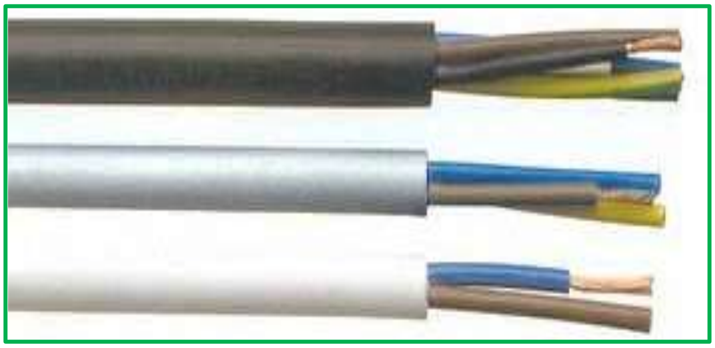
0.75		1480	1/0.039	1/0.991	0.039	0.99
	18	1620	1/0.0403	1/1.02	0.04	1.02
	18	1620	7/0.0152	7/0.386	0.046	1.16
1		1974	1/0.045	1/1.14	0.045	1.14
1		1974	7/0.017	7/0.432	0.051	1.3
	16	2580	1/0.0508	1/1.29	0.051	1.29
	16	2580	7/0.0192	7/0.488	0.058	1.46
1.5		2960	1/0.055	1/1.40	0.055	1.4
1.5		2960	7/0.021	7/.533	0.063	1.6
	14	4110	1/0.0641	1/1.63	0.064	1.63
	14	4110	7/0.0242	7/.615	0.073	1.84
2.5		4934	1/0.071	1/1.80	0.071	1.8
2.5		4934	7/0.027	7/0.686	0.081	2.06
	12	6530	1/0.0808	1/2.05	0.081	2.05
	12	6530	7/0.0305	7/0.775	0.092	2.32
4		7894	1/0.089	1/2.26	0.089	2.26
4		7894	7/0.034	7/0.864	0.102	2.59
	10	10380	1/0.1019	1/2.59	0.102	2.59
	10	10380	7/0.0385	7/0.978	0.116	2.93
6		11840	1/0.109	1/2.77	0.109	2.77
6		11840	7/0.042	7/1.07	0.126	3.21
	9	13090	1/0.1144	1/2.91	0.1144	2.91
	9	13090	7/0.0432	7/1.10	0.13	3.3
	8	16510	1/0.1285	1/3.26	0.128	3.26
	8	16510	7/0.0486	7/1.23	0.146	3.7
10		19740	1/0.141	1/3.58	0.141	3.58
10		19740	7/0.054	7/1.37	0.162	4.12
	7	20820	1/0.1443	1/3.67	0.144	3.67
	7	20820	7/0.0545	7/1.38	0.164	4.15
	6	26240	1/0.162	1/4.11	0.162	4.11
	6	26240	7/0.0612	7/1.55	0.184	4.66
16		31580	7/0.068	7/1.73	0.204	5.18
	5	33090	7/0.0688	7/1.75	0.206	5.24
	4	41740	7/0.0772	7/1.96	0.232	5.88
25		49340	7/0.085	7/2.16	0.255	6.48

25		49340	19/0.052	19/1.32	0.26	6.6
	3	52620	7/0.0867	7/2.20	0.26	6.61
	2	66360	7/0.0974	7/2.47	0.292	7.42
35		69070	19/0.061	19/1.55	0.305	7.75
	1	83690	19/0.0664	19/1.69	0.332	9.43
50		98680	19/0.073	19/1.85	0.365	9.27
	1/0	105600	19/0.0745	19/1.89	0.373	9.46
	2/0	133100	190/0.0837	19/2.13	0.419	10.6
70		138100	19/0.086	19/2.18	0.43	10.9
	3/0	167800	19/0.094	19/2.39	0.47	11.9
95		187500	19/0.101	19/2.57	0.505	12.8
95		187500	37/0.072	37/1.83	0.504	12.8
	4/0	211600	19/0.1055	19/2.68	0.528	13.4
120		237.8 mcm	37/0.081	37/2.06	0.567	14.4
		250 mcm	37/0.0822	37/2.09	0.575	14.6
150		300 mcm	37/0.090	37/2.29	0.63	16
		350 mcm	37/0.0973	37/2.47	0.681	17.3
185		365.1 mcm	37/0.100	37/2.54	0.7	17.8
		400 mcm	37/0.104	37/2.64	0.728	18.5
240		473.6 mcm	37/0.114	37/2.90	0.798	20.3
240		473.6 mcm	61/0.089	61/2.26	0.801	20.3
		500 mcm	37/0.1162	37/2.95	0.813	20.7
300		592.1 mcm	61/0.099	61/2.51	0.891	22.6
		600 mcm	61/0.0992	61/2.52	0.893	22.7
		700 mcm	61/0.1071	61/2.72	0.964	24.5
		750 mcm	61/0.1109	61/2.82	0.998	25.4
400		789.4 mcm	61/0.114	61/2.90	1.026	26.1
		800 mcm	61/0.1145	61/2.91	1.031	26.2
500		1000 mcm	61/0.1280	61/3.25	1.152	29.3

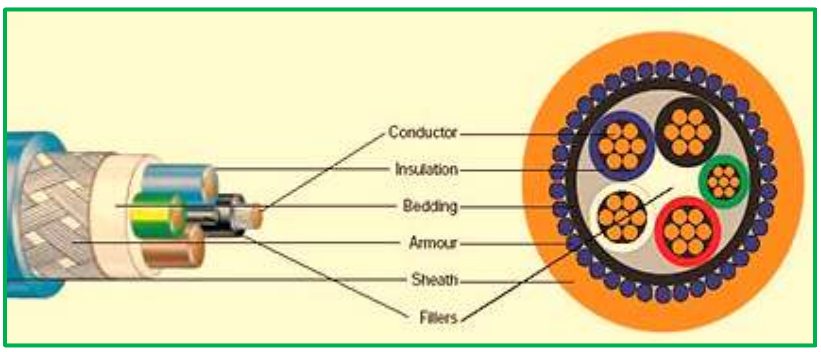
Control & Automation Cables: Consist in selection of high quality control cables including flexible *control cables or flexible* ***automation*** *cables*. These cables are supplied to a variety of industries and applications, including robotics, manufacturing, construction, power and distribution, computers and more. These are common in both commercial and industrial markets. *Flexible and continuous flex cables* are **not** the same, as flexible control cables may bend during installation, and should remain stationary in their final applications, but on the other hand, should **move** constantly. These cables may also be referred to as **chain-suitable** cable or **high-flex** cable. Flex cables are used for panel, conduit and general wiring applications where there is a requirement for

flexibility and, in the event of **fire**, there is a need to minimize the risk from smoke and toxic fumes, but circuit integrity is not required. There are *two main categories* of flexible control cables:

- ✓ **Control Cables Stranded in Layers:** Are less expensive than **stranded** in bundles, since they are designed with **multiple** layers of stranding on top of each other. The cable cores are stranded firmly and left relatively **long** in several layers around the center and are then enclosed in an extruded tube shaped jacket. Thus, the outer layers are pulled and the inner layers are compacted when the cable bends. Eventually, this may cause *distortion and warping* when installing flexible cables.



- ✓ **Control Cables Stranded in Bundles:** Bundled cables are generally a little more **expensive** than those stranded in layers, but in the bundled cables, the layers are **braided** around a tension-proof core. This allows layers to "*switch places*" throughout the bending, so no one layer is always compressed or always stretched. This gives the control cables a longer life span. Flex cables have much **longer** service lives than bundled cables.



Left, control cables stranded in *layers* and right, stranded in *bundles*

Different control cables are **designed** to meet the needs of different **applications**. If an application requires twisting, choose a torsion cable. For fast data transmission in bus systems, choose bus cable. The basic types of conductors and recommended applications are:

Single Conductors			Multiple Conductors	
HHN MTW	THHN may be used in dry locations and THWN in wet conditions at temperatures not to exceed 90°C. MTW may be used as machine tool wiring not to exceed		TW	Primarily used in residential wiring as branch circuits for outlets, switches, and other loads.

AWM	60°C. AWM marking signifies appliance at conductor temperatures not to exceed 105°C. Sizes 1/0 and larger is suitable for use in cable trays.	UF	May be used underground, including direct burial, for supplying power to outside lamp posts, well pumps, workshops, etc. May be used for interior branch circuit wiring in dry, wet or corrosive locations at conductor temperatures do not exceed 90°C.
USE	Type USE-2, RHH and RHW-2 can be used for underground service entrance, including direct burial. It may be used in wet or dry locations at conductor temperatures not to exceed 90°C.		
XHHW-2	Type XHHW-2 may be used in wet or dry locations where conductor temperatures do not exceed 90°C.	SEU	Service Entrance Cables may be used to transfer power from the service drop to the panel box. Each phase conductor is type THHN or THWN suitable for conductor temperatures do not exceed 90°C.

THHN Conductors: Thermoplastic High-resistant Nylon coated (THHN) wire is the **most** popular type of building wire is. This building wire, as defined by the National Electrical Code, is for use in construction. Engineers also commonly use THHN in machine tools, control circuits and some appliances. This wire **specification** comes in *two types* of conductors depending on the size; *stranded or solid*. It's manufactured with either *copper or aluminum*, and it's covered in *polyvinyl chloride* (PVC) *insulation* with a nylon jacket.

The wire is approved for up to **600 V** and is listed by Underwriters Laboratory (UL), an independent product standards company, as rated for **90°C** in dry locations and **75°C** in wet environments. Much of THHN wire comes with a dual rating: THHN/THWN, which means it's appropriate for both wet and dry applications.

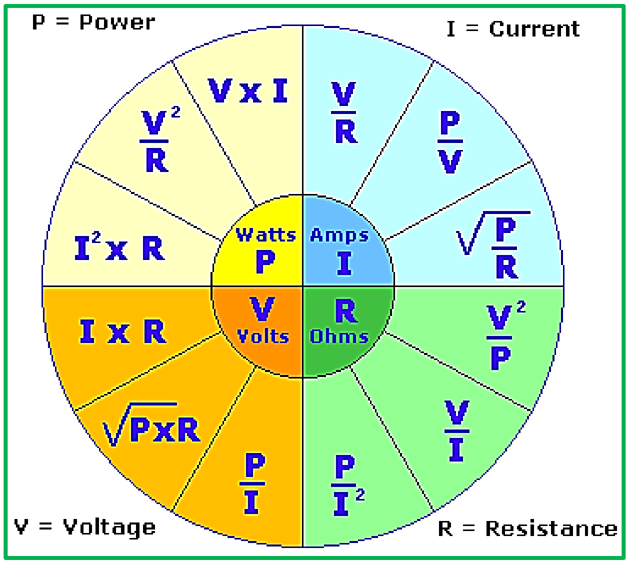
XHHW and XHHW-2 Conductors: Cross-linked Polyethylene High Heat-Resistant Water-Resistant (XHHW-2) wire is the **newest** generation of XHHW wire. While its main designation is for use in residential, commercial and industrial buildings, it's also **used** in raceways and feeder and circuit wiring. This wire is manufactured with *copper or aluminum* conductors and is either solid or stranded cable. A larger size wire is stranded to maintain flexibility. XHHW-2 is approved for use up to 600 volts and rated by UL for **90°C** Celsius in dry and wet locations.

Comparison between THHN and XHHW-2: THHN uses a **thinner** PVC insulation, but could be a disadvantage depending on the application. The reduced coating can lead to current leakage and can break down from chemical or environmental exposures. Wires types XHHW-2 has XLPE insulation **instead** of the PVC insulation used in THHN wire. This makes XHHW the more expensive option, but its coating is more resistant to chemicals, ozone and abrasions.

The THHN wire coating is **thinner** and emits a toxic smoke when burned. This is avoided in wire XHHW-2 with the use of a different insulation. The THHN wire isn't as flexible as some alternatives because of the nylon coating, gained in mechanical strength, but loses in flexibility. XHHW-2's coating is more flexible and may be advantageous for difficult projects. While XHHW-2 wire provides certain advantages over THHN, THHN wire is popular because it meets the needs of engineers for many projects and fits their budgets.

Electrical Calculations: There are a number of formulas that relate each of these four things; and change the relationship to one another to calculate all units. The formula wheel below, presents the calculation formulae, in an easy way to understand the format. There are four basic units of measurement for electricity:

- Power, measured in Watts, commonly referred to as "P";
- Current, measured in Amps, commonly referred to as "I";
- Voltage, measured in Volts, commonly referred to as "V";
- Resistance, measured in Ohms, commonly referred to as "R".



Basic Wire Application Examples:

Wire Use	Rated Ampacity (min)	Wire Gauge
Low-voltage Lighting and Lamp Cords	10 Amps	18 Gauge
Extension Cords	13 Amps	16 Gauge
Light Fixtures, Lamps, Lighting Runs	15 Amps	14 Gauge
Receptacles, 110-volt Air Conditioners, Sump Pumps, Kitchen Appliances	20 Amps	12 Gauge
Electric Clothes Dryers, 220-volt Window Air Conditioners, Built-in Ovens, Electric Water Heaters	30 Amps	10 Gauge
Cook Tops	45 Amps	8 Gauge
Electric Furnaces, Large Electric Heaters	60 Amps	6 Gauge
Electric Furnaces, Large Electric Water Heaters, Sub	80 Amps	4 Gauge

Panels		
Service Panels, Sub Panels	100 Amps	2 Gauge
Service Entrance Cables (SEU)	150 Amps	1/0 Gauge
Service Entrance Cables (SEU)	200 Amps	2/0 Gauge

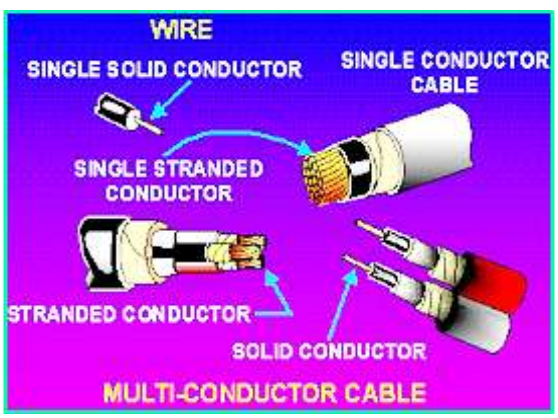
Note: For installations that need to be conform to the National Electrical Code, always use their guidelines.

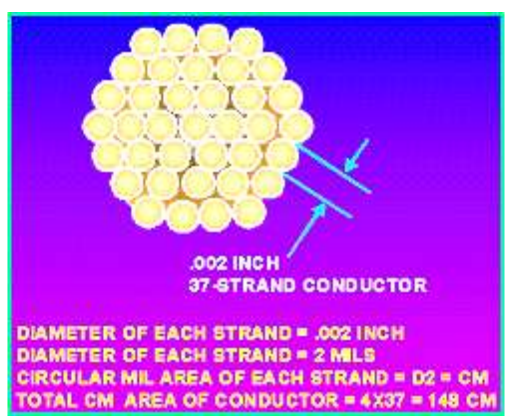
IV. DEFINITIONS OF WIRES, CONDUCTORS AND CABLES:

A **wire** is a **single** slender rod or filament of drawn metal. This definition restricts the term to what would ordinarily be understood as "*solid wire*". The word "*slender*" is used because the length of a wire is usually **large** when compared to its diameter. If a wire is covered with insulation, it is an insulated wire. Although the term "wire" properly refers to the metal, it also includes the insulation.

A **conductor** is commonly manufactured in a **stranded** form. A stranded conductor is composed of a group of **wires** in any group combination of wires. The wires in a stranded conductor are usually **twisted** together and not insulated from each other. Conductors are stranded mainly to increase their flexibility. The wire strands in cables are arranged in the following order:

- The first layer of strands around the center conductor is made up of six conductors. The second layer is made up of 12 additional conductors.
- The third layer is made up of 18 additional conductors, and so on. Thus, standard cables are composed of 7, 19, and 37 strands, in continuing fixed increments.
- The overall flexibility can be increased by further stranding of the individual strands.
- Figure below shows a typical cross section of a 37-strand cable. It also shows how the total circular-mil cross-sectional area of a stranded cable is determined.





A **cable** is either a **stranded** conductor (single-conductor cable) or a combination of conductors insulated from one another (multiple-conductor cable). The term "*cable*" usually applies only to the **larger** sizes of conductors. A small cable is more often called a **stranded wire** or cord (such as that used for an iron or a lamp cord). Cables may be bare or insulated. Insulated cables may be sheathed (covered) with lead, or protective armor.

Cable Insulation: Different types of insulation are applied at different temperatures. Therefore, the type of insulation used is a **third** factor that **determines** the current rating of a conductor. For instance, rubber insulation will begin deteriorating at relatively low temperatures, whereas varnished cloth insulation retains its insulating properties at higher temperatures. Other types of insulation are fluorinated ethylene propylene (FEP), silicone rubber, or extruded polytetra-fluoroethylene, effective at even higher temperatures.

Safe Current Ratings: The National Board of Fire Underwriters prepares tables showing the **safe current ratings** for sizes and types of conductors covered with various types of **insulation**. The allowable current-carrying capacities of single copper conductors in free air at a maximum room temperature of **30°C** (86°F) are given in table below. At ambient temperatures **greater** than 30°C, these conductors would have less current-carrying capacity.

Temperature Ratings and Current-Carrying Capacities (Amperes). Basic Single Copper Conductors at Ambient Temperature (30º C) (86°F).

Size	Moisture Resistant Rubber or Thermoplastic	Varnished Cambric or Heat Resistant Thermoplastic	Silicone Rubber or Fluorinated Ethylene Propylene (FEP)	Polytetra-Fluoroethylene
0000	300	385	510	850
000	260	330	430	725
00	225	285	370	605
0	195	245	325	545
1	165	210	280	450
2	140	180	240	390
3	120	155	210	335
4	105	135	180	285
6	80	100	135	210
8	55	70	100	115
10	40	55	75	110
12	25	40	55	80
14	20	30	45	60

Note: An **increase** in the **diameter**, or cross section, of a wire conductor decreases its resistance and increases its capacity to carry current. An increase in the specific resistance of a conductor increases its resistance and decreases its capacity to carry current.

V. INDUSTRIAL AND POWER CABLES:

Power Distribution Cables: Industrial cables are used in installations with one or more electrical **conductors**, usually held together with an overall **sheath**, usually used for transmission of electrical power. Power cables may be installed as permanent wiring within buildings, **buried** in the ground, run overhead, or exposed. Flexible power cables are used for portable devices, mobile tools and machinery.

The **first** power distribution system developed by Thomas **Edison** in **1882** in New York City, used copper rods, wrapped in **jute** and placed in rigid pipes filled with a bituminous compound. Although vulcanized rubber had been **patented** by Charles Goodyear in **1844**, it was not applied to cable insulation until the **1880s**, when it was used for lighting circuits.

Rubber-insulated cable was used for **11,000 V** circuits in **1897**, installed in the **Niagara Falls** power Westinghouse and Nikola Tesla project. During World War II several varieties of synthetic rubber and polyethylene insulation were applied to cables. Nowadays, cables consist of **three major** components; conductors, insulation and protective jacket, but vary according to application.

Modern high-voltage cables use **polymers** or polyethylene, including XLPE for insulation, but require special techniques for jointing and terminating. Many multi-conductor cables have a bare or insulated *grounding* or *bonding* wire, which is used for connection to **earth ground**. The rounding conductor connects equipment enclosures to ground for protection from electric shock.

Electrical power cables are often installed in raceways, including electrical conduit and **cable trays** that may contain one or more conductors. Power cables commonly use stranded copper or aluminum conductors, although **small** power cables may use solid conductors. A **hybrid** cable can include conductors for control signals or may also include optical fibers for data.

Power and control cables serve an extensive **range** of markets including industrial instrumentation, electronics, automotive, machine tools, solar wind, power generation, refining and petrochemical, natural gas production, steel, pulp and paper, and factory automation. Electronic **wires** include hook-up, communication cables, computer, coaxial, microphone cables, security, fire alarms and audio/video applications.

Flexible **cords** contain fine stranded conductors, not solid core conductors, and have insulation and sheaths to withstand the forces of repeated flexing and abrasion. Very **flexible** power cables are used in automated machinery, robotics, and machine tools. Other types of flexible cables include power cords, twisted pairs, extensible, coaxial, shielded, and communication cables.

Mineral-insulated Copper-clad Cables: Are electrical cables made from copper conductors inside a copper sheath, insulated by inorganic magnesium oxide powder. The name is often abbreviated to MICC or MI cable, and colloquially known as pyro (because the original manufacturer and vendor for this product in the UK was a company called Pyrotenax). A similar product sheathed with metals other than copper is called *mineral insulated metal sheathed* (MIMS) cable.

Automotive Cables: From **ignition** wire sets and single leads to bulk ignition wires and **battery** starter cables, should be according to requirements and strong quality control standards, of the ISO/TS 16949: 2002, as well as stringent process, performances, and service requirements.

Mining Cables: Mining cables are manufactured and tested to **meet** or exceed industry standards, such as UL, CSA, MSHA, and OSHA, ensure performance while meeting the most **severe** and extreme demands of the toughest mining applications, also meet approval of Federal and Military Specifications JC-580B, NEC® Article 400 and are RoHS compliant.

Nuclear Cables: Advanced **Class 1E** nuclear-qualified cable technology to support upgrades and new construction of nuclear facilities in both inside and outside containment environments. Control specifications are:

- Class 1E safety-related medium- and low-voltage cables;
- Non-Class 1E safety significant and non-safety related low- and medium-voltage cables;
- Conforms to IEEE 323 and IEEE 383 requirements for GEN III.

Oil, Gas & Petrochemical Cables: The **offshore** drilling and production market requires high-performance specialty wires and cables for utmost **safety**, productivity and resistance to harsh environmental conditions. From FPSO (Floating Production Storage and Offloading) platforms to jack-up rigs, mobile offshore **drilling** units and land-based drilling rigs, should be according to advanced IEEE, IEC and marine shipboard cables.

Solar Energy Cables: Are the interconnection cables used in **photovoltaic** power generation. Solar cables interconnect **solar panels** and other electrical components in the photovoltaic system, designed to be **UV resistant** and weather resistant. Single-core cables with a maximum permissible DC voltage of **1.8 kV** and a temperature range from -40°C to +90°C are generally used.

Wind Energy Cables: Fall into **three** categories; nacelle for signals and power, lightning protection, and balance of plant cables from turbine transformer to the collector. The **nacelle** cables carry low-voltage control signals, data, and communication connections. The **power** cables (15 to 45 kV) for **distribution** are in accordance with ANSI/ICEA S-94-649 for Type URD concentric neutral and flat-strap cables. The **conductors** come in solid or **class B** compressed, concentric-lay stranded aluminum or copper, meeting appropriate requirements of ICEA and ASTM.

VI. COMPUTER NETWORK CABLING SYSTEMS:

Structured Cabling Systems: Consist of wiring networks that **carry** data, voice, multimedia, security, wireless connections, throughout a building or an industrial plant, including cabling, connecting hardwares, equipment and telecommunication rooms. Also **include**, VoIP, PoE, cable pathways, work areas, and even the jacks on walls and racks. The importance of **structured** cabling has increased right alongside the growth of LANs, MANs, and WANs, as resumed below:

VoIP & PoE: VoIP or Voice-over-Internet Protocol is a **group** of technologies for **voice** communications and multimedia over Internet Protocol (IP) networks. **PoE** means **Power over Ethernet** using industrial Ethernet switches to **provide** data and power over the same piece of cable. The **services** commonly associated with **VoIP** are *IP telephony*, *Internet Telephony*, *Voice over Broadband* (VoBB), *Broadband Telephony*, *IP communications*, and *Broadband Phone Service*.

LAN, WAN & MAN: ***LAN** means Local Area Network* is a **computer network** that interconnects computers within a limited area, such as a home, school, computer labs or office buildings, using a network media. ***WAN** means Wide Area Network* and consists of two or more local-area networks (LANs). The largest WAN in existence is the Internet. ***MAN** or Metropolitan Area Network* is a network designed for a town or city. In terms of geographic breadth, MANs are larger than local-area networks (LANs), but smaller than wide-area networks (WANs), usually characterized by very high-speed connections using fiber optical cable or other digital media.

Ethernet Evolution: In 1985, ***10-Mbps Ethernet*** was first standardized. In 1995 new demand for bandwidth and speed increased for high-performance applications, which come with the standardization of ***100-Mbps Fast Ethernet***. In 1998 came the ***Gigabit Ethernet***, and in 2002, the ratification of the ***10-Gigabit Ethernet***. Each step forward represents a **tenfold** increase in performance. The 10-Gigabit Ethernet is a logical extension of previous Ethernet networks, transformed with the predominant technology for high-performance LANs.

The original **Ethernet** networks (10BASE5 and 10BASE2) ran over **coaxial cables**. An upgrade to 10BASE-T operated over **unshielded twisted-pair cable** with a speed of **10 Mbps**. Next, the technology progressed to 100BASE-TX, running at **100 Mbps** specified with minimum of **CAT5 cables**, and after the **CAT5e cables** became more common. The Gigabit Ethernet (1 Gbps) was developed to handle **backbone** and server traffic. Backbone is a structured cabling system that can **tie together** diverse **networks** in the same building, or in **different** buildings over wide areas. When Gigabit Ethernet first appeared, **optical fiber cables** turned to be crucial to running it effectively. Later the IEEE 802.3ab standard approved the Gigabit Ethernet over **Category 5 cables**, although CAT5e or higher is the recommended application.

The 10-Gigabit Ethernet (10-GbE) brings the cost effectiveness of Ethernet to **high-performance** networks with a speed **ten times** that of Gigabit Ethernet and a frequency of **500 MHz**, supporting high-bandwidth applications, such as **imaging** and **storage**. The 10-Gigabit Ethernet **enables** the construction of MANs and WANs to connect geographically dispersed LANs. Today, the most common **application** for 10-Gigabit Ethernet (10-GbE) is a **large** backbone connecting high-speed LANs. The 10-GbE over **fiber** was ratified in 2002. An IEEE amendment in 2006, 802.3an, approved 10-GbE over **twisted pair**. The TIA/EIA-568-B.2.10 draft specifies transmission performance for Augmented **Category 6** cable. The TSB-155 addresses existing Category 6 cabling for 10-GbE, emerging as the standard cabling, as indicated below:

Ethernet Standards

Network	Standard	IEEE	Cable	Speed	Distance
Ethernet	10BASE5, 2	802.3	Coaxial	10 Mbps	500 m/185 m
	10BASE-T	802.3i	CAT3	10 Mbps	100 m
	10BASE-F, -FB, FL, FP	802.3	Fiber	10 Mbps	2000 m/500 m
Fast Ethernet	100BASE-TX, T4	802.3u	CAT5	100 Mbps	100 m
	100BASE-FX	802.3u	MM Fiber	100 Mbps	400 m half-duplex 2 km full-duplex
Gigabit Ethernet	1000BASE-T	802.3ab	CAT5e/CAT6	1000 Mbps	100 m
	1000BASE-LX	802.3z	MM, SM Fiber	1000 Mbps	550 m/5000 m
	1000BASE-SX	802.3z	MM Fiber	1000 Mbps	550 m
10-Gigabit Ethernet	10GBASE-SR, -LR, LX -ER, -SW, -LW, -EW	802.3ae	MM, SM Fiber	10 Gbps	65 m to 40 km
	10GBASE-CX4	802.3ak	100-Ω Twinax	4 x 2.5 Gbps	15 m
	10GBASE-T	802.3an	UTP	10 Gbps	100 m

Cable Categories: The need for increased bandwidth grows and applications are continually more complex, thus, TIA/EIA-568B specifies several “categories” for both components and cables. The ISO/IEC specifies “categories” for components and “classes” for the cabling. Below are brief explanations for twisted-pair cablings and the best suited applications.

- ✓ **Category 3 (CAT3)** cable, is rated for networks operating up to 16 Mbps, suitable for voice transmissions (not VoIP). The ISO/IEC refers to the end-to-end channel as Class C.
- ✓ **Category 4** cable is rated for transmission of 16 Mbps up to 100 meters, but actually considered obsolete.
- ✓ **Category 5 (CAT5)** cable, was common for 100-Mbps LANs, ratified in 1991, and is also now considered obsolete.
- ✓ **Enhanced Category 5 (CAT5e/Class D)** cable, designed to enable twisted-pair cabling to support full-duplex, 100-MHz applications, such as 100BASE-TX and 1000BASE-T. The CAT5e introduces stricter performance parameters, such as Power-Sum Near-End Crosstalk (PS-NEXT), Equal-Level Far-End Crosstalk (EL-FEXT), and Power-Sum Equal-Level Far-End Crosstalk (PS-ELFEXT), channel and component testing.
- ✓ **Category 6 (CAT6/Class E)** cable, is a 100-ohm with a frequency of 250 MHz, easily handles Gigabit Ethernet (1000BASE-T). The CAT6 components must be compatible with lower-level components, and all the components in a channel must be of the same level. If not, the channel will perform at the lowest level.
- ✓ **Augmented Category 6 (CAT6a/Class EA)** cable, is a relatively new standard, designed to meet or exceed the requirements of 10-Gigabit Ethernet over copper at 100 meters, extending the frequency range to 500 MHz. Both UTP and F/UTP cables can be used as CAT6a sin- ce the F/UTP cable, virtually eliminates the problem of ANEXT.
- ✓ **Category 7/Class F** cable, is only an ISO/IEC 11801:2002 standard, not a TIA draft stage, designed to meet or exceed the requirements of 10-Gigabit Ethernet. The standard specifies a frequency of 600 MHz over 100 meters for fully shielded twisted-pair cabling. Category 7/Class F cable can be terminated with two interface designs. One is an RJ-45 compatible GG-45 connector. The other is the more common TERA® connector launched in 1999.
- ✓ **Category 7a/Class FA** is a pending ISO class based on the S/FTP cables to 1000 MHz.

Balanced Twisted-Pair Cable Specifications

	CAT5	CAT5e	CAT6	CAT6a	CAT7
Frequency	100 MHz	100 MHz	250 MHz	500 MHz	600 MHz
Attenuation (min. at 100 MHz)	22.0 dB	22.0 dB	19.8 dB	—	20.8 dB
Characteristic Impedance	100 ohms ± 15%	100 ohms ± 15%	100 ohms ± 15%	—	100 ohms ± 15%
NEXT (min. at 100 MHz)	32.3 dB	35.3 dB	44.3 dB	27.9 dB	62.1 dB
PS-NEXT (min. at 100 MHz)	—	32.3 dB	42.3 dB	—	59.1 dB
EL-FEXT (min. at 100 MHz)	—	23.8 dB	27.8 dB	9.3 dB	(not yet specified)
PS-ELFEXT (min. at 100 MHz)	—	20.8 dB	24.8 dB	—	(not yet specified)
PS-ANEXT (min. at 500 MHz)	—	—	—	49.5 dB	—
PS-AELFEXT (min. at 500 MHz)	16.0 dB	20.1 dB	20.1 dB	23.0 dB	14.1 dB
Return Loss (min. at 100 MHz)	16.0 dB	20.1 dB	20.1 dB	8.0 dB	14.1 dB
Delay Skew (max. per 100 m)	—	45 ns	45 ns	—	20 ns
Networks Supported	100BASE-TX	1000BASE-T	1000BASE-T	10GBASE-T	(not yet specified)

Note: In Shielded/Foiled Twisted Pair (S/FTP) or Foiled/Foiled Twisted Pair (F/FTP), each twisted pair is **enclosed** in foil. In S/FTP cable, the **four** pairs are **encased** in an overall metal **braid**. In F/FTP, the four pairs are encased in an overall foil **shield**, making this Category 7/Class F system ideal for high EMI areas, well suited for applications where fiber optics could be used, but F/FTP costs much less.

10-GbE and Twisted-pair Cables: The cabling industry is developing two different **standards** to be used in **10-GbE** applications. One is for use with Category 6 (CAT6) cables, and other is for the Augmented Category 6 (CAT6a). These standards specify **requirements**, such as cable and connecting hardwares, as well as for permanent links and channels, as defined below:

- **10-GbE for CAT6:** The CAT6 cable must **meet** the **10-GbE** electrical and ANEXT specifications up to **500 MHz**. However, the CAT6 standard specifies measurements only to **250 MHz**, and **does not** have ANEXT requirements, then, there is **no guarantee** CAT6 can support a **10-GbE** system. One way to **lessen** or eliminate ANEXT is to use **shielded** cable and equipment, such as the **UTP cable**. Another way is to use mitigating installation techniques, such as non-adjacent **patch panels**, separating equipment cords, unbundling horizontal cabling, avoiding areas of high EMI, etc.

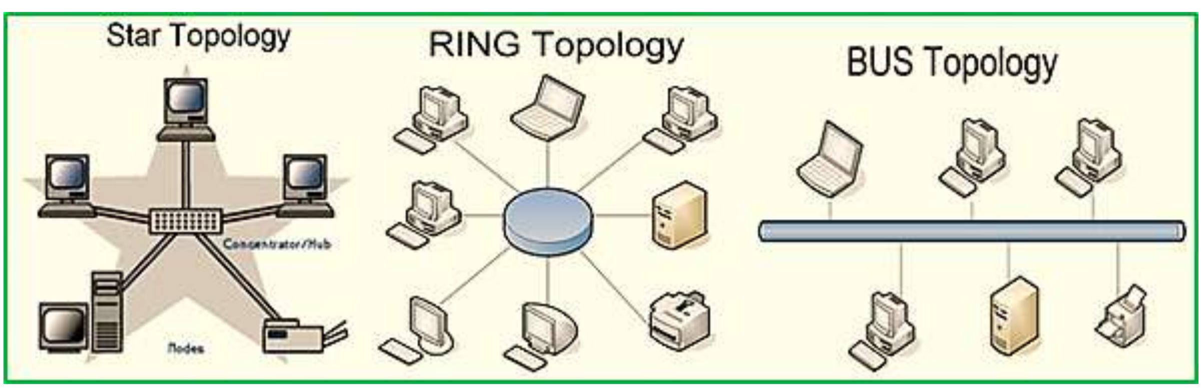
- **10-GbE for CAT6a:** This new augmented cabling system was designed to support **10-GbE** over a **100-meter** horizontal channel, and recognizes both **UTP** and **STP CAT6a** systems, extending the CAT6 electrical **parameters** such as NEXT, FEXT, return loss, insertion loss, and near and far-end Alien Crosstalk (ANEXT, AFEXT) to 500 MHz. The ISO Class EA standard will be published in a new edition of the 11801 standard.

Network Topologies: There are **three basic** network topologies: *star, ring, and bus*, as below:

- ✓ **Star:** Features point-to-point cable runs **radiating** from a central equipment room, which can have a PBX in voice or switches in data networks. Using a **star network** is possible to connect and disconnect equipment without **disrupting** the rest of the network, which facilitates smooth moves, additions, and changes. The 10BASE-T and later versions of Ethernet use a star topology. The TIA/EIA makes a few design recommendations for star topologies, such as, proximity to sources of EMI shall be taken into account; grounding should meet J-STD-607-A requirements.

- ✓ **Ring:** This topology links a **series** of **devices** in a continuous **loop**. A ring is a simple network, but it has some **disadvantages**. All the signals are passed from one device to the next until they reach the intended station.

- ✓ **Bus:** This topology consists of **one continuous cable**, commonly called as **backbone** cable. The original Ethernet topology was a bus. Devices are connected along this cable, and **data** travels in a linear fashion along the entire length of the bus. Devices can be removed **without** disrupting the entire network.

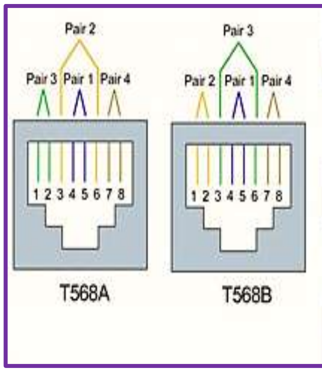


Work Area: Consists of **all components** between the telecommunications outlet and the user's desktop workstation equipment. The **UTP** wiring should follow T568A or T568B schemes, and the

4-pair UTP patch cable from the telecommunications outlet to the workstation equipment should be no more than **5 meters** (16.4 ft.). The specific recommendations in TIA/EIA-568-B.1 are:

- ✓ Telecommunications outlets, including wall plates, faceplates, surface-mount boxes, etc.;
- ✓ Patch cables;
- ✓ Adapters, including connectors, and modular jacks;
- ✓ Workstation equipment, such as PCs, telephones, printers, etc.;
- ✓ The first outlet is a 100-ohm, 8-position modular jack. Recommended CAT5e or higher.
- ✓ The second outlet is another 100-ohm, 8-position modular jack (min. CAT5e or CAT6), or...
- ✓ A 2-fiber, 62.5- or 50-micron fiber SC, ST, or other small-form factor duplex fiber connector.

T568A & T568B Pinning: The approved pinning **methods** are, T568Aand T568B. The T568A is the one **recognized** and used by the U.S. government. The T568A pinning is also common in Canada and in other parts of the world. The T568B pinning is the one used by AT&T® and is the standard in the U.S. The **T stands** for termination, and not TIA as commonly thought.



Wiring Color Codes				
Wire Color	Pair	Tip/Ring	T568A Jack Pin #	T568B Jack Pin #
White/Blue	1	Tip 1	5	5
Blue/White	1	Ring 1	4	4
White/Orange	2	Tip 2	3	1
Orange/White	2	Ring 2	6	2
White/Green	3	Tip 3	1	3
Green/White	3	Ring 3	2	6
White/Brown	4	Tip 4	7	7
Brown/White	4	Ring 4	8	8

UTP and Telecommunications Outlet/Connectors: Support **class F** cabling per IEC 61076-3-104. The Transmission measurement methods are for category 7 and class F specified by ISO/IEC 11801:2002 and 1.0 GHz per ISO/IEC 15018 and ISO/IEC 11801 Ed.2.

- ✓ 8-position modular jack, IEC 60603-7 (T568-B.1 states that all 4 pairs must be connected).
- ✓ Pin/pair assignment: T568A (US federal government publication NCS, FTR 1090-1997 recognizes designation T568A only).
- ✓ Optional assignment to accommodate certain systems: T568B.
- ✓ Durability rating 750 mating cycles minimum.
- ✓ Backward compatibility and interoperability is required.

Screened Cabling (F/UTP): Is a **media** with an overall shield over four twisted-pairs. This cabling type is recognized as F/UTP, which stands for a **Foil Applied over Unshielded Twisted-Pairs,** as a result of the release of TIA/EIA/IS-729, evolution for 568-B and 11801:2002 standards. The telecommunications groups recognize the presence of this type of cable. These UTPs should be marked "*100.ScTP*" or "*100.F/UTP*", in addition to any safety markings required by local or national codes. Same transmission requirements apply to **backbone** and horizontal cables. For instance, cable 0.51 mm (24 AWG) 100.4-pair enclosed by a foil shield. The **color** coding is:

- Pair 1 = White/Blue - Blue
- Pair 2 = White/Orange - Orange
- Pair 3 = White/Green - Green
- Pair 4 = White/Brown - Brown

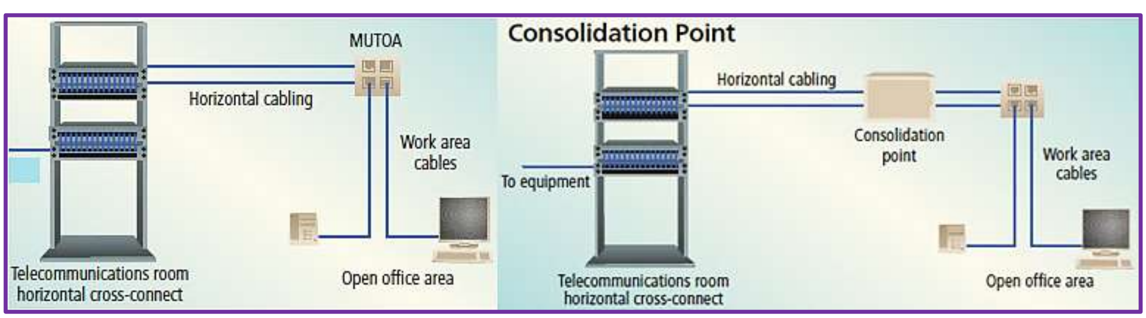
F/UTP Patch Cords: The specifications designates 26 AWG (7 strands @ 0.15mm) or 24 AWG (7 strands @ 0.20mm) stranded conductors, for an overall shield and **50%** more attenuation than horizontal cabling.

MUTOA (Multiuser Telecommunications Outlet Assembly): The MUTOA enables the **terminations** of **multiple** horizontal cables in a common, permanent location, such as a column, wall, or permanent furniture, close to a cluster of work areas. The TIA/EIA-568-B.1 has specified two horizontal cabling configurations; the MUTOA and the Consolidation Point. The horizontal system should be installed in a *star topology*. The guidelines include:

- ✓ Locate multi-user telecommunications outlets in a permanent location;
- ✓ Multi-user telecommunications outlets shall not be installed in the ceiling;
- ✓ The maximum cable length is 20 meters (65.6 ft.);
- ✓ A maximum of 12 work areas can be served;
- ✓ Uniquely identify work area cables on each end.

Consolidation Point: Consolidation Point (CP) is a straight-through interconnection point in the horizontal cabling. It provides another option for open office cabling and is ideal for work areas that are frequently reconfigured, but not as frequently as a MUTOA. Specifications include:

- ✓ Only one CP is allowed per horizontal run between the work area and telecommunications room. Cross-connection between the cables is not allowed.
- ✓ A CP should not be more than 15 meters (49.2 ft.) from the telecommunications room.
- ✓ A CP can serve a maximum of 12 work areas.



Open Office Cabling: For a dynamic office where people and or furniture is always changing regularly the standards allow for a MUTOA consolidates up to **24 sockets** in one enclosure rather than having multiple dual outlets placed on walls or floors, based on the length of the work area patch cord. Below is a table that summarizes these cable lengths:

Open Office Horizontal Cabling Distances		
Horizontal Cable Length	Maximum Work Area Cable Length (24 AWG)	Work Area, Patch, and Equipment Cord Maximum Combined Length
90 m (295.3 ft.)	5 m (16.4 ft.)	10 m (32.8 ft.)
85 m (278.9 ft.)	9 m (29.5 ft.)	14 m (45.9 ft.)
80 m (262.5 ft.)	13 m (42.6 ft.)	18 m (59.1 ft.)
75 m (246.1 ft.)	17 m (55.7 ft.)	22 m (72.1 ft.)
70 m (229.6 ft.)	22 m (72.1 ft.)	27 m (88.6 ft.)

Backbone Cabling Distances: The backbone cabling provides the **main information** for connecting all equipment in a **horizontal** cabling within a building and between buildings. It's the interconnection between telecommunication rooms, equipment rooms, and entrance facilities. In large organizations, is **recommended** to connect multiple LANs with a high-speed backbone to create large service areas. The distances to the backbone will most likely determine the type(s) of cables to be used, as below:

Backbone Cabling Distances			
Media Type	Main Cross-Connect to Horizontal Cross-Connect	Main Cross-Connect to Intermediate Cross-Connect	Intermediate Cross-Connect to Horizontal Cross-Connect
100-ohm Copper	800 m (2624.7 ft.)	500 m (1640.4 ft.)	300 m (984.3 ft.)
Multimode Fiber	2000 m (6561.7 ft.)	1700 m (5577.4 ft.)	300 m (984.3 ft.)
Single-mode Fiber	3000 m (9842.5 ft.)	2700 m (8858.3 ft.)	300 m (984.3 ft.)

Coaxial Cables or Coax Cables: Are cables that have an **inner** conductor surrounded by a tubular insulating layer, surrounded by a conducting shield. Coaxial cables have braided-grounded strands of wires that can provide some shielding and **noise** immunity, fitted with connectors called BNC (Bayonet Nut Connector), used in the older LAN technology, ARCnet and cable TV.

Obs.: Coaxial cable **differs** from the **shielded** cable used for lower-frequency signals, such as **audio** signals, as the dimensions of the cable are controlled to give a **precise**, constant conductor spacing, which is needed to function efficiently as a **radio** frequency transmission line. Coaxial cables are defined according to:

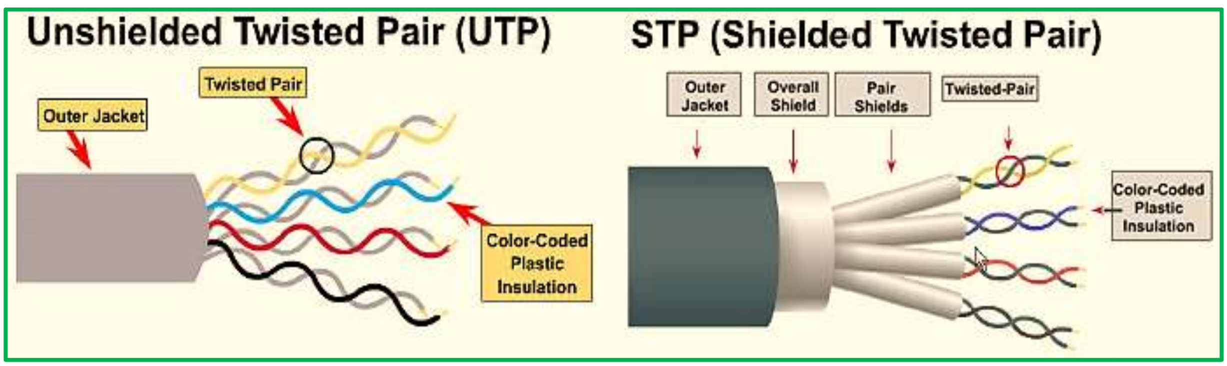
- **IEC standards:** Cables designed **primarily** for power, control, instrumentation and signal cables for use in the offshore oil and gas, ship & marine according to IEC standards.
- **IEEE/UL standards:** Cables designed **primarily** for power, control, instrumentation and signal cables for use in the offshore oil and gas, ship & marine industries in compliance with IEEE standards.

Unshielded Twisted Pair (UTP) Cabling: Consists of a set of **three** or **four** pairs of **wires**, in each pair, **twisted** together with the purposes of **preventing** electromagnetic interference (EMI) from external sources, for instance, electromagnetic radiation and crosstalk between neighboring pairs. The UTP cables were **invented** by Alexander Graham Bell.

The UTP cabling comes in form of ***Cat 2, 3, 4, and 5*** *grades*; however, only **Cat 5** is now recommended for any **data** applications, using RJ-45, RJ-11, RS-232, and RS-449 **connectors**. Examples of UTP applications are **telephone** networks that use RJ-11 connectors, and 10BASE-T networks that use RJ-45 connectors. The maximum length is **100 meters**, without using any kind of signal **regeneration** device, and a maximum data transfer rate of **1000 Mbps** for Gigabit Ethernet.

Shielded Twisted Pair (STP): Has also **four** pairs of wires, in each pair, twisted together. The difference is that **STP** is surrounded with a **foil shield and copper** braided around the wires, which allows more **protection** from external electromagnetic interference. The cable is physically **larger**, due the shielding, more difficult to install and terminate, and more expensive than UTP.

The STP cabling also uses RJ-45, RJ-11, RS-232, and RS-449 **connectors** for applications in electrically **noisy** environments, and also comes in **Cat 2, 3, 4, or 5 grades**, however, only **Cat 5** is recommended for any **data** applications. The maximum cable length with no signal regenerating device is **100 meters**, but the maximum data transfer rate is **500 Mbps** for Gigabit Ethernet.



New UTP Development: The UTP cabling evolved and the most common **shielded** cable types used today are under ***Cat. 6a, Cat.7 and Cat.8*** cables that also became common in many Ethernet **networks** and indoor telephone systems, often grouped into sets of **25 pairs** according to a standard 25-pair **color** code originally developed by AT & T Corporation. The most common of these cables are **white/blue, blue/white**, **white/orange** and **orange/white**, typically made with copper wires, sizes **22 or 24 AWG**, with colored insulation, such as **polyethylene or FEP**, which can use *BNC connectors* designed for coaxial cable. These **types** of cables also include:

- **Shielded Twisted Pair (U/FTP):** Has pairs in **metal foil**, and individual shielding in each twisted pair or quad. This type of shielding protects cable from external EMI from entering or exiting the cable and also protects neighboring pairs from crosstalk.

- **Screened Twisted Pair (F/UTP, S/UTP and SF/UTP):** Has overall foil and braided shields across all of the pairs within the **100-Ohm** twisted pair cable. This type of shielding protects EMI from entering or exiting the cable. It has also **foiled** twisted pairs for F/UTP.

- **Screened Shielded Twisted Pair (F/FTP and S/FTP):** Has also fully screened foiled twisted pairs and shielded foiled twisted pairs, between the twisted pair sets, and also an outer metal and/or foil shielding, within the **100-Ohm** twisted pair cable.

Note: For urban outdoor telephone cables containing hundreds or **thousands of pairs**, the cable is **divided** into smaller but identical bundles. The bundles are twisted together to make up the cable. Each bundle consists of twisted pairs and has **different** twist rates. Pairs having the same twist rate within the cable can still experience some degree of **crosstalk**. Wire pairs are selected carefully to minimize crosstalk within a large cable.

Cabling Specifications Chart: ANSI/TIA/EIA-568-B-SERIES AND ISO/IEC 11801 - 2nd Edition:

ANSI/TIA/EIA-568-B Series: Commercial Building Telecommunications Cabling Standard:	ISO/IEC 11801:2002 2ND Edition: Generic Cabling for Customer Premises:
Cross-connect (enabling the termination of cable elements and connection by patch cord or jumper).	Distributor (enabling the termination of cable elements and connection by patch cord or jumper).
MC (Main Cross-connect)	CD (Campus Distributor)
IC (Intermediate Cross-connect)	BD (Building Distributor)
HC (Horizontal Cross-connect)	FD (Floor Distributor)
CP (Consolidation Point): An interconnection scheme that connects horizontal cables from building pathways to horizontal cables extending into work area pathways.	Consolidation Point is a **location** in the horizontal cabling where a cable may be terminated, is not subject to moves and changes, and another cable starts leading to what is adaptable to changes, or, is a location for **interconnection** between horizontal cables extending from building pathways and horizontal cables extending into furniture pathways.
INTRA-BUILDING BACKBONE:	**CAMPUS BACKBONE:**
Horizontal Media Choices:	**Horizontal Media Choices:**
4-pair 100Ω unshielded twisted-pair (UTP or F/UTP)	4-pair 100Ω balanced cable (UTP or F/UTP)
Two fiber, 50/125µm or 62.5/125µm optical fiber	Optical fiber (50µm, 62.5µm or single-mode)
Backbone Media Choices:	**Backbone Media Choices:**
100Ω balanced twisted-pair (UTP or F/UTP)	100Ω balanced twisted-pair (UTP or F/UTP)
Multimode 50/125µm or 62.5/125µm optical fiber	Multimode 62.5/125µm or 50/125µm optical fiber
Singlemode optical fiber	Single-mode optical fiber
Bend Radius:	**Bend Radius:**

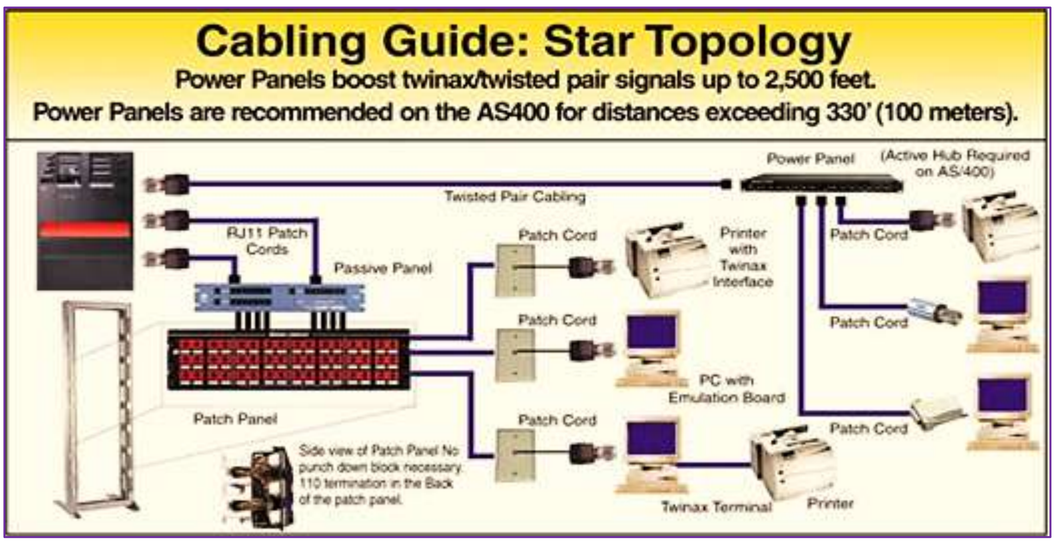
Horizontal ≥ 4 times cable O.D. No load for UTP, 8 times cable O.D. For ScTP backbone ≥ 10 times cable O.D.	Horizontal ≥ 4 times cable O.D. Backbone ≥ 6 times cable O.D. ≥ 8 times cable O.D. while pulling cables.
Connector Termination:	**Connector Termination:**
All pairs shall be terminated at the outlet.	Termination at the 100Ω or 120Ω outlet is permitted.
Pair-untwist not to exceed 13mm (0.5 in.) for category 5e or higher cables. Pair-untwist for category 3 shall be within 75mm (3 in.) from the point of termination.	In accordance with manufacturer's guidelines.
Categories of Cabling Performance:	**Categories of Cabling Performance:**
Category 3 is specified to 16 MHz.	Class C is specified to 16 MHz.
Category 5e is specified to 100 MHz.	Class D is specified to 100 MHz. An Optical Class is also specified.
Category 6 is specified to 250 MHz.	Class E is specified to 250 MHz.
Augmented category 6 will be specified to 500 MHz.	Class E, edition 2.1 will be specified to 500 MHz Class F is specified to 600 MHz.
Performance Specification:	**Performance Specification:**
Stranded Cable Attenuation = 20% worse than solid requirements for UTP, 50% worse for F/UTP.	Stranded Cable Attenuation = 50% worse than solid requirements for both UTP and F/UTP.
Hybrid requirements call for power sum NEXT loss margin + 3dB over pair-to-pair NEXT loss limit.	Hybrid requirements call for 6 dB better PSNEXT loss between cable units than the PSNEXT loss specified for the cable.

Note: For TIA standards, the term "***category***" is used to specify both components and cabling performance. The term "***class***" is used to describe a cabling (i.e., link and channel) performance.

Twin Axial Cabling or "Twinax": Is also a **twisted-pair cable**, but with **2-inner conductors** instead of **one**, very *similar to coaxial cable*. This cable has a characteristic impedance of **78 ohms** at **1 MHz**, commonly used to connect **bus** and **stub** devices. Due to cost efficiency it is becoming common in modern short-range and high-speed differential **signaling** applications.

AS/400: Is an IBM non-mainframe, introduced in 1988, as a **business computer family**, as an IBM hardware. The AS/400 may serve in a variety of networking configurations, as a **host** or intermediate node to other AS/400s, as a remote system to mainframe-controlled, or as a network server to PCs. A powered **hub** is recommended between the AS400 and the devices. This hub conducts **signal** for optimum performance, and greatly increases the distance to each device (2500 to 3000 feet, depending on the brand). Star hubs also provide individual LED port diagnostics to assist in problem isolation, and may come with either one **Twinax** cabling or RJ11/RJ45 input port to every seven RJ11/RJ45 port outputs.

Obs.: The insulated pairs are balanced and have an overall shielding braid around the pairs. The twisting of the signal-carrying pairs, theoretically cancels the random induced **noise**, caused any pair. Traditionally, the **systems 34/36/38 and AS400** were cabled with using Twinax cabling, while networks were cabled using the unshielded twisted pair cable (UTP).

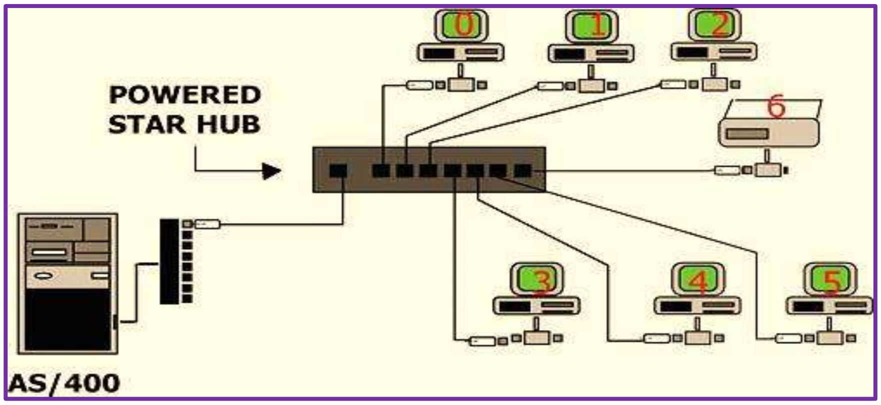


System/36: The **IBM** System/36 (often abbreviated as S/36) was a minicomputer marketed by IBM from **1983 to 2000**. It was a multi-user, multi-tasking successor to the **System/34**, primarily programmed in the **RPG II language**. The System/36 also had many mainframe features such as programmable job queues and scheduling priority levels.

System/38: Was an advanced system for its time, incorporating a relational **database** management system as part of its core software. The System/38 evolved into the AS/400. However, most System/38 applications were converted to run on AS/400s.

Migrating to Twisted Pair: When there is a necessary migration from a **Twinax** infrastructure to **twisted pairs cabling**, star topology hubs and RJ11/RJ45 baluns are used. All communication devices should be also connected in a star topology, each of them on a dedicated cable, with complete isolation from other devices.

Twinax Cable Disadvantages: Twinax cabling is **bulky** and difficult to install, **only** used for the **AS/400**. New cables are always needed when adding a network. There can be up to **7 devices** on the same chain and any **break** or bad peripheral in the daisy chain **brings down** all other devices, after the bad device. The **daisy** chain is a rigid topology, making it hard to make changes or accommodate moves.



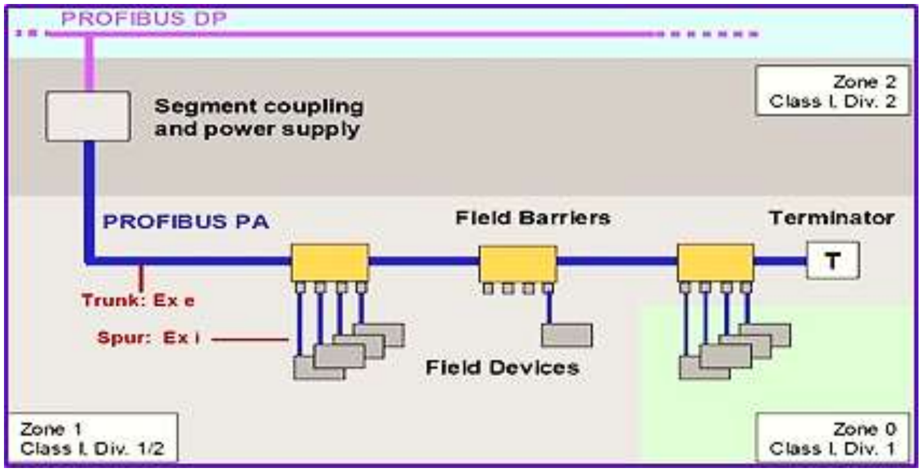
Automation Fieldbus Cabling: Fieldbus generally uses **twisted-pair cabling** to reduce introduction of external **noise**, with a **shield** over the twisted-pair for further noise suppression. The **Fieldbus Foundation** released the cable specification **FF-844** to provide the Fieldbus users with better guidance in selecting cables. The FF-844 includes the **electrical** requirements of ISA 50.02 and IEC 61158, and additional requirements for use in **control** networks. The UL 2250 ITC corresponds to NEC Article 727 Instrumentation Tray Cable, written to simplify the guidelines when the instrumentation and control circuits operate at 150 volts or less and 5 amperes or less.

Example: Choosing a Fieldbus cable, Type A, for bus-systems according to IEC 61158-2, type A, suitable for use in hazardous classified locations class I and class II division 2 - NEC 501.10(B) and NEC 502.10(B) or zone 1 and zone 2, group II, or IEC 60079-14, respectively. The **table** below provides **examples** of wire types and allowable segment lengths:

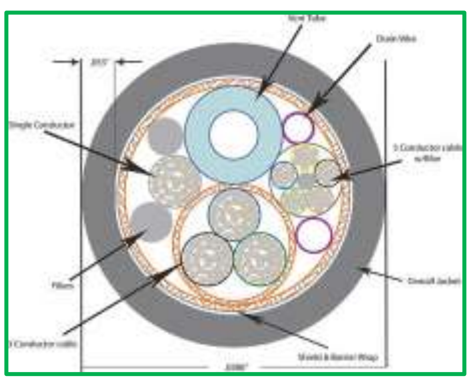
Type	Description	Size	Maximum length
A	Individual shielded, twisted pair	#18 AWG ($0.8\ mm^2$)	1900 m (6232 ft.)
B	Multiple-twisted-pair with overall shield	#22 AWG ($0.32\ mm^2$)	1200 m (3936 ft.)
C	Multiple-twisted-pair without shield	#26 AWG ($0.13\ mm^2$)	400 m (1312 ft.)
D	Two wires with no shield and not twisted	#16 AWG ($1.25\ mm^2$)	200 m (656 ft.)

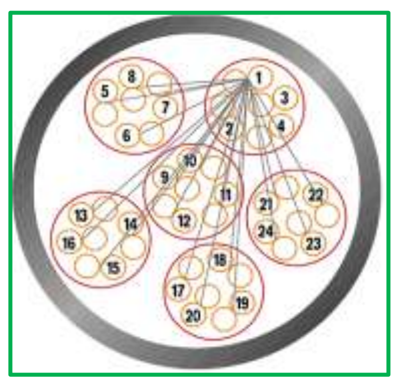
- ✓ Maximum resistance of 23.5Ω/km @ 20ºC (18 AWG minimum);
- ✓ Characteristic Impedance of 100Ω +/- 20Ω @ 31.25 kHz;
- ✓ Signal Attenuation < 3 dB/km @ 39 kHz**;**
- ✓ LSZH version is recommended for use as fire protection.

Automation STP Cabling Installation: Single twisted-pair cables can be installed in a **bus or trunk** system, to connect multiple devices. The connected **devices** and components are called segments, either individually or in groups. When connected through an individual main trunk, the result is called a branch layout or **topology**. Spur and trunk cabling are used for fixed installation indoor and outdoor, on racks, trays, in conduits, in dry and wet locations, as example below:



Hybrid Cables: Are cables with multiple **sizes** or **types** of conductors and other components are incorporated into a single neat **package**. Overall shielding and jacketing in a **hybrid** cable may also provide a **reduced** diameter, but the need to support multiple telecommunications in a shared sheath for hybrid cables has been revised. Thus, **pair-to-pair** required measurements are **3 dB better** than the NEXT pair-to-pair loss for **1 of a 24-pair** hybrid cable.

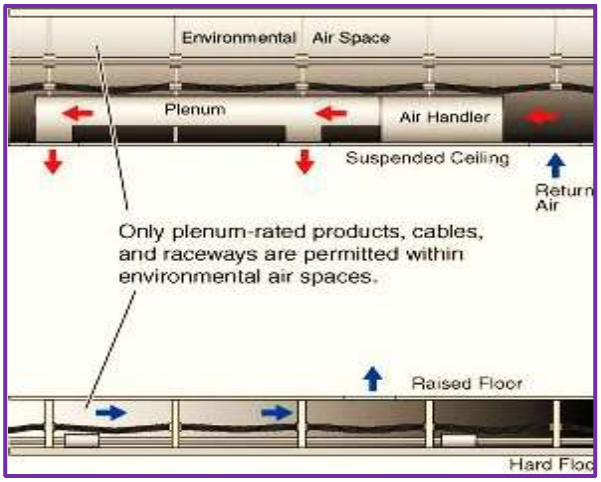


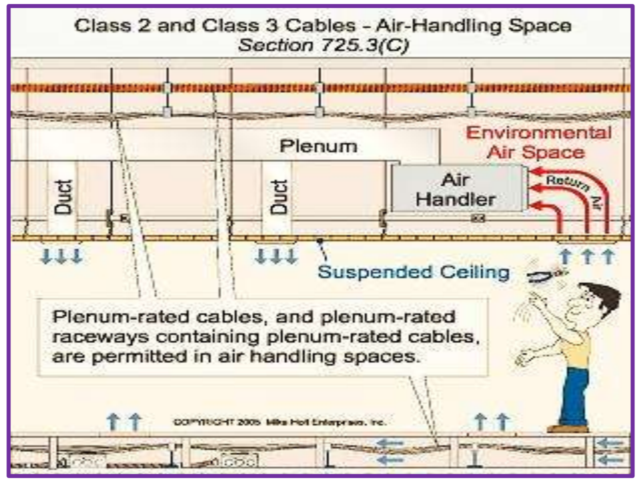


HVAC Plenum Cables: Are special cables that have a special **coating**, such as **Teflon or FEP** to **prevent** toxic fumes when it burns. Plastics used in the construction of plenum cables are regulated under the National Fire Protection Association, **NFPA 90A**: Standard for the Installation of Air Conditioning and Ventilating Systems.

Riser Cables: Are cables installed between **floors in non-plenum** areas, but **fire** requirements are not so **strict**. Plenum cables can always **replace** riser cables, but riser cables **cannot** replace plenum cables. Twisted-pair, coaxial, HDMI, and DVI are also **available** in both plenum and riser versions. Both plenum and riser cables commonly include a rope or polymer filament with high tensile strength, helping to support the weight of the cable when it is dangling in an open chute.

Obs.: The **plenum** is a **space** above a building **ceiling** designed for **air movement** and HVAC environmental air. All cables through this space must be "*plenum-rated*". The **LS0H** (Low Smoke, Zero Halogen) is a type of plenum cable, with a thermoplastic compound that reduces the amount of toxic and corrosive gases. Wire and cables intended to be placed in **plenum** spaces should meet rigorous **fire safety** test standards in accordance with NFPA 262 and NFPA 90A.





VII. TELEPHONE CABLING SYSTEMS:

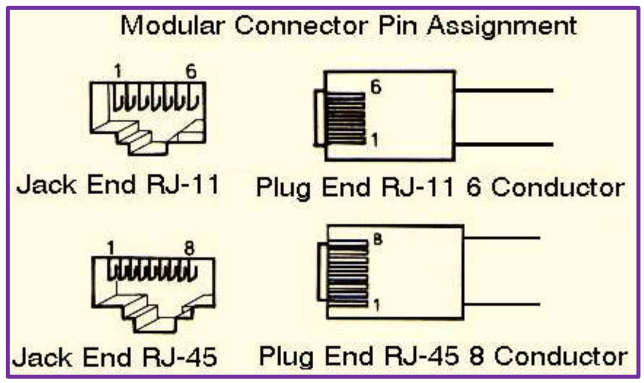
According to installation**,** generally a pair of **copper wires** runs from a container at the road to a **box** (often called an entrance bridge). From there, the pair of wires is **connected** to each *phone jack* (usually using red and green wires). If a user has two phone lines, then two separate pairs of *copper wires* run from the road to this house. The second pair is usually colored *yellow and black* inside a house. Along the road runs a **thick cable** packed with 100 or more copper pairs. This thick cable runs directly to the phone company's switch. When it reaches the user area or it will run to a box about the size of a refrigerator that acts as a **digital** concentrator.

Telephone Cabling Development: There were two major improvements made to telephone cable in the late **1880's**. The first was the issuance of a specification for a standard type of telephone cable in **1888**. The wires were **18 AWG** gauge copper conducting wire (40 mils in diameter) covered with at least two **layers** of cotton and sheathed in a 97% lead, 3% tin alloy pipe. A two inch diameter cable could contain up to 52 pairs of wires. The second improvement was the development of paper insulated dry core cable.

The benefits of using **copper** conducting wires were known, but the technology was not available to make a copper wire **strong** enough for an overhead wire, till in **1877** Thomas Doolittle developed the process for **hard drawn copper** wire soft, annealed copper wire drawn through a series of **dies** in order to increase its tensile strength. In **1888**, the first specification standard type of t**elephone cable** outlined a metallic circuit, or twisted pair cable. The wires were **18 B&S gauge** copper conducting wire (40 mils in diameter) covered with at least **two layers** of cotton and sheathed in a 97% lead, 3% tin alloy pipe.

By **1891** a dry core, paper **insulated cable** became the standard. The size of the conductor and the electrostatic capacity requirement were further reduced and greatly decreased the **noise** in the lines. In **1912**, 1% antimony, 99% lead alloy was developed for cable sheaths. Carrier systems or multiplexing **enabled** single pair of wires to be used for **multiple calls**. These wires were typically copper, although **aluminium** has also been used, and were carried in balanced pairs separated by about **25 cm** (10 pol.) on poles above the ground, and later as **twisted pair** cables. Modern lines may run underground, and may carry analog or digital signals to the exchange, or may have a device that converts the analog signal to digital for transmission on a carrier system.

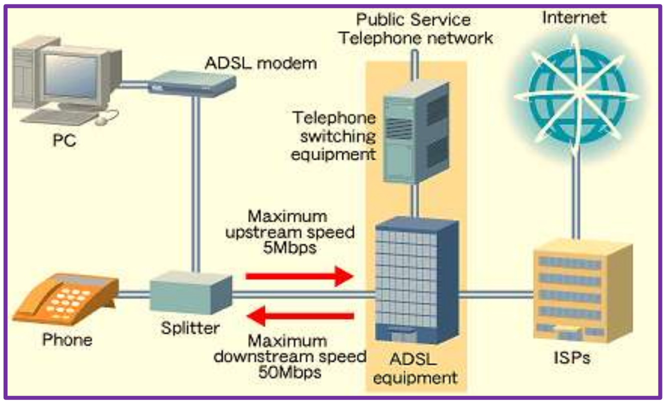
The wires between the **junction box**, known as a local loop, and the group of wires that run to a building box are known as the access network. Most of houses in the U.S. are wired with 6-position modular **jacks** with four conductors wired to the house's junction box with copper wires. RJ14 jacks are used when telephone wires are connected **back** to two telephone lines at the local telephone exchange. RJ11 jacks are used when only two of the telephone wires are connected in one telephone line, and the others are unconnected.

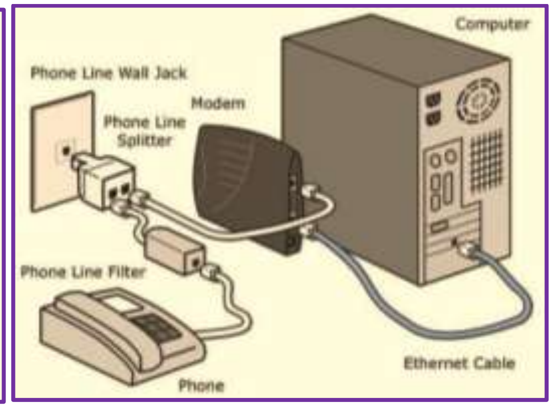


Older houses may have other types of cables in the walls, 2-pairs of 22 AWG (0.33 mm²) solid copper. Installation "*line 1*" used **red/green** pairs and "*line 2*" used the **yellow/black** pairs. In **new** installation has been used *Category 5 cables*, 4 pairs 22 AWG (0.33 mm²) solid copper. Some of the more recent improvements are the use of plastic **insulation** and the development of **coaxial** cable which occurred during World War II. Up to 600 conversations could be transmitted over **two** coaxial cables. Today most of the improvements in telephone cables have been centered for sending more information at a faster rate over the same wires. One area of interest is in the development of ADSL or asymmetrical digital subscriber line.

ADSL (Asymmetrical Digital Subscriber Line): Is a way to send a lot **more information** using an ordinary copper wire. The ADSL transmission technology brought the potential to transmit voice, data, plus up to 4 video channels to the subscriber, or up to 8 Mega-bits per second (Mbps) of information, and voice and data back to the telephone company using copper telecommunications wires. These include a public switched telephone network (PSTN) and the data communications network (usually the Internet or media server). The ability of ADSL systems to **combine** and separate low frequency signal (POTS or IDSN) is made possible through the use of a splitter. The splitter is composed of two frequency filters; one for low pass and one for high pass.

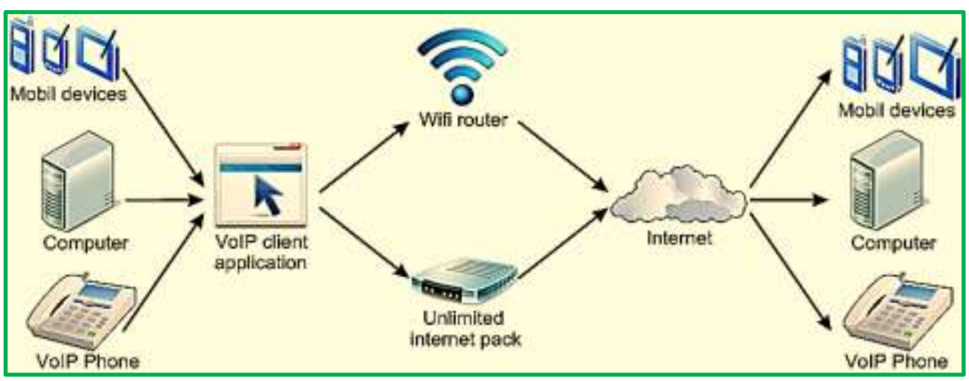
The DSL modems are ADSL transceiver units at the central office (ATU-C) and the ADSL transceiver unit at the remote home or business (ATU-R). The digital subscriber line access module (DSLAM) is connected to the access line via the main distribution frame (MDF). The MDF is the termination point of copper access lines that **connect** end users to the central office. The figure below shows a typical ADSL system, which can allow a single copper access line (twisted pair) to be connected to different networks.





TLS (Transport Layer Security): The TLS protocol is used to **encrypt** data flowing and allows client-server applications to communicate across a network in a way designed to **prevent** secure public Internet. This encryption allows for data/message confidentiality, and message authentication codes for e-mails integrity and as a by-product. Several **versions** of the protocols are in widespread use in applications, such as web browsing, electronic mail, Internet faxing, instant messaging, and voice-over-IP (VoIP). The common **safety** technologies are:

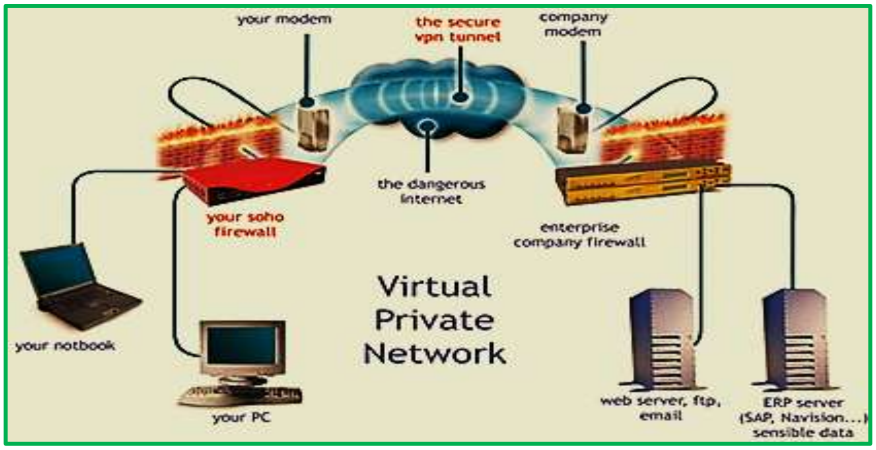
- ✓ **VoIP (Voice-over-Internet Protocol):** Is a methodology for the delivery of **voice** communications and multimedia using the Internet Protocol (IP). VoIP telephone **calls** are similar to traditional digital. This telephony system involves signaling, channel setup, digitization of analog voice signals and **encoding**, instead of being transmitted over a circuit-switched network. The second-generation providers, such as the old Skype, have built closed networks for private user bases, offering the benefit of free calls.



- ✓ **VPN (Virtual Private Network):** Is a **private** network across a public network, such as the **Internet**, which enables a computer to send and receive data across shared or public networks. Data networks allow VPN-style **remote** connectivity through dial-up modems or through leased line connections, utilizing the Frame Relay and Asynchronous Transfer Mode (ATM) virtual circuits, through a network owned and operated by telecommunication carriers.

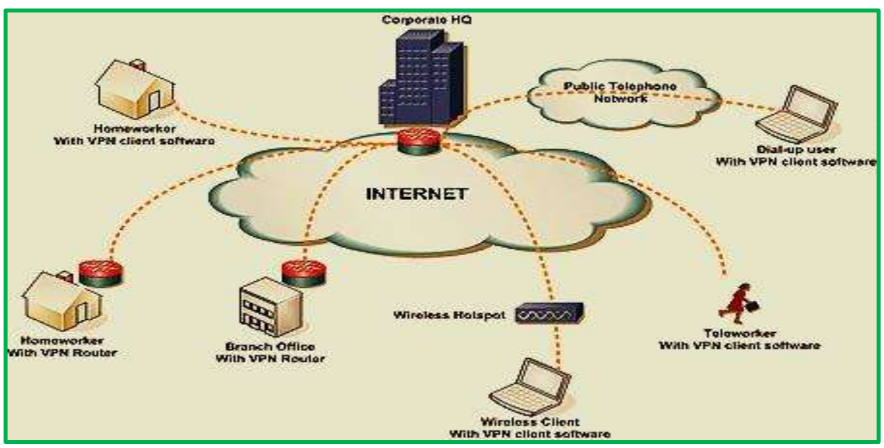
VPNs are based on **IP** and Multiprotocol Label Switching (MPLS) Networks, due to increased bandwidth provided by new technologies, such as Asymmetrical Digital Subscriber Line

(ADSL) and fiber-optic networks. VPNs can be **either** remote-access (connecting a computer to a network) or site-to-site (connecting two networks). In a corporate setting, remote-access VPNs also allow employees to access their company's intranet from home.

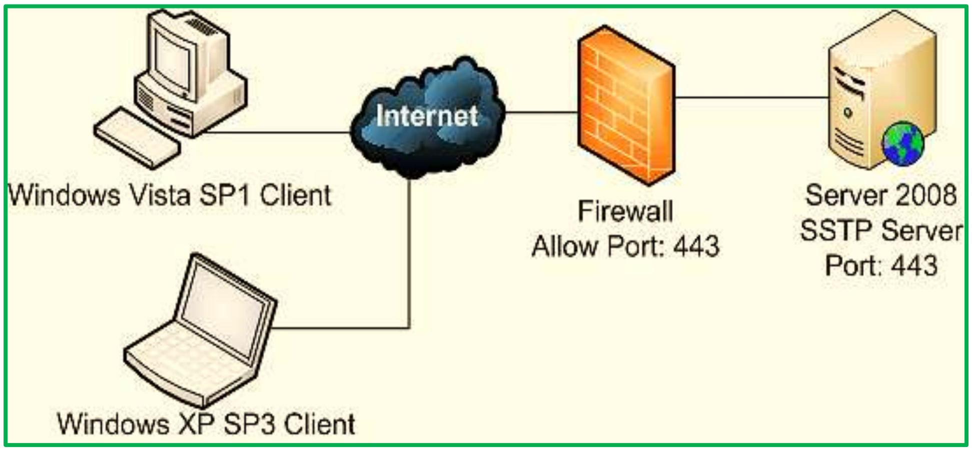


Note: The VPN **creates** a (virtual) encrypted '*tunnel*' between a computer network and a VPN provider's server, to ensure that the **data** passing through public Internet is **secure** from hackers and spammers. Though the technology behind VPN is complicated, the feature basically blocks people from **peeking** into your data, and helps protect your identity by hiding your IP address.

- ✓ **PPTP (Point-to-Point Tunneling Protocol):** Provides a weak 128-bit **encryption**, but is comparatively **faster** than the rest because of the low encryption overhead. It supports most platforms like Windows, Mac OS X, iOS, Android, Linux, DD-WRT routers, etc., and requires **no software** installation or special operating systems to support it.



- ✓ **(SSTP) (Secure Socket Tunneling Protocol):** Is a **new** VPN tunnel with features that allow traffic to pass through **firewalls** that block the PPTP and L2TP/IPsec traffic. The use of HTTPS means that traffic will flow through the *TCP port 443*, a port commonly used for **web access**. The use of SSL (Secure Sockets Layer), which is a cryptographic protocol over TCP port 443, allows the SSTP to pass through virtually all firewalls and proxy servers, except for **authenticated** web proxies. Thus, the Secure Sockets Layer (SSL) provides transport-level security with enhanced key negotiation, encryption, and integrity checking.



Types of Telephone Cables: Standard Telephones and Cables Ltd (later STC PLC) was a British telephone, telegraph, radio, telecommunications and related equipment R&D manufacturer. During its history, **STC developed** several groundbreaking new technologies including PCM and optical fibers. The company was owned from 1925 to 1982, by ITT of the USA.

- ✓ **CW1308 Internal Telecom Cable:** Cables primarily designed for the interconnection of telephone equipment that is installed indoors. These cables may be used for the interconnection of **other** communication and **control** equipment or low level signaling applications. **Sheath** Colour: White or Black.

- ✓ **CW1308B Internal/External Telecom Cable:** Cables also designed for the interconnection of telephone equipment **both** internally and externally. These cables may be used for the interconnection of **other** communication and **control** equipment or low level signaling applications. The cable specification is further enhanced by the use of a **LSZH** (Low Smoke Zero Halogen) outer sheath.

- ✓ **CW1128 Telephone Cable:** Cables designed for the interconnection of **general** telephone equipment. These cables may be used for interconnection of other communication and control equipment or **low level** signaling applications. **Sheath**: PE (Polyethylene).

- ✓ **CW1128/1198 Direct Burial Telephone Cable:** External armoured cable primarily designed for the interconnection of telephone equipment, suitable for direct **burial**, UV and moisture **resistant**. These cables may be used for interconnection of other communication and control equipment or low level signaling applications. **Sheath** Colour: Black.

- ✓ **Coaxial Cable:** Used primarily for TV, Satellite, and Cable Modems. In some cases, coax cables can also be used for security **cameras** or for digital audio. There are **2 types** of Coaxial Cable: **RG-59 & RG-6**. Since everything is already evolving to **digital**, is recommended only use the higher quality **RG-6 cable**. For **longer** runs, is necessary to consider a Quad-Shield cable over the standard Dual-Shield for less signal loss.

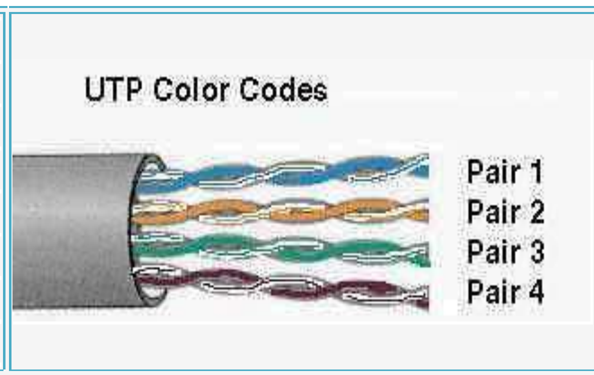
- ✓ **Flat IPC Telephone Cable FCC68/CW1311:** To be used in wiring telephone line **outlet** sockets, also ideal for use in other **low** voltage, low current applications. The cable contains **four solid** tinned annealed copper conductors, each **0.5 mm** diameter, insulated with colour-coded PVC.

- ✓ **Category 3 Wire-PVC/CMR-25 Pair:** Is made for **riser** telephone cabling applications and constructed of **50-24 gauge** solid bare copper conductors with a PVC jacket, gel-filled for direct **burial**, non-gel-filled for aerial **armored** cables, with and without wire support, manufactured in various conductor sizes, from 19 AWG to 24 AWG.

- ✓ **Category 5, 5e, 6, & 7 Wire:** Used for Internet networks, the Cat 5 has the **lowest** quality, and the Category 7 standard, is the **best**. All 4 types basically look the **same**, but the extra **twists** and better **shielding** in the higher categories allows for greater amounts of **data** to be transmitted. This wire can be used for other data applications, such as **remote** volume control knobs, security cameras, infrared (remote control) distribution, etc.

Note: The Cat 5 cable is **commonly** used, instead of station wire for telephony. In this case, the *blue pairs* are the **first** line, and the *orange pairs* for the **second** line. The T-568B Color Code for RJ-45 plug is; eight-conductor **data** cable contains *4 pairs of wires*. Each **pair** consists of a solid colored wire, and a white wire with a stripe of the same color, the pairs are **twisted** together. To maintain reliability on Ethernet, this cable **cannot** be untwisted more than necessary (about 1 cm).

Pair 1	**White with Blue**	**Tip**
	Blue	**Ring**
Pair 2	**White with Orange**	**Tip**
	Orange	**Ring**
Pair 3	**White with Green**	**Tip**
	Green	**Ring**
Pair 4	**White with Brown**	**Tip**
	Brown	**Ring**



Equipment Room: Telecommunication room, engineering room, operations center, data center, rack room, whatever it is called, is a **central part** of any telecommunication **facility**. The telecommunication room is **like** a room with computer servers, switches and routers, structured cabling, telephone, audio routing equipment, satellite receivers, wire termination blocks, microwave transmitters and receivers, and sometimes broadcast transmitters. Generally, an **equipment room** is considered distinct from a t**elecommunication** room, because it is considered to be a building or campus (opposed to floor serving) facility, and because of the nature or **complexity** of the equipment that it contains. Specific room **sizes** are recommended in TIA/EIA-569-B, based on the floor-

area size, since it provides sufficient **space** for all connecting hardware, as well as enough room for maintenance technicians to **work** comfortably.

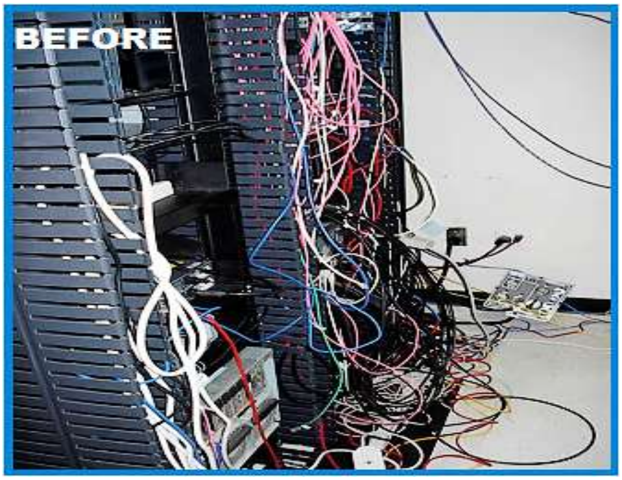
Well Designed Engineering Rooms: Future wiring work needs to be **carefully** planned for every contingency. Keeping the cables, wire conduits, raceways, patch panels, trays and troughs in a clean and **accessible** assembly, are keys to a happy existence. This can be done by good structured cabling management. The most common considerations are:

- ✓ Ground everything to a single point ground buss. There are no too much cables for grounding, as everything is bonded together.
- ✓ Have direct paths outside to accommodate racks, transmission lines, cabling, etc. If there are equipment located on the roof or far places, have a good access in the rack room.
- ✓ Environment directly impacts the life of equipment. HVAC systems should be sized for the highest equipment load on the hottest day of the year. Having some type of back up air conditioning is also a good idea.
- ✓ Leave plenty of room to work behind racks or on the wire wall and make sure there is plenty of light to work, lack of light also creates mistakes.
- ✓ Reserve some space for future growth. Extra room on the back wall for more punch blocks, extra space for additional racks is always a good plan.
- ✓ Keep the wiring neat and documented. There is nothing worse than an undocumented engineering room, it makes maintenance work difficult in many cases.
- ✓ Make the room secure. Keep the doors closed and keep unauthorized people out.

Documenting and Labeling the Cables: There are a myriad of **details** involved in the **telecom room**, not to mention the entire facility. Getting everything down on **paper** before a single wire is pulled, is the **best way** to insure that a neat, logical, and orderly product ensues. For wire run documentation, even single Excel **spreadsheet** templates may be used.

Cabling **maintenance** in a **bad** environment system is often very **cumbersome**, if patch cables are not properly **routed**, labeled and documented, creating a lot of **problems** on the network. The incorrect **routing** and **connecting** of power cables pose potential **fire hazards** and can increase the likelihood of major network outages. A **dark**, cramped area will lead to a hurried work, **poor** workmanship, and **mistakes** in wiring. Not only is the mess unattractive, but it also limits the overall functionality of the entire system.

A **good installation** is necessary, and must have **adequate** space and light to work on the room. All the wires and cables must be labeled. The ground conductors must have heat shrinks required on insulation displacement terminations. Once all the work is done, the wire installation must be **documented** with all necessary **changes** and **additions** (there are always changes and additions) to keep the documentation updated.



Labeling & Color Coding: The elements in a system must have **alphanumeric codes**, or labels, for each location, pathway, cables, termination points, and should **contain** all the information related to that **component**, including linkages. The **codes** or labels must be consistent, logical, easily readable, and should **withstand** environmental conditions. The labels must be **printed** or produced mechanically, recommended to simplify maintenance and system administration. For easy label **identification**, a **rule** of thumb is that each end of a cable must be the same color.

Label Color Coding

Color	Pantone Number	Element Identified
Orange	150C	Demarcation point (central-office termination)
Green	353C	Network connections on the customer side
Purple	264C	Common equipment
White		First-level backbone
Gray	422C	Second-level backbone
Blue	291C	Horizontal cabling terminations
Brown	465C	Interbuilding backbone
Yellow	101C	Auxiliary circuits
Red	184C	Key telephone systems

VIII. DATA CENTERS INFRASTRUCTURE:

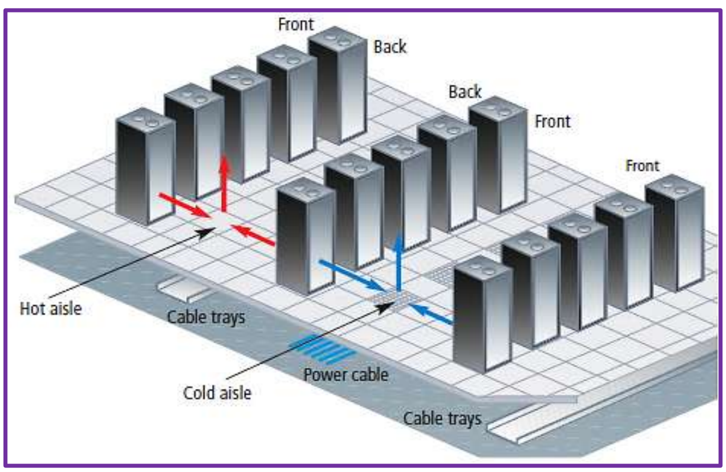
Data Centers are **facilities** used to **house computer systems** and associated components, such as telecommunication equipment, data and storage systems, backup **power supplies** (UPS´s and DRUPS´s), redundant data communications connections, environmental controls, HVAC (air conditioning), **fire control** suppressions, and many other **safety** devices.

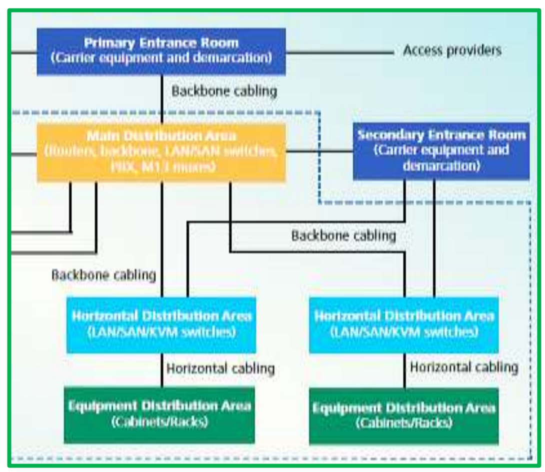
Data Center Requirements: Design **guidelines** for data centers, started in **2005** with the ratification of "*TIA/EIA-942: Telecommunications Infrastructure Standards for Data Centers*", developed to ensure **uniformity** in design, performance, improvement and for designers that are **beginners** in the **building** development process. A good part of the standard involves facility **specifications**, functional areas, and equipment placement in a hierarchical star topology

Data center has a **crucial** aspect in the most organizational **operations** around the world. If a system becomes **unavailable**, company operations may be impaired or **stopped** completely, and for this reason a data center has to **offer a secure environment**, which minimizes the chances of a security breach. A data center must keep high **standards** for hosting the computer environment. This is accomplished through **redundancy** of UTP cables, fiber optics and power cabling, including emergency backup power generation.

*Telcordia (*formerly Bell Communications Research*,* now **part** of *Ericsson) "GR-3160*, *NEBS Requirements for Telecommunications Data Center Equipment and Spaces"*, also provides **guidelines** for data center **spaces** within telecommunications networks, and **environmental** requirements for the **equipment** that may be applied to data center spaces, housing data processing, or Information Technology (IT) equipment.

Data Center Pathways: The standard lists many recommendations for **cable management**, such as each cable type must have separate **racks and pathways**. Power cables must be in **separate** pathways with a physical barrier. Abandoned cable should be **removed**. And large data centers should have **access** floor systems for running cable.

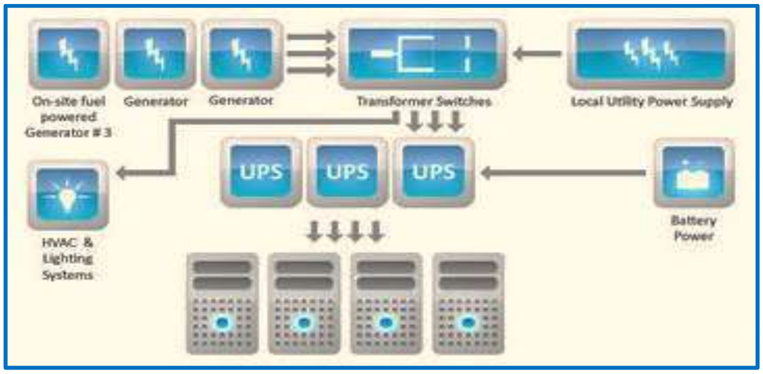




Hot and Cold Aisles: ***Cold*** *aisles* should be in **front** of the **cabinets and racks**. ***Hot*** *aisles* should be **behind** the cabinets and racks where the hot equipment air is exhausted. Cabinets and racks should be **arranged** in rows with the fronts facing each other to create the "*hot and cold*" aisles. A minimum of **1.2 meters** (3.9 ft.) of front space must be provided for equipment installation.

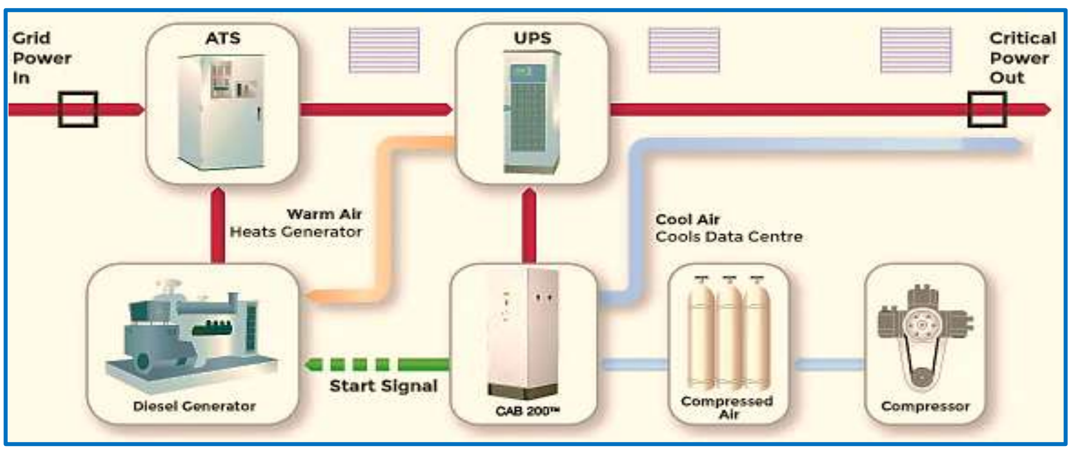
UPS (Uninterruptible Power Supply): Is an **electrical apparatus** that provides **emergency power** when **AC input source fails**, commonly used in Data Centers. Most of the UPS installations **use only** ***batteries*** *for power supply*, usually up to ***several tens of minutes***, but sufficient to start a **standby power** source or shut down the protected equipment. For **longer** backup time the

UPS must be coupled with a **generator** using diesel or gas fuelled internal combustion engine or micro-turbine as a prime mover.



DRUPS (Diesel Rotary Uninterruptible Power Supply): Combine the functionality of a **battery-powered** or **flywheel-powered UPS** and a **diesel generator**. When mains electricity supply is within specification, an electrical generator with a mass function has to **store** kinetic energy in an electro-mechanical flywheel. Typically a DRUPS should have **enough fuel** to power the load for **days** or even weeks in the event of failure of the mains electricity supply.

At the **same time** (or with some delay, for example 2 to 11 seconds, to **prevent** the diesel engine from starting at every incident), the **diesel engine** takes over from the **flywheel** to drive the **electrical** generator to make the **electricity** required. The electro-magnetic flywheel can continue to **support** the diesel generator in order to keep a stable output frequency.



Data Center Spaces: When planning a data center, plan plenty of "white space" or empty space to accommodate future equipment. The basic elements include:

- **Entrance Room(s):** Recommended that this be outside of the computer room for security.
- **Main Distribution Area (MDA):** Is in a centrally located area to house routers and switches. It includes the main cross-connect (MC), and may include a horizontal cross-connect.
- **Horizontal Distribution Areas (HDA):** There may be one or more HDAs, for distribution point for horizontal cabling. The HDA houses the horizontal cross-connects and active equipment, such as switches.

- **Equipment Distribution Areas (EDA):** These are where the horizontal cables are terminated in patch panels.
- **Zone Distribution Area (ZDA):** This is an optional interconnection or consolidation point between the EDA and HDA for zone cabling.

Data Center Recommended Cables: Both TIA/EIA-568-B standards, and TIA-942 recommend:

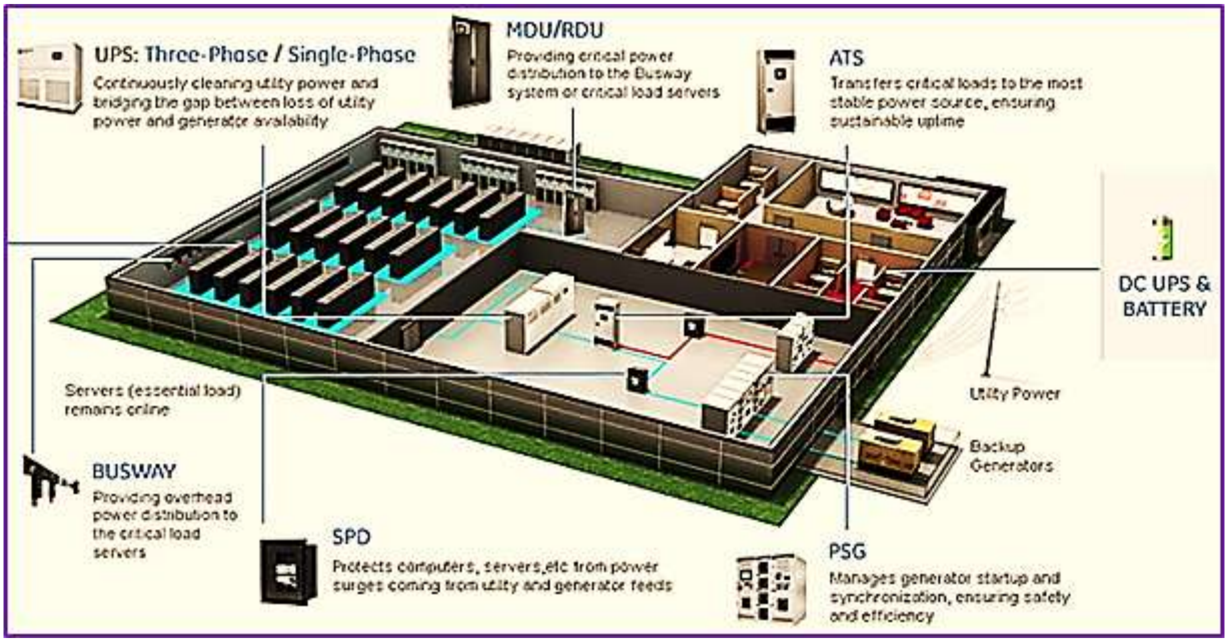
- ✓ 100-ohm twisted pair cables, Category 6. (The Augmented Category 6 is still in draft form);
- ✓ 50 and 62.5-micron Multimode optical fibers. (Laser-optimized 50-micron is recommended);
- ✓ Singlemode fiber optic cables;
- ✓ 75-ohm coax cables. (According to requirements in TIA/EIA-568-B.2 and TIA/EIA-568-B.3).

In 2005, ANSI/TIA-942 "*Telecommunications Infrastructure Standard for Data Centers*", defined **four levels** (called **tiers**) for data centers. *TIA-942 "Data Center Standards Overview"* **describes** the requirements for the data center infrastructure. The **Tier 1** is the simplest data center, which is basically a **server room**, following basic guidelines for the installation of computer systems. The crucial operation of any data center is the **safe systems** that enable continued operation even under catastrophic conditions. The tiers are based on researches from the Uptime Institute. The higher the tier, greater is the availability. The levels are:

Tier Level	Requirements
Tier 1	Annual downtime: ~28.8 hours (1729.2 minutes) Non-redundant capacity components Single path for power and cooling Expected availability of 99.671%
Tier 2	Annual downtime: ~22 hours (1361.3 minutes) Single path for power and cooling Redundant components (N + 1) Expected availability of 99.741%
Tier 3	Annual downtime: ~1.6 hours (94.6 minutes) Multiple power and cooling paths Redundant components (N + 1) Expected availability of 99.982%
Tier 4	Annual downtime: ~0.4 hours (26.3 minutes) All cooling equipment is dual-powered, including chillers and heating, ventilating and air-conditioning (HVAC) systems. Redundant components 2 (N + 1) Expected availability of 99.995%

Note: The **N** indicates need or level of redundant components for **each tier with N** representing only the necessary system need. In the U.S., beginning in 2014, must meet **strict emissions** reduction requirements according to the U.S. Environmental Protection Agency's "Tier 4" regulations for off-road including **diesel generators**. These regulations require near zero levels of emissions.

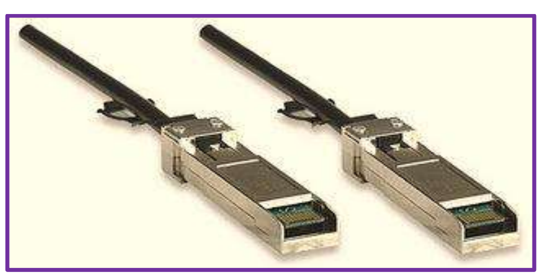
The **Tier 4** has the most **stringent** levels, designed to **host** critical computer systems, with fully redundant subsystems and **security** zones controlled by **biometric** access controls methods. Another consideration is the placement of the data center in a **subterranean** context for data security, as well as, environmental considerations, such as HVAC **cooling** requirements.



Mechanical Engineering Infrastructure Design: Data Center mechanical engineering infrastructure design addresses mechanical systems, such as heating, ventilation and **HVAC** (air conditioning), humidification and dehumidification equipment, pressurization, etc. Modern designs include modularizing IT loads, and **optimized** building construction.

Electrical Engineering Infrastructure Design: Data Center electrical engineering infrastructure design is focused on designing electrical **configurations**, such as utility service planning, distribution, switching and bypass from power sources, UPS systems, etc. Modern electrical design is modular, scalable and available for AC low and medium voltage requirements, as well as DC.

Data center networks are always requiring **higher speeds**, greater scalability and higher levels of **reliability** to better meet new business requirements. Then, modern copper cables are becoming an integral part of the overall system design. The *Intellinet 10 Gbps* Direct Attached Small Form-Factor Pluggable (SFP+) copper cable is fully **optimized** for **10 Gbps** solutions. These cables are perfect for **in-rack** connections between servers and top-of-rack switches.



Technology Infrastructure Design: Data Center technology infrastructure design addresses the telecommunications **cabling systems**, including horizontal cabling, voice, modem, and facsimile telecommunications services, premises switching equipment, computer and telecommunications management **connections**, keyboard/video/mouse connections and data communications. Wide area, local area, and storage area networks should link with other building signaling systems (e.g. fire, security, power, HVAC, EMS).

Modularity and Flexibility: Data center modules are pre-engineered, standardized building **blocks** that can be easily **configured** and moved as needed. A **modular** data center may consist of data center equipment contained within shipping **containers** or similar portable containers. But, in a design style, components of the data center are **prefabricated** and standardized, so that they can be constructed, moved or added to quickly as needs change.

Environmental Control: **Air conditioning** is used rigorously to control the temperature and humidity in the data center. ASHRAE's "*Thermal Guidelines for Data Processing Environments*" recommends a temperature range of **18-27°C** (64-81°F), a dew point range of **5-15°C** (41–59°F), and a maximum relative humidity of 60% for data center environments. The temperature in a data center may naturally rise, because the electrical power used also heats the air.

IX. WIRELESS NETWORK TECHNOLOGY:

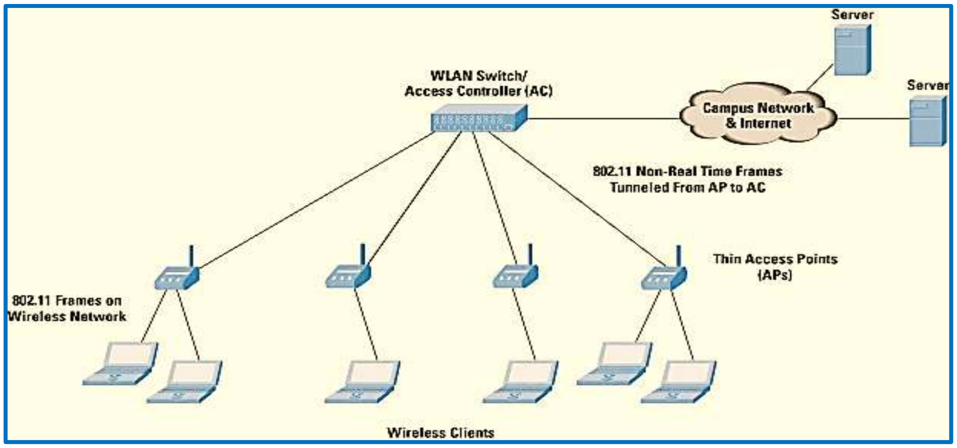
The wireless system usually applies **solutions** where conventional **cabling** infrastructure (copper or optical fiber) **cannot** be used. Its main **advantage** is that dispense with the wires and mobility, being ideal for environments where the passage of cables is impractical. Although, this type of networks had initially extremely **low transmission speed** and currently this topic has been improved, by the developers of wireless technology suppliers, **reaching** high transmission rates. Wireless networks enable the attendance of points with the same efficiency and more cost/benefit in relation to conventional cabling systems. The installation of wireless networks and new points eliminates the need to pass new cables, reducing the time of setting up new positions of work and facilitate the construction of temporary building structures.

Networking technologies **evolve** every day and there are **several types of networks**: LAN (Wireless Local Area Network), WLAN (Wireless Local Area Network), WMN (Wireless Metropolitan Networks), WMAN (Wireless Metropolitan Area Network), WWAN (Wireless Wide Area Network), WLL (Wireless Local Loop) and a new concept of wireless personal area networks or WPAN (Wireless Personal Area Network).

The WLAN (Wireless Local Area Networks) is a **wireless LAN**, or a computer network that links two or more **devices** using **wireless** communication to form a local area network within a **limited** area, such as a home, school, computer laboratory, campus, or office building. The WLAN constitutes an **alternative** to conventional wired networks, providing the same functionality but in a flexible way, easy configuration and with good connectivity in buildings or campuses. WLANs also establish data communication between network points, using **radio** or **infrared** carrier. The data is modulated on a carrier and radio transmitted through electromagnetic waves.

IEEE 802.11 WLAN (Wireless Local Area Network): The IEEE (Institute of Electrical and Electronics Engineers), is responsible for setting the **standard** for wireless networks locals or

WLANs. The proposed standard provides **two physical-layer** specifications (depending on the regulations of each country), and a specification with infrared option. The draft specifies **three physical** layers (PHY) and only a MAC sub-layer (Medium Access Control), as indicated below:



- **Frequency Hopping Spread Spectrum Radio PHY:** This layer provides operation 1.0 Mbps, 2.0 Mbps as optional. 1.0 Mbps version uses 2.0 levels of modulation GFSK (Gaussian Frequency Shift Keying), and 2 Mbps uses 4 levels in the same modulation;
- **Direct Sequence Spread Spectrum Radio PHY:** This layer provides both operation speeds (1.0 and 2.0 Mbps). The version of 1.0 Mbps modulation uses DBPSK (Differential Binary Phase Shift Keying), while that of 2.0 Mbps modulation uses DBPSK (Differential Quadrature Phase Shift Keying);
- **Infrared PHY:** This layer provides operation 1.0 Mbps, 2.0 Mbps as optional. 1.0 Mbps version uses modulation 16-PPM (Pulse Position Modulation with 16 positions), and 2.0 Mbps version uses 4-PPM modulation.

Note: WLAN also used **radio waves** to make an Internet **connection,** as originally the WLAN was too expensive and only used as an **alternative** to LAN-Internet with cable, where cabling was difficult or impossible to install. Such places could be buildings or old classrooms, although restricted range IEEE 802. 11b limits its use to smaller buildings.

WPAN (Wireless Personal Area Network): Generally uses the **Bluetooth standard** to establish the communication, employed in far Infrared Ray (similar to that used in TV remotes), commonly used to connect electronic devices physically **close**, usually used to **connect** keyboards, printers, mobile phones, handheld computers, digital cameras, mouse and other peripherals.

Bluetooth (IEEE 802.15.1): Is a global standard of **wireless communication**, allowing the transmission of data between **compatible** devices, that is, two or more devices can exchange information with simple **approximation** between them. Bluetooth is a **standard** for networks PAN (Personal Area Network). This technology allows a simple communication, quick, safe and cheap between computers, smartphones, cell phones, mouse, keyboards, headphones, printers, and other devices using radio waves instead of cables.

The Bluetooth data **transmission** is done via **radio** frequency, allowing a device to detect each other regardless of their positions, as long as they are within the limit of proximity. The data transmission speed in the Bluetooth **is low**, may reach a maximum of **1 Mbps**. In version 2.0, this value passed up to **3 Mbps**. Although these rates are short, are **sufficient** for a satisfying connection between most devices. Bluetooth is a technology designed to work worldwide, which has required the adoption of an open **radio frequency**, which is **standard** anywhere on the planet. The bluetooth was divided into three classes, namely:

- ✓ Class 1: maximum power of 100 mW with range up to 100 meters;
- ✓ Class 2: maximum power of 2.5 mW with range up to 10 meters;
- ✓ Class 3: maximum power of 1.0 mW with range of up to 1 meter.

WWAN (Wireless Wide Area Network): The concept of a WWAN network is the **same** given to a **WAN** network, so a WWAN is the **aggregated** or the sum of a GWEN and WLAN networks geographically distributed. It is common to hear talk of WWAN, but rather about WLAN and WENMAN.

GWEN (Wireless Metropolitan Area Network): Is an **alternative** to *current mobile phone technology,* according to IEEE 802.16 and IEEE 802.20. However, the **frequency** at which the standard 802.11b - 2.4 GHz is operating, may lead to interference with many cordless phones.

WiMAX (Worldwide Interoperability for Microwave Access): Currently works with IEEE 802.16d, ensuring connectivity at speeds of up to **30 Mbit/s**, whose equipment began to be available in 2006. The 802.16d standard operates in a frequency range from **2 to 11 GHz**. WiMAX supports point-to-multipoint topologies, and operates in **unlicensed** frequency bands (2.4 and 5.8 GHZ) and in **licensed bands** (3.5 and 10.5 GHZ). The modulation used in WiMAX can be used to provide the connection "*without line-of-sight*" (NLOS - Non-Line of Sight) between base stations and customer equipment. WiMAX can achieve a range **75 Mbps** in channeling of 20 MHz.

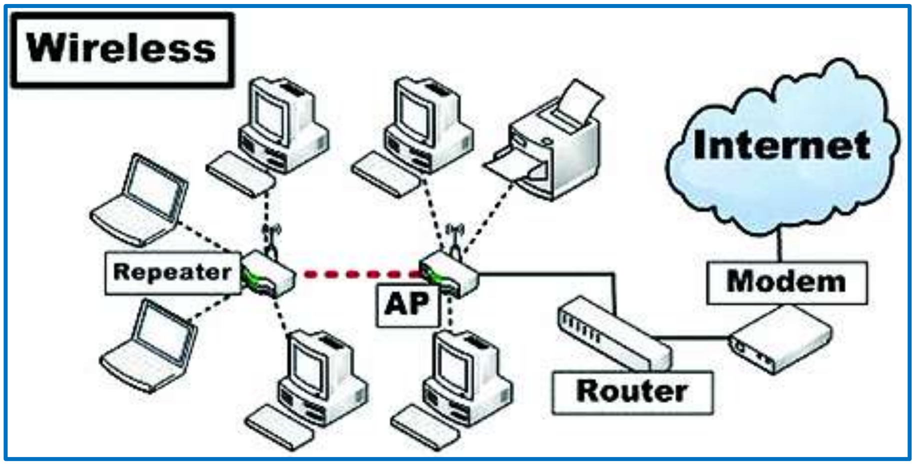
Wi-Fi (IEEE 802.11): This technology is a **brand** originally licensed by the **Wi-Fi Alliance** to describe an embedded WLAN system. The term Wi-Fi is understood as an **interconnection** technology between **wireless devices** using the IEEE 802.11 Protocol. The term Wi-Fi was chosen as a play on the term "***Hi-Fi***" and usually that is an abbreviation for **wireless fidelity**, but the Wi-Fi Alliance does not recognize it. To access the Internet through a Wi-Fi network, is necessary to be within the **range** or area of an **access point** (usually known as **Hotspot**), or be in a public place where operate a wireless network.

Wi-Fi hotspots exist to establish access point to **connect** to the Internet. The access point transmits a **wireless signal** in a small distance, about **100 meters**. Most public networks are supported by Internet Service Providers (ISPs) that charge a **fee** from users, but many Hotspots are located in **places** accessible to the public, such as airports, cafes, hotels and bookstores. In these places it is possible to use mobile devices, such as laptop, Tablet PC or personal Digital Assistant (PDAs) with wireless communication capability. The main standards in IEEE 802.11 family are:

- ✓ **IEEE 802.11:** Standard Wi-Fi for 5 GHz frequency with max. capacity of 54 Mbps;
- ✓ **IEEE 802.11(b):** Standard Wi-Fi for 2.4 GHz frequency with max. capacity of 11 Mbps. This standard uses the DSSS (Direct Sequences Spread Spectrum) for reducing interference;
- ✓ **IEEE 802.11(g):** Standard Wi-Fi for 2.4 GHz frequency with max. capacity of 54 Mbps;

Note: In the late 90 emerged several **versions** of Wi-Fi IEEE 802.11 by standardized as the Home RF (2 Mb/s, for home. However, all laptops have now come standard with Centrino Wireless Networking installed and thus eliminate the need for an additional plug-in card (PCMCIA). The **WPA** and **WPA2** are only **safety standards** established to replace the WEP (Wired Equivalent Privacy), had serious safety flaws, making possible a hacker could break the encryption key after monitor within minutes of communication.

Wireless Networks: Using **radio or infrared**, WLANs establishes data communication between network points. The data is **modulated** and radio transmitted through **electromagnetic waves**. Multiple carriers can co-exist in the same way, without an interfering in another. To extract the data, the **receiver tunes** to a specific frequency and rejects others with **different** frequencies.



The device transceiver (transmitter/receiver) or an **access point** is connected to a local network conventional Ethernet (wired). The access points not only provides communication with the conventional network, but also mediates the traffic with neighboring access points, as micro-cells with roaming schemes, similar to cellular phone systems. Basically the topology is composed of:

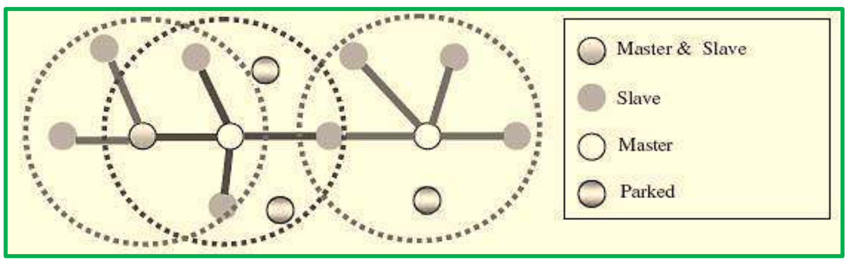
- ✓ **BSS (Basic Service Set):** Corresponds to a cell of wireless network communication;
- ✓ **STA (Wireless LAN Stations):** Are the various network clients.
- ✓ **AP (Access point):** Is the node that coordinates communication the STAs within the BSS.
- ✓ **DS (Distribution System):** Is a WLAN backbone, for communication between the APs.
- ✓ **ESS (Extended Service Set):** Are cells where APs are connected to the same network.

Networking Switches, Wireless Access Points, Cabling, and Tools		
Type	Description	Codes*
L2 Managed Gigabit Ethernet Switches	8,16, or 24 1000BASE-TX copper and two dual-media SFP ports; Switch copper and fiber; Allocate bandwidth; Prioritize traffic.	LGB1001A Series
Pure Networking™ 802.11g Wireless Access Point with Switch	Transmit at 54 Mbps; Includes 4-port switch; IP sharing with NAT/NAPT; Includes security features.	LW6004A
400- and 600-Style Bulk Coax Cable	50-ohm coax cable for connecting wireless antennas.	CA400-REEL Series
Hyperlink 400- and 600-Style Cable	Low-loss coax cable for wireless connections.	CA3N010, CA6N100 Series
400- and 600-Style Connectors	N-Type connectors for wireless coax cable.	ANM-1406 Series
Wireless Cable Tools	Stripping, crimp, and tool kits for wireless coax cable.	HT-STRIP400 Series

Infrared Systems: The frequencies are **too high**, but **below the visible light** in the electromagnetic spectrum, as the infrared signal **cannot** penetrate opaque objects. Thus, infrared transmissions are direct or diffuse. Low cost direct infrared systems provide a **very limited distance** (around **1.5 m**), commonly used in PAN (Personal Area Network) and occasionally in WLANs.

ISM (Industrial, Scientific, and Medical): Operates in the **2.45 GHz** frequency, with variations ranging from 2.4 GHz to 2.5 GHz. A device using **Bluetooth** may both **receive and transmit** data in Full-Duplex mode, which means to make a **Piconet** to communicate with another. This system is called **Scatternet** (computer network consisting of **two or more piconets**). The terms "***Scatternet***" and "***Piconet***" are typically applied to Bluetooth wireless technology).

- ✓ **Piconet:** Is when **two or more** devices communicate via a **Bluetooth** connection. Each **piconet** can support up to **8 devices** (a Master and 7 Slaves), but it is possible to make larger through the overlapping piconets. The **figure** below shows an example of a network with **3 piconets**, 3 Masters, 1 Master/Slave, and a Slave active and inactive (Parked).



IAPP (Inter Access Point Protocol): Consists in a group of **companies** coordinating the development this technology, whose goal is to ensure the interoperability between manufacturers providing **support** for *roaming* through the cells. The IAPP Protocol defines how to access points communicate through the ***backbone*** of the network, controlling the data from multiple mobile stations. There are several technologies involved in wireless local area networks and each one has its peculiarities, its limitations and its advantages. The most important are:

- ✓ **Narrowband Systems & Spread Spectrum Systems:** The **narrowband** system operates on a specific **radio frequency** while maintaining the radio signal the narrowest enough to pass the information. The spread spectrum system operates with a **spectrum** technique with a broadband, **radio frequency** for providing greater security, integrity and reliability in There are two types of *spread spectrum* technologies:

a) FHSS (Frequency-Hopping Spread Spectrum): This system uses a *narrow-band carrier* that changes frequency in a code known by the transmitter and the receiver that, when properly synchronized, the effect is to maintain a single logical channel.

b) DSSS (Direct-Sequence Spread Spectrum): This system generates a bit-code (also called chip or chipping code) for each redundant bit transmitted. How higher the chip, the greater the recovery of the original information. However, greater bandwidth is required.

Even if one or more bits in the chip are damaged during transmission, statistical techniques embedded in the radio can recover the original data without the need for retransmission.

X. CABLING AND WIRELESS STANDARDS:

IEEE 802.11: Supports speeds only up to 2 Mbps and two different methods of encoding, since is known that the Frequency Hopping Spread Spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS) lead to incompatibility between equipment.

IEEE 802.11a: Uses the 5.8-GHz band, which is called U-NII (Unlicensed National Information Infrastructure). It has a higher frequency and a larger bandwidth allotment, than the common 2.4-GHz band, and achieves speeds up to 54 Mbps.

IEEE 802.11b: Is the most common wireless standard, operating from 2 Mbps up to 11 Mbps, in a 2.4-GHz band, and transmitting up to 328 feet (100 m) under good conditions. Use (DSSS Direct-Sequence Spread Spectrum), and dropped the FHSS (Frequency-Hopping Spread Spectrum).

IEEE 802.11e: Defines Quality of Service (QoS) mechanisms for wireless to operate bandwidth-sensitive applications such as voice and video.

IEEE 802.11g: Extension of 802.11b that operates in the same 2.4-GHz band. It brings data rates up to 54 Mbps using Orthogonal Frequency-Division Multiplexing (OFDM) technology, compatible with 802.11b, to interface directly with the 802.11g, access point.

IEEE 802.11i: Addresses many of the security concerns, by adding Wi-Fi Protected Access (WPA) and Robust Security Network (RSN) to 802.11a and 802.11b standards. It loses security if used with non-802.11i devices.

IEEE 802.11n: May achieve wireless throughput of up to 540 Mbps, although is expected a more typical data rate as 200 Mbps. It may achieve these speeds by using a technique called Multiple-Input/Multiple-Output (MIMO), increasing wireless capacity while also increasing network reliability and coverage. This standard is an extension in 2007, not yet ratified.

IEEE 802.3af: Power over Ethernet. (PoE).

IEEE 802.3at (draft): Power over Ethernet Plus (PoE Plus).

IEEE 802.11: General Requirements for Wireless Networking.

IEEE 802.3an: 10BASE-T - 10 Gbps (1250 Mbps) Ethernet over Unshielded Twisted Pair (UTP).

ANSI/TIA/EIA: Commercial Building Telecommunications Cabling Standard, also covered in ANSI/TIA/EIA-568-B.1, -B.2, and -B.3.

ANSI/TIA/EIA-568-B.1-Part 1: General Requirements. Covers the general requirements for planning, installing, and verifying structured cabling systems in commercial buildings, establishes parameters for cable channels and permanent links.

ANSI/TIA/EIA-568-B.2-Part 2: This standard discusses balanced twisted-pair cabling components and transmission requirements, or balanced Twisted-Pair cabling components.

ANSI/TIA/EIA-568-B.2-1-Part 2, Addendum 1: This standard specifies components and transmission requirements for the 4-Pair, 100-Ohm Category 6, transmission performances.

ANSI/TIA/EIA-568-B.2-10 (Draft): Augmented Category 6 transmission performance.

ANSI/TIA/EIA-568-B.3: Optical Fiber Cabling Components Standard.

ANSI/TIA/EIA-568-B.3-1: Additional Transmission Performance Specifications for 50/125 Optical Fiber Cabling Systems.

ANSI/TIA/EIA-569-B: Commercial Building Standard for Pathways and Spaces.

ANSI/TIA/EIA-570-A: Residential Telecommunications Cabling Standard.

ANSI/TIA/EIA-606-A: Standard for Telecommunications Infrastructure of Commercial Buildings.

ANSI/TIA-607: Commercial Building Grounding and Bonding Requirements for Telecom.

ANSI/TIA/EIA-758: Customer Owned Outside Plant.

ANSI/TIA/EIA-862: Building Automation Systems Standard for Commercial Buildings.

ANSI/TIA/EIA-942: Telecommunications Infrastructure Standard for Data Centers

TIA/TSB-1005: Telecommunications Infrastructure Standard for Industrial Premises

TIA/TSB-162: Telecommunications Cabling Guidelines for Wireless Access Points.

TIA/TSB-162: Cabling recommendations in compliance with TIA/EIA-568-B.2 and TIA/EIA-569-B, which also addresses pathways, cabling between network and wireless equipment.

TIA/TSB-155: Characterizing Existing Category 6 Cabling to Support 10-Gigabit Ethernet.

ISO 11801:2002: Information technology and generic cabling for customer premises.

ISO/IEC 11801, 2nd Ed.: Includes Class D, E, and F Cabling.

ISO/IEC 11801, 2nd Ed. Amendment 1: Covers Class EA and FA.

ISO 11801 Class Ea, Edition 2.1: 10-Gigabit over Copper.

ISO/IEC TR 24704: Information technology and customer premises for general Cabling and Wireless Access Points.

XI. CABLING INSTALLATIONS & TESTING STANDARDS:

Advanced ***Level III and IV* testing** instruments, calculate, automatically test, and certify copper cable links in accordance with **TIA** and **ISO** standards. Level **III** tester is designed for frequency measurements ***up to 250 MHz***. Level **IV** testers certify accuracy ***up to 600 MHz***. Manufacturers of test instruments are conforming to the changes in standards with firmware updates. Results of the tests are very important, to confirm if a system meets all the applicable performance standards.

10-GbE Considerations: 10-GbE transmission requires a **bandwidth** of **500 MHz**. The industry is using **two** different cables for 10-GbE applications; Category **6** (CAT6) cable and Augmented Category 6 (CAT6a). However, in 2007, the CAT6 standard specified measurements **only** to **250 MHz** and did not specify ANEXT requirements.

10-GbE over CAT6a: Augmented Category 6 (CAT6a) and Augmented Class E (Class EA) cabling are designed to support 10-GbE over a **100 meter** horizontal channel. The TIA/EIA-568B.2-AD10 (draft) extends CAT6 electrical parameters, such as NEXT, FEXT, return loss, insertion loss, and more to **500 MHz**. The CAT6a draft specifies near and far-end alien crosstalk (ANEXT, AFEXT) to 500 MHz for closely bundled “six around one” cable configurations.

Alien Crosstalk: Is a phenomenon, when a signal transmitted on one circuit or channel of a transmission system creates an **undesired effect** in a circuit or channel, or causes the **mixing** of signals between wire pairs within a cable of 10/100/1000BASE-T. Alien crosstalk is also the measurement of the signal **coupling** between wire pairs in different and adjacent cables. The alien crosstalk (ANEXT) is also a critical measurement to 10-GbE systems.

Measuring ANEXT: Or alien next, measures the ability of cabling to reject **crosstalk**. The Interference between two pairs in a cable is measured at the **same** end of the cable with the interfering transmitter. Near-end crosstalk (NEXT) is computed as the **ratio** in **amplitude** (in volts) between the test signal transmitted and the crosstalk signal received, when measured from the same end of the link. This ratio is generally expressed in **decibels** (dB).

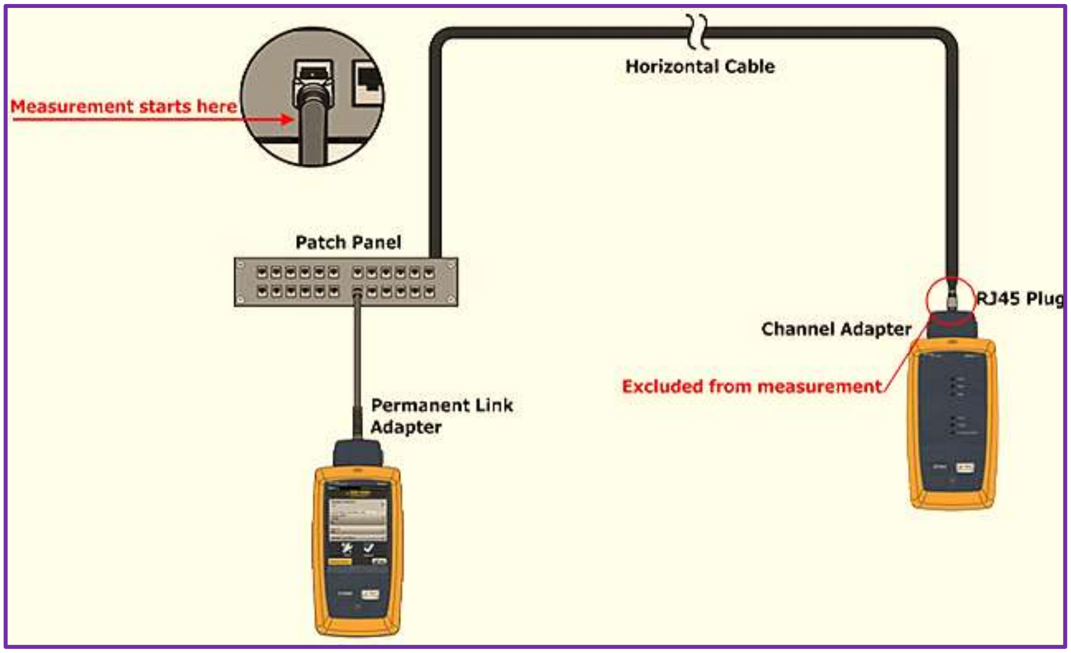
Near-end crosstalk (PS-ANEXT) and power-sum alien far-end crosstalk (PS-AFEXT) are based on cables in a “*six-round-one*” configuration. Every circuit is **measured** against the other, so, there are **96** individual measurements. One strategy is to use a **sampling** technique to **select** a limited number of links for testing. The chosen links should be those most likely to **fail**, such as the longest links, or shorter links with the shortest distance between connectors.

Note: One way to lessen or completely **eliminate** ANEXT is to use shielded equipment and cables such as S/FTP or F/UTP cables. Another way is to follow mitigation guidelines, such as using non-adjacent patch panels, separating equipment cords, unbundling cabling, etc.

Testing 10-GbE: Field certification for 10-GbE consists of *two phases*. The *first phase* is to certify the transmission capability and quality of each individual link. The 10-GbE test limits are identical to CAT6 and ISO 11801, but the frequency **range** is extended from 250 MHz to 500 MHz. However, there is **no guarantee** CAT6 can support a 10-GbE system. But the TIA TSB-155, ISO/IEC 24750, and IEEE 802.3an characterize 10GBASE-T over UTP cabling.

The *second phase* is to **field certify** the cabling system for **compliance** with alien crosstalk (ANEXT) requirements, which are the between-channel **parameters**. The testing parameters, to be certified are; insertion loss, return loss, pair-to-pair near-end crosstalk (NEXT), power sum NEXT, pair-to-pair equal-level far-end crosstalk (ELFEXT), Power-Sum ELFEXT (PS-ELFEXT), propagation delay, length, delay skew, and wire map.

The ***Fluke DSX Cable Analyzer*** test, enables testing and certification of **twisted** pair cabling up to 10 Gigabit Ethernet, and handles any cabling system, whether it is a *Cat 5e, 6, 6A or Class FA*. Certifying a cable is one part of a **process** that starts with system design and ends with system acceptance. The amount of ANEXT depends on a number of factors, including connectors, cable length, cable twist density, and EMI. Patch panels and connecting hardware are also affected by ANEXT. This should include sample testing of some links in a bundle to verify compliance.



Field Testing of Optical Fibers: Compared to copper, the **fiber optic cable** is relatively simple to test. Basically, you ***shine a light*** *down* the cable and *measure how much* ***arrives*** on the other end. This is called **attenuation**, and it is the performance **parameter** used for fiber testing. Unfortunately, attenuation can be affected by the installation, but can be easily **tested** in the field. The typical fiber test link includes:

- Optical fiber cable (horizontal or backbone, depending on application);
- Telecommunications outlet connectors;
- Consolidation points, if any;

Optical Fiber Testers: There are professionals and advanced **fiber test equipment**, which includes a **power meter** and a **light source**. Very advanced equipment can test different wavelengths, in both directions, eliminating a lot of legwork for either you or a professional technician.

These testers, like their copper counterparts, automatically calculate all test results and save them for future downloading and documentation.

XII. CONTROL & INSTRUMENTATION CABLES:

Instrumentation & Process Control: Instrumentation cables are mainly used for industrial **automation**, industrial **process control** and other modern **instrumentation circuits** in normal and **hazardous** areas. These cables may come with or without **flame** retardant properties, designed to offer excellent resistance to noise and induction phenomena encountered in instrumentation circuits, conforming to standard specifications, such as: IEC 189-5, IS 5608, EN 50288-7, BS 5308, BS 1584, BS 6360, and BS 5099. Instrumentation cables **can be** solid, stranded, tinned and bare, with sizes ranging from **0.5 mm²** to **2.5 mm²**. Insulation can be PVC, PE, special thermoplastic materials, and **heat** resistant 85ºC - 105ºC operation. Halogen free polymeric or elastomeric i**nsulation** can be provided. Core identification by color-coding or printed with numerals or letters.

Cables can be **armored** with galvanized steel wires & strips or double helical steel tape, designed to combat all the basic type of **noise** that affects process instrument **signals**, such as static, magnetic, and cross-talk. Reference specification for testing IS: 10810, ASTMD2863, ASTMD2843, IEC-754, IEE383, IEEE Transit Nº 467, and as per customer specification requirements. The European standard EN 50288-7 represents the **first standard** for instrumentation cables for **onshore, offshore** and industrial applications, which has been created by a recognized international standardization organization. This standard **enables** the user to convert all systems, security, environmental and installation **demands** to appropriate products with wanted characteristics. The standard EN 50288-7 main groups are:

- Common Types (PVC-sheathed);
- Halogen-free, flame retardant Types (LSZH-sheathed);
- Fire-resisting, flame retardant Types (LSZH-sheathed).

These special cables are commonly subdivided in **sub-groups**. Each sub-group describes different **product-families**, each containing unarmoured and armoured products. For the "*common types*" groups there are additional **versions** with chemical protection (generally lead sheath and multi-layer sheath). Product-family stands for a specific insulation material which offers choices for optimizing electrical, thermic or other relevant product properties.

Armor: The selection of instrumentation cables mainly depends on the cable installation and required **mechanical properties**, such as maximum tensile loads, pressure loads, minimum bending radius, and direct **burial** installation. There are several **types** of cable, as galvanized steel wire braid, galvanized steel wire tape and galvanized steel wire round armor with their own advantages.

Sheath/Jacket: Twisted pair is commonly specified in **4-20mA analog signal** cable to reduce the effect of interference. As recommended by **API 552** Transmission System, twisted cables shall have minimum of ***six*** *crossover per foot*. The ***eight*** *crossover per foot* is a typical specification. Material of outer cable sheath/jacket shall be selected with regards to the following consideration:

- Environmental condition (humidity, temperature, solar radiation);
- Method of installation (indoor, outdoor, direct buried, on trays, etc.;

- Possibility of oil, chemical spills or abrasion;
- Behavior in fire (low smoke, zero halogen to avoid toxicant);
- Flame retardant or fire resistant;

Control & Instrumentation Cables: The **difference** between **control** and **instrumentation cable** is defined by **application**, as either can be solid or stranded, typically terminated by **screw** terminals. The i**nstrumentation** cable has **smaller** diameter and frequently made of **stranded wire**, which is more flexible. Today, with greater use of electronic **starter** controls, as motor and pumps wiring, several installations always need **larger** diameter wires, many times for safety reasons. The **other** difference between control and instrumentation cable is that the instrumentation cable is typically a **shielded** (screened), twisted pair. This construction serves to minimize "*crosstalk*" (inductive coupling) that causes **erroneous** readings for the instrumentation.

Control and instrumentation cables generally have circuits operating at **125 VDC, 110 VAC or 220 VAC** levels, not requiring the **shielding**. The **most used** instrumentation and control cables according to IEC 60228 Class 2/5, with insulation low smoke, halogen free, cross linked polyethylene compound (XLPE) are shown below:

- ✓ **Power & Control Cables:** Commonly used as **fixed** installation cables in various **electromechanica**l and **electronic** equipment of **marine** vehicles. Usable in all conditions of a marine environment, such as dry, wet or oily locations.

- ✓ **Shielded Control Cables:** Also used as **fixed** installation cables in various electromechanical and electronic equipment of marine vehicles. Usable in all conditions of a marine environment, such as dry, wet or oily locations, according to according to IEC 60228 Class 2/5, insulation Low smoke, halogen free, cross linked polyethylene compound (XLPE).

- ✓ **Overall Shielded Instrumentation Cables:** Used as **control and communication** cables, radio, radar and information systems for marine applications. Enables proper transmission of **high frequency** signals while minimizing environmental electromagnetic interference. Also commonly used in **all conditions** in marine environment, such as dry, wet or oily locations, and inside engine rooms.

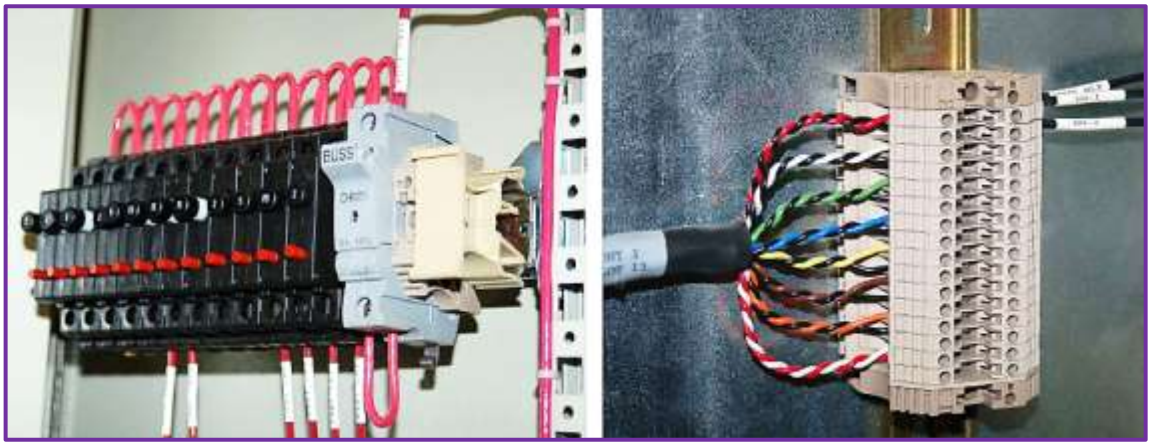
- ✓ **Single Insulated Conductor Cables:** Also commonly used as fixed installation cables in various electromechanical and electronic **equipment**, including marine switchboards. Usable in all conditions in marine environment, such as dry, wet or oily locations.

Connections and Wire Terminations: Many different **techniques** exist for **connecting** electrical conductors together: twisting, soldering, crimping (using compression connectors), and clamping (either by the tension of a spring or under the **compression** of a screw) are popular examples. Most industrial **field wiring** connections utilize a combination of compression-style crimp, called as "*lugs*" (often referred to as ferrules or compression terminals) and screw **clamps** to attach wires to instruments and to other wires.

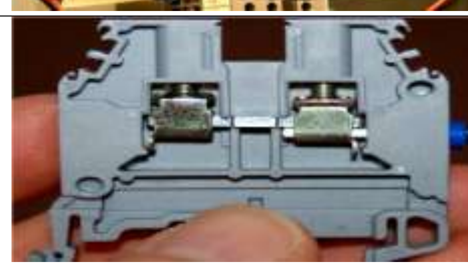
Single Pair Cables: Usually, there are **4 types of instrumentation cables** commonly used to carry analog signals; plain pair cable; twisted pair cable; co-axial cable; shielded pair cable. These cables are normally **single** pair cable with a cross sectional area from **0.5 mm² to 1.5 mm²**. As defined before, analog signal cables has to carry only **4-20 mA DC current**, normally used in RTD

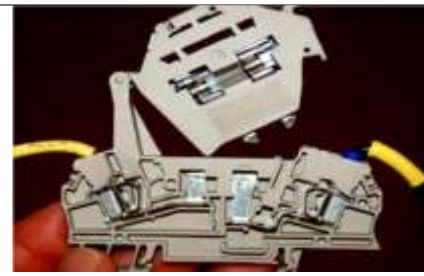
(Resistance Temperature Detector) transmissions, which typically **consists** of two-wire signal leads or three-wire signal leads. Power cable carries **24DC/110/230 VAC**, however, power cables and analog signal cables **cannot** run in the same route. In the three-wire configuration, the shield is grounded at the signal source to reduce common-mode noise.

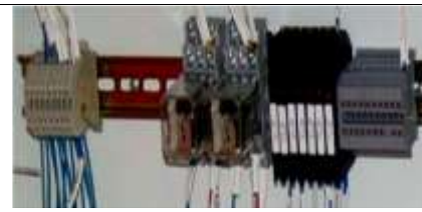
Distribution Wiring: Below, at **left**, is shown a **120 volt AC** power distribution wiring. Note how the hoop-shaped "***jumper***" wires are all **cut** to (nearly) the same length, and how each of the **wire labels** is oriented in the way that the printing is **easy to read**. At **right**, a picture shows a great way to **terminate** multi-conductor **signal cable** to terminal blocks. Each of the pairs was **twisted** together using a hand drill set to very slow speed. Note how the end of the **bundle cable** is wrapped in a short section of heat-shrink tubing for a neat appearance.



Control Cables Assembly: There are many different styles of modular terminal blocks are manufactured to suit different wiring needs:

The following photograph shows a typical terminal strip or terminal block array whereby twisted pair signal cables connect to other twisted-pair signal cables.	
A close-up photograph of a single terminal block section shows how the screw-clamp system works. Into the right-hand side of this block a single wire (tipped with a straight compression ferrule) is clamped securely. No wire is inserted into the left-hand side:	

Some terminal blocks are screw-less, using a spring clip to make firm mechanical and electrical contact with the wire's end:	
Some terminal block modules, for example, have multiple "levels" instead of just one. The following photograph shows a two-level terminal block with screw-less wire clamps:	
Other modular terminal blocks include such features as LED indicator lamps, switches, fuses, and even resettable circuit breakers in their narrow width, allowing the placement of actual circuit components near connection points. The following photograph shows a swing-open fused terminal block module, in the open position:	
Modular terminal blocks are useful for making connections with both solid-core and stranded metal wires. The clamping force applied to the wire's tip by the screw mechanism inside one of these blocks is direct, with no sliding or other motions involved. Some terminal blocks, however, are less sophisticated in design. This next photograph shows a pair of "isothermal" terminals designed to connect thermocouple wires together.	
Solid wires may be adequately joined to such a screw-head connection point by partially wrapping the bare wire end around the screw's circumference and tightening the head on top of the wire, as is the case with the two short wire stubs terminated on this instrument:	
This next photograph shows five such stranded-copper wires connected to screw-style connection points on a field instrument using compression-style terminals. Compression-style terminals come in two basic varieties: fork and ring:	

DIN rail: Is a narrow channel of metal, made of bent sheet steel or extruded aluminum, with edges designed for plastic components to “clip” on. The following photograph shows terminal blocks, relay sockets, fuses, and more terminal blocks mounted to a horizontal length of DIN rail in a control system:	
This next photograph shows some of the diversity available in DIN rail mount components. From left to right we see four relays, a power supply, and three HART protocol converters, all clipped to the same extruded aluminum DIN rail:	

Instrumentation Cable Standards: Instrumentation cables are **suitable** for use with **digital** or **analogue** communication, telecoms, water treatment, oil & gas, petrochemical and **general** industries, to carry **voice** and **data** signals. For instance, the BS5308 instrumentation cables, including Part 1- Type 1, Part 1-Type 2, and Part 2-Type 1 are available with PVC or LSZH sheaths, and Part 2- Type 2 is available with a PVC sheath.

- ✓ **Unarmoured:** Recommended for indoor and outdoor installation, on racks, trays, in conduits, in dry and wet locations. Not recommended for direct burial.
- ✓ **Armoured:** Recommended for outdoor installation, on racks, trays, in conduits, in dry and wet locations, for direct burial. Recommended for direct burial.
- ✓ **Armoured with Chemical Protection:** Recommended for direct burial, especially in presence of oil and aggressive chemical substances.

BS5308 Instrumentation Cable Part 1-Type 1; Part 2-Type 1: These cables are designed to carry communication and **control signals** in various installation types including the **petrochemical** industry. Signal **can be** of analogue, data or voice type and a variety of **transducers**, such as pressure, proximity or microphone. The **insulation** material is either PE or XLPE, but not recommended for **direct burial**.

All **Part 1-Type 1, Part 2-Type 1** cables are designed for **indoor/outdoor** use, racks and conduits, and where mechanical protection is **not required,** for transmission of analogue and digital signals for instrument and control systems. These cables are **allowed** for use in **zone 1 and zone 2**, group II, **classified** areas (IEC 60079 Part 14), but **not allowed** for direct connection to low impedance sources (e.g. public mains electricity supply). Collectively and individually screened pairs are available within the range where further signal security is required.

- ✓ **Standards:** BS/PAS 5308, BS 60228, BS 6234, BS 50363, IEC 60332-1, IEC 60332-3-24;
- ✓ **Conductor:** Class 2 or 5 plain copper conductors;
- ✓ **Sheath:** PVC (Polyvinyl Chloride) to BS7655 or LSZH (Low Smoke Zero Halogen);
- ✓ **Sheath Colour:** Blue or Black;
- ✓ **Voltage Rating:** 300/500V.

BS5308 Instrumentation Cable Part 1-Type 2; Part 2-Type 2: Are designed to carry communication and control signals in various installation types including the **petrochemical** industry. The signals can be of analogue, data or voice type and a variety of transducers, such as pressure, proximity or microphone. These cables are **also designed** for indoor/outdoor use, racks and conduits, **direct burial** and where a **greater degree** of mechanical protection is required, namely outdoor or direct burial. The insulation material is either PE or XLPE. Also collectively and individually screened pairs are available within the range where further signal security is required.

- ✓ **Standards:** BS/PAS 5308, BS 60228, BS 6234, BS 50363, IEC 60332-1, IEC 60332-3-24;
- ✓ **Conductor:** Class 2 or 5 plain copper conductors;
- ✓ **Sheath:** PVC (Polyvinyl Chloride) to BS7655 or LSZH (Low Smoke Zero Halogen);
- ✓ **Sheath Colour:** Blue or Black;
- ✓ **Voltage Rating:** 300/500V.

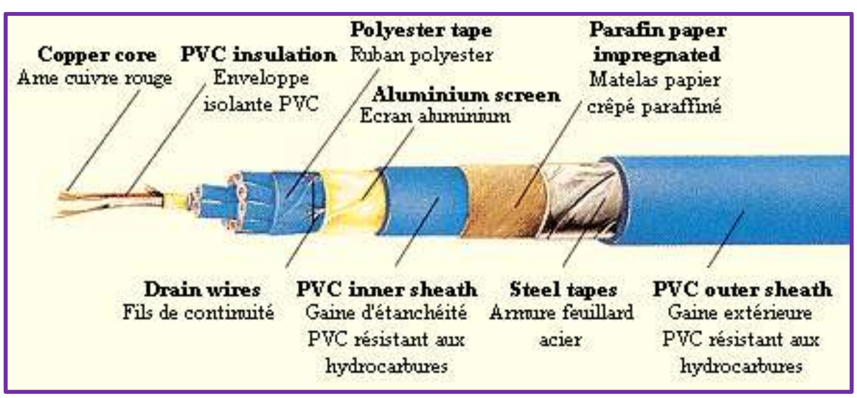
BS5308 Instrumentation Cable Part 1-Type 3: Are also **designed** for indoor/outdoor use, racks and conduits, for transmission of analogue and digital signals for instrument and control systems, and for **direct burial**, especially in the presence of **aggressive chemical** substances. These cables are allowed for use in **zone 1** and **zone 2**, group II, **classified** areas (IEC 60079 Part 14), but not allowed for **direct connection** to low impedance sources (e.g. public mains electricity supply).

- ✓ **Standards:** BS/PAS 5308, BS 60228, BS 6234, BS 50363, IEC 60332-1, IEC 60332-3-24;
- ✓ **Conductor:** Class 5 plain annealed copper conductors;
- ✓ **Metal Sheath:** Lead alloy;
- ✓ **Sheath Colour:** Black;
- ✓ **Voltage Rating:** 300/500V.

Common Cable Specification: Twisted Pair Shielded Instrumentation Cables; Copper/Tinned Conductor; PE/XLPE insulation; Foil shielded; Wire Armoured, according to BS5308:

- ✓ Single and multipair cables, collective screen, Type 1, Type 2
- ✓ Single and multitriple cables, collective screen, Type 1, Type 2
- ✓ Multipair cables, individual and collective screen, Type 1, Type 2
- ✓ Multitriple cables, individual and collective screen, Type 1, Type 2

- ✓ Single and multipair cables, collective screen, lead sheath armour, Type 3
- ✓ Single and multitriple cables, collective screen, lead sheath armour, Type 3
- ✓ Multipair cables, individual and collective screen, lead sheath armour, Type 3
- ✓ Multitriple cables, individual and collective screen, lead sheath armour, Type 3



Instrumentation Cable for Petrochemicals

SCADA / Pilot Cable: Supervisory Control and Data Acquisition (SCADA) is a system that aims to monitor and control field devices at your remote sites. SCADA systems are critical as it helps maintain efficiency by collecting and processing real-time data. SCADA is a centralized system that monitors and controls the entire area. The cables for these based supervisory systems are paired core compound filled, operating in the VF range 300 to 3000 Hz.

- ✓ **Standards:** NR/PS/ELP/27220 (formerly RT/E/PS/0034);
- ✓ **Conductor:** Class 1 solid plain copper conductor 0.9mm diameter, complies with BS3573;
- ✓ **Sheath:** PE (Polyethylene) Type 03C to BS6234;
- ✓ **Colour:** Black.

Remote Control, Signaling, and Power Circuits: When these circuits are in **classified** areas such as oil, gas, and petrochemical facilities, the **NFPA 70** mandates additional **cabling** requirements **beyond** the **insulation** ratings. The cable types suitable for each circuit, assuming the installation is in a classified area, are defined in three classes, as shown below:

NEC-725 Remote-Control, Signaling, and Power Limited circuit classes

Circuit Class	Circuit Voltage	Maximum Current
Class 1—Remote-Control & Signaling (Not Power Limited)	0–600 Volts	Unlimited
Class 1 (Power Limited)	0–30 Volts	33 Amps
Class 2 (Power Limited) (Fire & Shock Safe)	0–30 Volts (AC & DC) 30–150 Volts (AC) 30–60 Volt (DC) 60–150 Volt (DC)	8 Amps 0.005 Amps (150/ V_{max}) Amps 0.005 Amps
Class 3 (Power Limited) (Fire Safe Only)	30–100 Volts (AC) 60–100 Volts (DC)	(150/ V_{max}) Amps

Signal Noise and Interference: Modern digital instruments prove to be more **sensitive to noise** and **interferences** when compared with the **old** analog instrumentation devices, however avoids old wiring **practices** and techniques that may allow the transfer of noise into the control loops. Before to **address** factors necessary to minimize signal interference, it is worthwhile to **list** some of the common types of signal noise and interference.

- ➢ **Magnetic coupling:** Is also known as **inductive** coupling and occurs when the noise interference magnitude is proportional to the mutual inductance, between the control loop and the source of interference current. Such noise is there, when several wires of different circuits are together, running in parallel with the same cable or in raceways.

- ➢ **Electrostatic coupling:** It is similar to the **magnetic** coupling, when interference manifests primarily in the parallel wiring. This is more often with parallel AC discrete (switching) circuits, when the loop lengths exceed 1,000 feet. It is worthwhile to note that in some literature, they call this phenomenon "distributed capacitance."

- ➢ **Electromagnetic coupling:** Occurs when control circuits, within the electromagnetic or interference sources, radiate an **electromagnetic** energy during their normal operation. Examples are radio transmitters, television stations, communication equipment, AC motors, and power transmission lines. Based on IEEE-518, the effect of noise is dependent on the susceptibility of the control system and the strength of the produced electromagnetic field.

- **Common impedance coupling:** This type of interference **noise** commonly occurs when more than one circuit shares a common wiring, such as when a common return lead wire is used for multiple field devices, as solenoids or relays. This type of noise is also common when trying to consolidate the DCS or PLC loops, in one cable. The length of the shared wiring aggravates such noise.

- **Common mode:** This type of noise manifests primarily because of different **grounding** potentials at various locations of the **plant**. It sometimes occurs even if the receiving instruments or input module has a high common mode rejection rating. It is more common when shields are not properly connected or when they connect at more than one place. It is more prevalent in thermocouple loops, especially when the thermocouple is a grounded type.

Reducing Signal Interference: There are wiring **techniques** that help to **reduce** noise and its impact on the overall health of the loops, which include proper cable construction, classification of signals into specific susceptibility levels, signal segregation, signal separation, and **proper** grounding. The **classification** of wiring shown below is based on **Noise Susceptibility Levels** (NSL); IEEE-518 classified wiring levels into four major classes. Saudi Aramco developed a slightly modified categorization to simplify segregation and separation. The IEEE NSL levels settled into three levels, based on practical experiences.

- ✓ **NS Level 1:** High to medium susceptibility with analog signals of **less** than **50 V** and discrete instrument signals of **less** than **30 V**. Examples of these signals are; Foundation Fieldbus 4-20 mA; and HART 4-20 mA; RTD; Thermocouple; Millivolt/pulse.

- ✓ **NS Level 2:** Low susceptibility with switching signals **greater** than **30 V**, analog signals **greater** than **50 V**, and 120-240 AC feeders **less** than **20 amps**. Examples are; discrete input and output DC signals like pressure switches, valve position limit switches, indicating lights, relays, solenoids, etc.

- ✓ **NS Level 3:** Power AC and DC buses of **0-1000 V** with currents of **20-800 amps**. It is a good practice to segregate various signals from each other. Each type of signal (within each NSL) will transmit on dedicated cables and rout to dedicated junction boxes. For example, 4-20 mA signals will **rout** on separate cables from all other signals under NSL-1.

Recommended separation distances (millimeters)

	NSL-1	NSL-2	NSL-3
NSL-1			
(Metallic conduits)	0	75	300
(On tray & in trench)	0	150	650
(Tray - conduit)	0	100	450
NSL-2			
(Metallic conduits)	75	0	150
(On tray & in trench)	150	0	200
(Tray - conduit)	100	0	150
NSL-3			
(Metallic conduits)	300	150	0
(On tray & in trench)	650	200	0
(Tray - conduit)	450	150	0

1. Separation distance between NSL-1 & 2 and strong electromagnetic sources such as motors, generators, and transformers of greater than 100 KVA shall be at least two meters.
2. Separation distance between NSL-1 & 2 and power cables rated above NSL-3 should be at least 1-1.5 meter.

As a **rule of thumb**, it is highly recommended be utilized twisted and individually **shielded** pairs or triads, for all analog signals such as **4-20 mA**, thermocouple (T/C), millivolt signals, RTD, strain gauges, and pulses. For proper protection, the **shield coverage** should be 100% and the same cable construction works and serves for all **digital signals**. For discrete signals (on/off), such as process switches, limit switches, relay contacts, solenoid circuits, and indication lights, **twisted pairs** can also be used. An overall **shield** is fine for multi-pair/triad cables and the wire cuts at the junction box and grounds should be indicative at the marshalling cabinet, or marshalling panel.

Grounding for Automation Systems: A proper **grounding** plays a significant role in the overall installation safety and integrity of **process signals**, which protects the automation systems from potential damages due to surges, voltage fluctuations, lightning, and short circuits. The enclosures of all **instrument devices** must be **connected to ground**, typically on the plant overall grounding grid, or bond to an electrically **conductive structure**, connected to the grid. Raceways, such as **conduits and trays** must be grounded at both ends. From the field instruments to the marshalling cabinets, the shield drain wires should be treated and terminated similar to the signal wires.

Note: Exposed parts of the drain wires within junction boxes or marshalling cabinets should be inside **insertion** jackets to protect against the possibility of multiple drain wires touching each other. Once the loop reaches the marshalling cabinet, the shield drain wires have to consolidate and terminate at the **DC** and shield grounding bus bar.

Grounding in Control Interface Buildings: In the **control room** or process interface buildings, the **process automation system** panels and marshalling cabinets must be equipped with **two grounding** bus bars; **one for AC and one for DC** common and shield drain wires. The **DC** and shield grounding **bus bar** must be electrically **isolated** from the cabinet structure. All shield drain wires and DC common wires must **merge** and connect to the isolated bus bars. The isolated DC and shield grounding bus bars within all cabinets must be consolidate into a **master** instrument grounding bus bar within that building. Similarly, all **AC bus bars** within these cabinets must come together at a **master safety-ground** bus bar within the building.

Technical Data: Instrumentation cables are specially designed to transmit signals without any external interference, used in Digital / Analog Control / Measuring & Communication Systems.

Conductor Resistance at 20° C Ohms/Km:	Conductor Size, mm^2	0.5	0.75	1.0	1.5	2.5
	Maximum Resistance	39.0	26.0	19.5	13.3	7.98
Capacitance nf/Km:	Between conductors	Less than 250 nf/km				
	Between conductors & screen	Less than 400 nf/km				
Inductance mH/Km:		Less than 1.0				
L/R Ratio µH/Ohm:	Conductor Size, mm^2	0.5	0.75	1.0	1.5	2.5
	L/R	<25	<25	<25	<40	<40
Insulation Resistance at 20° C M ohm-Km:	PVC	More than 100				
	LDPE	More than 5000				
Electrostatic noise rejection ratio:		More than 76.0 dB				

Specifications for Instrumentation and Thermocouple Cables:

Cable Types:	Instrumentation Cable Possibilities:
Conductor and cable types:	Plain or metal coated, stranded or flexible (Class 1, 2 or 5) 0.5 mm^2 up to 4 mm. RE- Instrumentation and Instrumentation Control Cable; RT- Thermocouple Extension or Compensating Cable.
Insulation and/or sheath materials:	Polyethylene (low, medium and high density), flame-proof polyethylene, cross-linked polyethylene, low smoke, zero halogen compounds, polypropylene, PVC, cold and heat-resistant PVC. (Y) - Insulation, inner or outer sheath of Polyvinylchloride (PVC); (Yw) - Insulation, inner/outer sheath of heat resistant, Polyvinylchloride (PVCw); (Yv) - Outer sheath of Polyvinylchloride of increased thickness; (2Y) - Insulation, inner or outer sheath of Polyethylene (PE); (2X) - Insulation of cross-linked Polyethylene (XLPE); (H) - Inner or outer sheath of halogen-free; (LSZH) - Flame retardant compound; (Sil) - 2G Insulation of silicone; (4Y) - Covering of Polyamide (Nylon).
Cabling elements:	Core, pair, triple, quad, bundle. Copper conductor, tinned.
Screening:	Foils, metal tape, copper braids. (ST) - Static screen of Aluminium laminated plastic tape; (L) - Longitudinally applied Aluminium foil, one or both sides plastic coated; (C) - Braid of tinned or un-tinned copper wires over cable core; (K) - Wrapping of copper foils; (PiMF) - Pair in Metal Foil; (TiMF) - Triple in Metal Foil; (C) - Braid of tinned or un-tinned copper wires over single cabling element.

Inner and outer sheath:	Polyethylene (low, medium and high density), flame-proof polyethylene, cross-linked polyethylene, low smoke, zero halogen compounds, special oil-resistant PVC, cold and heat-resistant PVC.
Chemical protection:	(M) - Sheath of lead, (Mz) - Sheath of lead alloy; Multi-layer sheath;
Armour:	(SWA) - Galvanized round steel wires; (RG) - Galvanized round steel wires with counter helix of galvanized steel tape; (FG) - Galvanized flat steel wires with counter helix of galvanized steel tape; (B) - Double layer of galvanized steel tapes; (Q) - Braid of galvanized round steel wires.
Moisture barrier and other properties:	Laminated sheath, water swellable tapes and/or powder, filling compound. (CI) - Circuit Integrity (Fire resistant). (-fl) - Increased flame retardancy (IEC 60332-3-24 cat.C) fulfilled F Cable core petro jelly filled.

Note: **Example** for cable **specification**: RE-2Y(St)YMYSWAY-fl 24 x 3 x 1.3 mm² TiMF 300 V EN 50288-7, is: Instrumentation cable RE, 24 triples 3, conductor size 1.3 mm², insulation of PE 2Y, individual TiMF and overall screen (St), inner sheath of PVC Y, lead sheath M, inner sheath of PVC Y, steel wire armour SWA, outer sheath of PVC Y-fl, rated voltage 300 V, standard EN 50288-7.

Bus Cables: Shielded wire pairs and flexible bus cables are applied in cabling industrial in **automation field bus systems**, such as Profibus, Interbus, CAN, HART, DeviceNet Profinet, Ethernet, machine tools, conveying systems, actuator-sensor-interface components, industrial plants equipment and in an increasing number of **industrial applications**. In single words, **bus cables** technology can be applied in every branch of industry where process-control techniques. Bus cables have a combination of abrasion-proof thermoplastic elastomers (TPE) outer jackets, PVC or flame-retarding halogen-free (FRNC), or PUR external sheath, ensure millions and millions of bending cycles, become possible in energy chain and control bus systems.

These cables are meant for bi-directional communications protocol used for communications among field devices and to the control system, installed in many process applications, such as, refining, petrochemicals, power generation, food & beverage, pharmaceuticals and nuclear applications. The ***common bus*** *cables* **types** are specified as:

Voltage	300 V / 600 V
Conductor	Plain/Tinned Annealed Copper (up to 120 Deg. C) Silver Plated Annealed Copper (up to 200 Deg. C)

	Nickel Plated Annealed Copper (up to 260 Deg. C)
Range	22 AWG / 18 AWG / 16 AWG / 14 AWG
Insulation	Solid Polyethylene/ XLPE / PFA for temp. >150 Deg. C
Screening	Individual and/or overall with following options: - Aluminum Mylar/Copper Tape with Tinned Copper Drain Wire or - Braided with Bare or Tinned or Nickel Plated or Silver Plated Copper.
Inner Sheath	PVC/HR PVC/FR PVC/FRLS PVC/ZHFR/LSF/FEP/PFA
Armoring	Round Galvanized Steel Wire / Flat Strip / Steel Wire Braid
Outer Sheath	PVC/HR PVC/FR PVC/FRLS PVC/ZHFR/LSF/FEP/PFA with Plain Orange Jacket or with strip for easy identification and Blue jacket available for Intrinsically safe applications
Standards	Cable specification Foundation Fieldbus FF-844 H1, Cable design based on EN 50288-7/BS-5308 Part 1, IEC 60332 Electrical properties: FF-844 H1 and IEC 61158-2, Type A
Our FF Cable Features	Excellent Electrical Characteristics; Low Capacitance (for long runs); RoHs compliant and CE marked.

Cable Bus Types: For cabling of industrial **field bus systems** with the globally accepted bus network, TCP/IP protocols and for applications as automation technology, transport, conveyor or machine tools manufacturing, particularly developed for process automation and instrumentation application in hazardous and intrinsically safe areas.

- ✓ **Profibus DP Q-Strip Cables:** For cabling of industrial field bus systems, particularly developed for factory automation applications.

Standards: IEC 60754-1
Conductor: Class 1 solid plain copper
Sheath: PVC (Polyvinyl Chloride); LSZH (Low Smoke Zero Halogen)
Sheath Colour: Violet
Voltage Rating: 250V

- ✓ **Profinet Cables:** Specially designed for use with Hart connectors, as well, RJ45, IP 20, IP 65 and IP 67 applications. The bus cabling portfolio includes cable types A, B and C, connectors, accessories, panels, feed-troughs and hybrid interfaces for simultaneously supplying devices with both data and power.

Standards: IEC 60754-1
Conductor: Class 1 solid plain copper
Sheath: HFFR (Halogen Free and Flame Retardant)
Sheath Colour: Green
Voltage Rating: 30V

Basic Technical Data:

Cable Type		Trunk	Spur
Conductor Resistance @ 20 Deg C Ohms/Km	Minimum Conductor Size Sq mm	18 AWG	22 AWG
	Maximum Resistance	23.5	59.4
Capacitance nf/Km	Between Conductors	Less Than 150 nf/Km	
	Between Conductors & Screen	Less Than 400 nf/Km	
Inductance mH/Km		Less than 1.0	
Insulation Resistance @20 Deg C M Ohm-Km		More Than 5000	
Characteristic impedance		100 Ω±20%	
Wave Attenuation @ 39 KHz:		< 3 dB/km	
Capacitive unbalance to shield		≤ 4 nF/km	
Temperature range		-30°C to + 90°C	

Obs.: Cable properties include active and passive interference resistance, chemical resistant, free from paint wetting and disruptive substances.

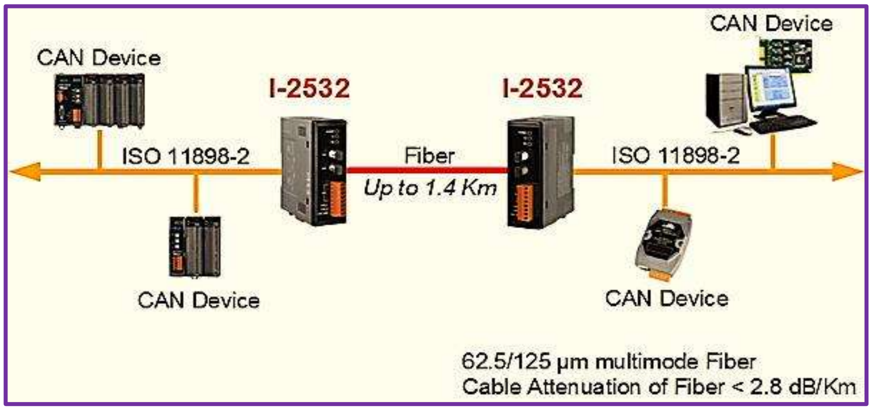
Conductor: Class 1 solid plain copper
Sheath: PVC (Polyvinyl Chloride)
Sheath Colour: Blue or Black
Voltage Rating: 300V
Baseband & Broadband Coaxial Cables: Are cables that transmit a **single signal** at a time at very **high speed,** mainly used for LANs and simultaneous signals, using different frequencies. Broadband coaxial digital signaling cables support frequency range **up to 4 kHz** and analog signaling cables support a frequency range **above 4 kHz**, generally **75 ohm**, used with a modem. Baseband coaxial cables used for "*digital transmission*" may reach **50 ohm**, and the bandwidth for **1 Km** cables is **1-2 Gbps**. Longer cables can be used with **low data rates** or periodic amplifiers.

Note: The baseband coaxial cables were originally used for the Ethernet system at **10 Mbps**, but for large areas, it requires unidirectional amplifiers. The dual band systems use two identical cables running together, one for outgoing data, other for incoming data. The two systems that use bus **LANs**, namely **10 BASE 5** and **10 BASE 2**, is shown in the table below:

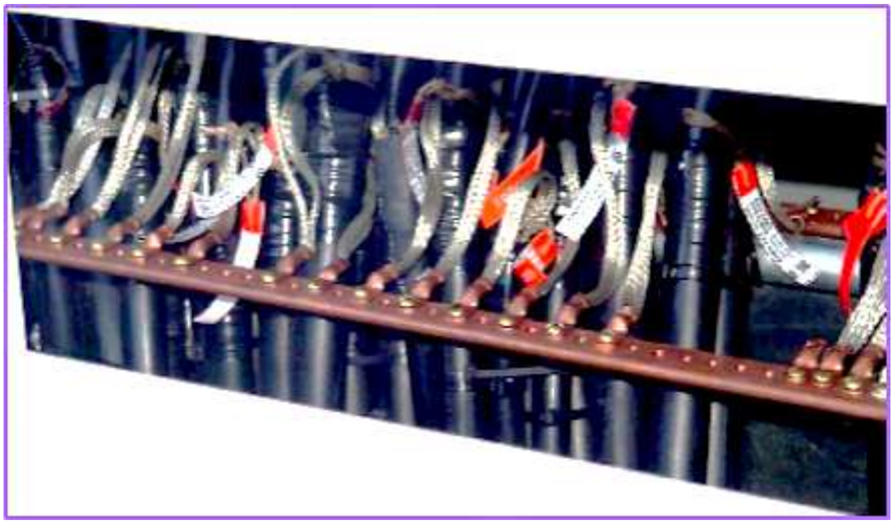
IEEE 802.3 specifications for 10 Mbps baseband co-axial cable Bus LAN

Sr. No.	Parameter	10 BASE 5	10 BASE 2
1.	Data rate	10 Mbps	10 Mbps
2.	Maximum segment length	500 m	185 m
3.	Network span	2500 m	1000 m
4.	Nodes per segment	100	30
5.	Node spacing	2.5 m	0.5 m
6.	Cable diameter	1 cm	0.5 cm

Electromagnetic Interference: The fiber optic transmission protects data transmission from electromagnetic interference (EMI), or radio-frequency interference (RFI) in control systems. In order to solve the problem between using different transmission mediums, **I-2532** was specially designed for **converting electrical** bus signals to **fiber optic** cables. The fiber length between two I-2532s can be up to **1.4 km** (4,593 ft), with the cable attenuation of fiber and the bus baud. Then, I-2532 is an economical solution where is required data transmission protection from electrical exposure, surges, lightning or chemical corrosion.



Cable Routing: All **electrical cables** must be properly **supported** to relieve mechanical stresses on the conductors, and protected from **harsh** conditions, such as abrasion which might degrade the insulation. The following picture shows a set of signal cables with **braided** shield conductors all connected to a common copper "***ground bus***". This particular application happens to be in the control panel of a **500 kV** circuit breaker, located at a large electrical power substation.

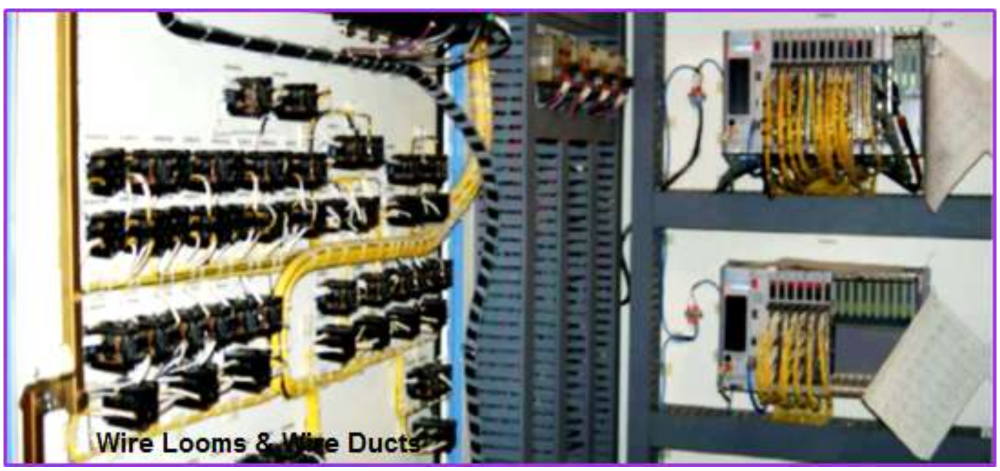


The plastic conduit provides **no electrical grounding or shielding** and is superior to **metal** conduit with regard to chemical corrosion resistance. That is why plastic conduits are generally used to **route** wires in areas **containing** water, acids, caustics, and other wet chemicals. When connecting electrical conduit to **end-point devices**, it is common to use flexible liquid tight conduit as a connector between the rigid metal (or plastic) conduit and the final device. Below, is shown a motor-operated control valve with **two runs** of liquid-tight conduit routing conductors.

Cable Trays: Is **another** technique for **cable routing**. Cable trays may be made of solid **steel** wire for **light-duty** applications, such as instrumentation signal cabling or computer network cabling, steel **plate** or **aluminum** channel for **heavy-duty** applications, such as electrical power wiring. Cable trays are open, leaving the cables exposed to the environment. A great advantage of cable trays is ease of cable installation, especially when compared to electrical conduit. An **example** of light-duty cable tray is shown below, used to support **Ethernet cabling** near the ceiling of a room at a college campus. The cable tray is made of solid steel wire, bent to form a "*basket*" to support dozens of yellow Ethernet cables:

Bus Ways: A special form of **wiring** often seen in industrial facilities for **power** distribution is the **bus way**, also known as **bus duct**. Bus ways are generally rectangular **sheet-metal tubes** containing pre-fabricated copper **bus bars** for the conduction of **three-phase AC power**. Special junction boxes, "*tees*" and **tap boxes** allow the bus ways to extend and branch to other bus ways and/or standard conductor wiring. Bus ways are commonly used in **indoor applications**, often in **motor control center** (MCC) and **power distribution** center rooms to route electrical power to and from large disconnect switches, fuses, and circuit breakers. In this photograph, we see bus way used to distribute power along the ceiling of an MCC room, alongside regular rigid conduit:

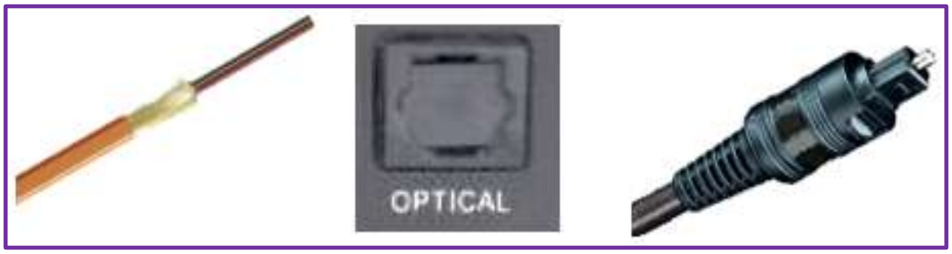
Wire Looms & Wire Ducts: The **wire loom** is always the **grey-colored** plastic spiral surrounding the **bundle of wires** near a panel **door** hinge. The **wire duct** is the **grey-colored** rectangular plastic channel mounted **vertically** and **horizontally inside** the panel. The wire loom is a loose **spiral tube** made of plastic, used to **hold** a group of individual wires together into a neat bundle. Wire loom is frequently used when a group of **flexible** conductors, as bundle joining devices, are inside a panel mounted on the hinging **door** of a panel. The picture below shows both **wire duct** and **wire loom** inside an instrumentation panel:



XIII. AUDIO/VIDEO, TRAFFIC, RAILWAY & WELDING CABLES:

Network, Phone, Security and Speaker Cables: Are commonly installed for very **long runs** in a central **junction box**, usually in the basement. Other cable types have limited ranges and run point-to-point, such as digital phone interfaces, internal cables, Ethernet, camera links, etc. The USB (Universal Serial Bus) is only a serial peripheral interface.

Audio/Video Optical Cables: Are currently used for digital **audio and video**, but in the future it may be used for many other applications like cellphones. Some phone companies are starting to wire new neighborhoods with **fiber cables** to provide Internet and television. Some structured (bundled) cables come **only** with one or 2 fiber optic cables.



BNC Cables: Are used in many situations as composite or component cables. Many times a connector can be converted between BNC and a composite or component. The BNC cables offer a better quality, usually a shielded coax cable with a **quick** twist connector.

S-Video Cables: Are generally 2 **coaxial cables in one**. There are 2 signal cables (Y & C) and 2 grounds. The 2 coaxial cables may be used instead of a specific **S-Video cable** or even a Cat 5e cable, although the signal won´t be as good with Cat 5e, because of the **lack** of shielding. A popular video format can be quickly replaced with DVI and HDMI cables.

VGA (Video Graphics Array) Cables: These cables were used in the **old desk computer** and monitor video format that can be found is some old flat panel televisions. Most flat panel computer monitors have now adopted the DVI-D format, leaving the VGA format for CRT tube monitors.

DVI (Digital Visual Interface) Cables: Are video **format cables** for audio/video of most desk computer monitors and old panel televisions, before the advent of the **HDMI format cables**. The DVI cables come in 3 formats. The DVI-D (Digital), which carries only a digital signal. The DVI-A (Analog) the wire carries only an analog signal. The DVI-I (Integrated) cables that carry both the digital and analog signals. There are also converters that can convert a DVI digital signal to HDMI or DVI analog to VGA and vice versa.

HDMI (High-Definition Multimedia Interface) Cables: Are the latest **standard** for computers and flat panel televisions to carry both **audio and video** signals.

Display Port Cables: Capable of **higher resolutions** compared to HDMI standards and also carry both **audio and video** signals.

Alarm/Security Cables: These cables are thicker than Cat 3 cables, commonly used to wire **security** systems, such as, Alarm Panels, Window/Door Sensors, Motion Detectors, Sirens, etc.

Infrared Sensors: Used when exist stereo components to be controlled with an Infrared (IR) repeater. The sensor needs to be located in the room that will use the remote control. The main unit and repeaters should all be with the stereo components. The IR repeater systems are usually supplied as all-in-one kits, although, some types can be used for **longer runs wiring**.

Balloons (or Baluns) and Coaxial Cables: Installed to achieve compatibility particularly in frequency **conversion** mixers to make cellular phone and **data** transmission networks possible. Balloons are also used to **convert** an E1 carrier signal from coaxial cable (BNC connector,1.0/2.3 connector,1.6/5.6 connector) to UTP CAT-5 cable or IDC connector.

A 75-to-300 Ω balun built into the antenna plug. Three audio transformers, two of them baluns.

Note: In television and **antenna installations** and connections, balloons are **converters** between impedances and symmetry of feed lines, **for example**, transformation of **300Ω** twin-lead or **450Ω** ladder line (balanced) and **75Ω** coaxial cable (unbalanced), or to directly connect a balanced antenna to unbalanced coaxial cables. In **audio** applications, balloons convert **high** unbalanced impedance and **low** balanced impedance lines or decoupling of devices (avoid earth loops).

HDCP (High-Bandwidth Digital Content Protection): All **video formats** DVI and later are compatible with **HDCP**, as a copy **protection** scheme to prevent **theft** of TV/movies. Not all devices support HDCP, and connecting **two** devices may bring some trouble on the protection scheme.

Traffic Signal Cables: These types of cables include the *Traffic Signal Cable* according to BS 6346 and *Loop Feeder Cable*, as defined below:

- **Traffic Signal Cables:** Are primarily for use in permanent traffic light systems and urban traffic management systems or other applications requiring high core configurations with mechanical robustness.

- **Loop Feeder Cables:** Are used to connect traffic lights to the central control management system. These cables are suitable for use in small power, lighting or control circuits where the *orange sheath* would be for circuit identification. Are also used within NMCS (National Motorways Communication Systems) and Inductive Loop Detectors. Loop Feeder Cables are available unarmoured or armoured, for direct burial.

- **Traffic Signal Cables - BS 6346 SWA PVC:** For interconnection of traffic signal equipment or other applications requiring high core configurations with mechanical robustness.

Standards: BS 6346, BS EN/IEC 60228, BS EN/IEC 60332-1-2, BS EN/IEC 50363-2:2007;
Conductor: Class 1 plain annealed copper conductor to BS EN 60228;
Sheath: PVC (Polyvinyl Chloride) conforming to TM1 as specified in BS EN 50363-4-1:2005;
Sheath Colour: Orange (Ral 2008);
Voltage Rating: 600/1000V.

Loop Feeder Cables: Come in armoured, for **direct burial**, or unarmoured for applications where additional mechanical protection has been afforded by other means, such as **ducting**. The loop feeder cables are supplied in a highly visible **orange** for easy location of buried services.

Standards: Generally to Highways Agency TR2031;
Conductor: Class 1 Solid Copper Conductor;
Sheath: PE (Polyethylene);
Sheath Colour: Orange;
Voltage Rating: 600/1000V.

High Voltage Cables: Are designed for **primary transmission** in network voltages **above 36 kV up to 550 kV**. These cables range from High Voltage Power cables to Low Voltage and Medium Voltage cables. Low Voltage is **up to 1000** volts and Medium Voltage is from **1 kV (1000 V) to 36 kV (36,000 V)**. The Ultra-High Voltage **above 550 kV** is defined by IEC 60840 (add. to Cenelec HD 632). ABB has made equipment for voltages up to **1200 kV**.

High Voltage Power Cables -IEC 60502, VDE 0276/62: Single-core cables with insulation of cross-linked polyethylene (XLPE) are **designed** for transfer and distribution of electrical power with a nominal voltage **Uo/U 6/10; 12/20; 18/30 kV**, frequency **50/60 Hz** in urban and district electrical networks, transformers substations, small and medium industrial plants. These cables are **suitable** for use in distribution installations, electric power stations, indoor installations, cable ducts, conduits and shafts, over shelves and grills directly underground, and outdoor shelter.

Standards: IEC 60502, VDE 0276/62, IEC 60840, HRN HD 632;
Conductor: Class 2 Copper or Aluminium Conductor;
Sheath: HDPE (High Density Polyethylene). Other options also available;
Colour: Black;
Voltage Rating U0/U: 64/110kV;
Highest Network Voltage Um: 123kV.

High Voltage Power Cables 2XS (FL) 2Y, A2XS (FL) 2Y: Are suitable for the **primary** distribution of **power** up to a maximum network voltage of **110kV**. Water blocking options ensure that the cables can be damaged; repair lengths and associated works are kept to a minimum. The cables are provided with a High Density Polyethylene chosen to give the best compromise between **abrasion** resistance and flexibility to ensure installation confidence.

Standards: IEC 60840, HRN HD 632;
Conductor: Class 2 Copper or Aluminium Conductor;
Sheath: HDPE (High Density Polyethylene);
Colour: Black;
Voltage Rating U0/U: 18/30 kV 12kV; 24kV; 36kV;

Highest Network Voltage Um: 36kV.

Railway Cables: Advanced cables for **railway applications** as light signaling, track switching, axle counters, incorporate railway specific technologies, including medium and low-voltage power cables, communication cables, according to railways specific requirements. The main types are:

- **Signaling Cable Type A1, A2, A3:** Light Duty LSZH sheathed single and multi-core generally for internal use. Smooth sheath suitable for installation in ducting:

Standards: NR/PS/SIG/00005 (formerly RT/E/PS/00005);
Conductor: Class 2 stranded tinned copper to BS EN 60228:2005 (previously BS6360);
Sheath: LSZH (Low Smoke Zero Halogen);
Sheath Colour: Black. (Also available in violet, red, orange grey, brown and blue);
Voltage Rating: 650/1100V.

- **Signaling Cable Type B1, B2:** Heavy Duty EPR insulated and Heavy Duty PCP sheathed single, twin and multicore cables:

Standards: NR/PS/SIG/00005 (formerly RT/E/PS/00005);
Sheath Colour: Black;
Voltage Rating: 650/1100V;

- **Signaling Cable Type D1, D2:** LSZH single, twin and multicore cables:

Standards: NR/PS/SIG/00005 (formerly RT/E/PS/00005);
Sheath Colour: Black;
Voltage Rating: 650/1100V.

Welding Cables: Are designed for transmission of high currents from **electric welding machines** to welding tools, manually or automatically operated, and spot welding machines. The welding cables types include orange, black, H01N2-D and H01N2-E that are flexible rubber jacketed welding cables. Orange and black types welding cables are very **similar** in their construction, except that orange has **tinned copper** conductors, making it more resilient against corrosion. H01N2-D and H01N2-E welding cables have **Class 5** and **Class 6** conductors respectively, giving H01N2-E greater flexibility for use as an **electrode lead**. Welding cables conform to BS 638 Part 4 also additionally comply with CENELEC HD 22.6 and VDE282-6.

The welding cables conforming to BS 638 can be used in a wide range of **applications** including Arc Welding, Manual Metal Arc Welding, and the interconnection of equipment **up to 450 V** (with suitable protection), with welding accessories, such as cable connectors and heavy duty cable connectors. The common standard **welding cables** are:

- **Orange Welding Cable - BS 638:** For transmission of **high currents** from the electric welding machine to the welding tool. Suitable for flexible use under rough conditions, on assembly lines and conveyor systems, in machine tool and motor car manufacturing, ship building, for manually and automatically operated line and spot welding machines.

Standards: BS 638 Part 4, BS EN 60332-1-2;
Conductor: Class 5 flexible tinned copper for 120 mm² and above. Class 6 extra flexible tinned copper conductors according to BS60228;
Sheath: HOFR (Heat and Oil Resistant and Flame Retardant), Sheath to BS 7655;
Sheath Colour: Orange;
Voltage Rating: 100V (450V suitably protected from mechanical damage).

- **Black Welding Cable - BS 638:** For transmission of **high currents** from the electric welding machine to the welding tool. Suitable for flexible use under rough conditions, on assembly lines and conveyor systems, in machine tool and motor car manufacturing, ship building, for manually and automatically operated line and spot welding machines.

Standards: BS 638 Part 4, BS EN 60332-1-2;
Conductor: Class 5 flexible plain copper conductors for 120 mm² and above. Class 6 extra flexible plain copper conductors to BS EN 60228:2005 (previously BS 6360).
Sheath Colour: Black;
Voltage Rating: 100V (450V suitably protected from mechanical damage).

- **H01N2-D Welding Cable - BS 638:** For transmission of **high currents** from the electric welding machine to the welding tool. Suitable for flexible use under rough conditions, on assembly lines and conveyor systems, in machine tool and motor car manufacturing, ship building, for manually and automatically operated line and spot welding machines.

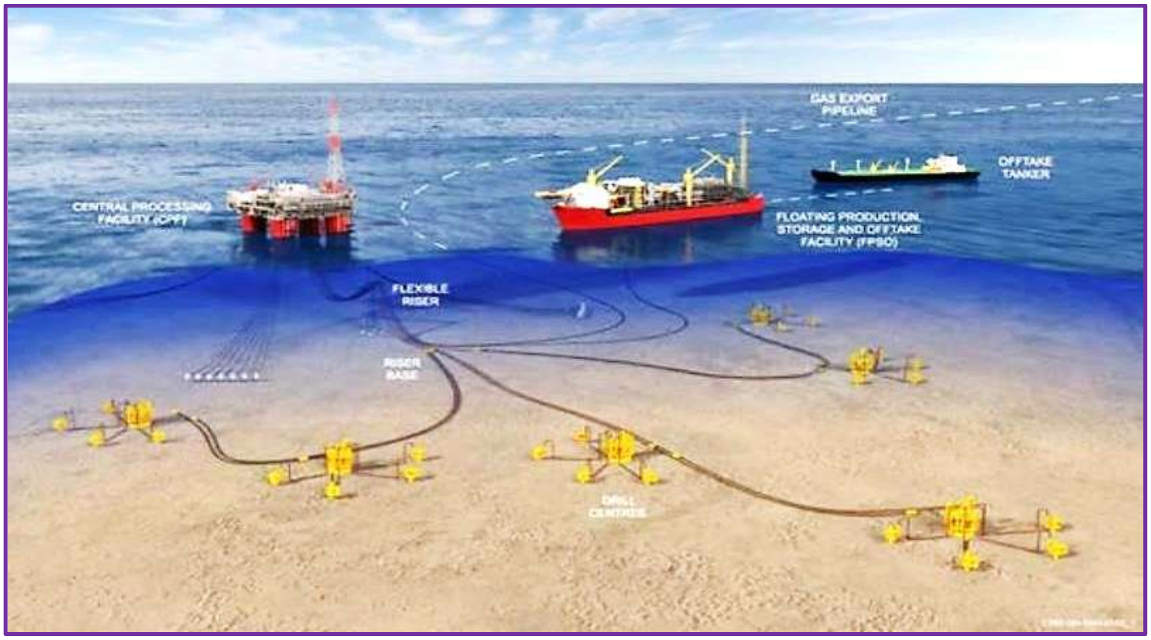
Standards: BS 638 Part 4, VDE0282-6, CENELEC HD22.6;
Conductor: Class 5 flexible plain copper conductors;
Sheath: HOFR (Heat and Oil Resistant and Flame Retardant);
Colour: Black;
Voltage Rating: 100V (450V suitably protected from mechanical damage).

- **H01N2-E Welding Cable - BS 638:** For the transmission of high currents from the electric welding machine to the welding tool. Suitable for flexible use under rough conditions, on assembly lines and conveyor systems, in machine tool and motor car manufacturing, ship building, for manually and automatically operated line and spot welding machines.

Standards: BS 638 Part 4, DIN VDE 0282-6, CENELEC HD22.6;
Conductor: Class 6 extra flexible plain copper conductors;
Sheath: HOFR (Heat and Oil Resistant and Flame Retardant);
Sheath Colour: Black;
Voltage Rating: 100V.

XIV. OFFSHORE AND SUBSEA CABLES:

Umbilicals: An umbilical is a **subsea cable**, which supplies required **consumables** to **offshore equipment**, supply air and **power** to a hydraulic pressure assembly, electrical power and **fiber optics** to any subsea apparatus. Subsea umbilicals are deployed on the **seabed** (ocean floor), connected on **platforms**, to supply necessary control, energy (electric, hydraulic) and chemicals to oil & gas wells. By analogy, it is named with an umbilical cord.



Subsea **umbilicals** are also commonly used for offshore **drilling** activities. Subsea umbilicals, **raisers** and **flowlines** form a vital **link** among oil & gas centers of **operation**. These cables must be able to **withstand** high mechanical and chemical stresses, high operating **temperatures** and **pressures** in order to ensure the continuous and reliable supply of services in the harsh environments below the sea, designed to suit static and dynamic applications.

Umbilical cables - Subsea raisers & flowlines

Umbilical cables are also **subsea power** cables, but **differ** from **traditional** power cables due to their long lay-length, internal elements encased by longitudinal channel elements, radial high abrasion contact and design flexibility. Umbilicals offer a full range of **solutions**, thanks to innovative designs, materials and state-of-the-art processes that meet the demanding requirements of all **offshore** applications, following major benefit standards, such as API17B and API17J.

Power and Optical Umbilicals: As described, provide **transmission** of electric and fiber optic **signals**, electrical power, hydraulic fluids and injection of chemical fluids through respectively electric-and/or fiber optic cables through steel tubes or steel tube umbilicals. The STU (Steel Tube Umbilicals) technology provides enhanced **response** times and higher working pressures when compared to more traditional thermoplastic hose based designs.

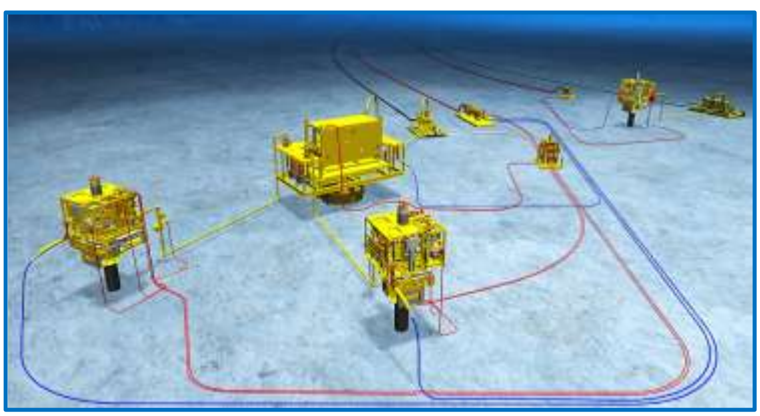
The STUs use high-alloy stainless steel tubes with high mechanical strength and fatigue resistance, with an excellent corrosion resistance. Designed and tested to withstand harsh environmental conditions in water depths as deep as 2,500 meters in both static and dynamic applications, these submarine cables, require a high level of structural resistance, comprise the following elements: Low or medium voltage power cores; Optical core.


Power and Optical Umbilicals


Composite Umbilicals

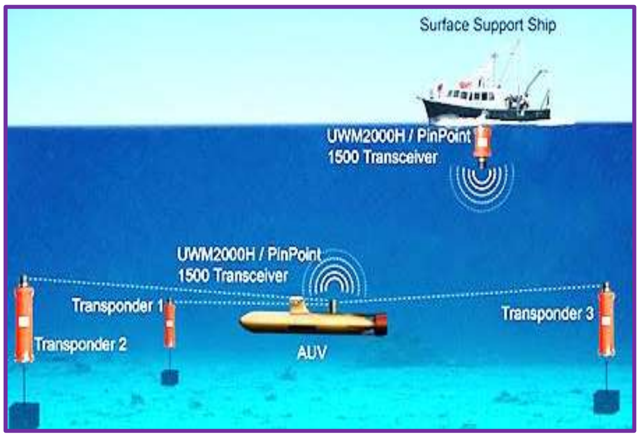
Subsea Interconnection: For safe and efficient interconnection from the **topside** platforms and vessels to the **well heads and pumps** on the seafloor is necessary to transfer power, data, as well as hydraulic and **other fluids** to guarantee reliable **oil extraction** operations in water depths of up to **2,500 meters**, composed of any possible combination of hydraulic lines (thermoplastic hoses or steel alloy tubes), low-voltage electrical control cables, medium-voltage power transmission cores and optical signal components. These umbilicals comprise the following typical functions:

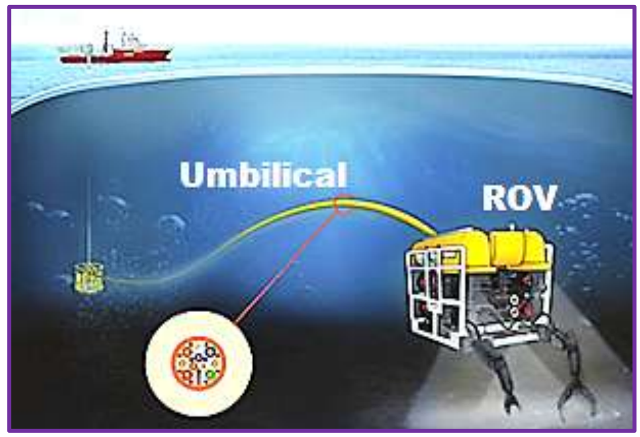
- High-pressure hydraulic control hoses;
- High-pressure chemical injection hoses;
- Electric control cable (optical fiber control core can be provided as an option, on demand).



Note: The subsea **umbilicals** are generally the **link** between the **facility** (onshore/offshore) and the **subsea** production systems. Umbilicals make the **interconnection** from platforms and vessels to equipment on the seafloor, necessary to **transfer** power and **data** to guarantee reliable oil extraction operations. Underwater umbilical cables, subsea risers and flowlines connector and cable assemblies form **important links** for reliable operations.

AUV's (Autonomous Underwater Vehicles), ROV´s (Remote Operated Vehicles) and UUV (Unmanned Undersea Vehicles): The oil and gas industry use all these devices to make detailed maps, before starting the building subsea **infrastructure**, such as umbilicals, pipelines and seafloor completions, in an **effective** manner with minimum disruption to the **environment**. The offshore systems **include** communication module applications, high voltage/high current for hydraulic power units (HPUs), optical fibers, UTPs, coaxial cables paths for video, phone, radio and computer communication, or a combination of all.





XV. FIBER OPTICS OR OPTICAL FIBER CABLES:

Introduction: Since optical fibers were developed, this technology represented a revolution in the way of conveying **information**. The optical fiber has been used to transmit voice, television and data signals by **light waves**, by means of thin and flexible wires, consisting of glass or plastic. Optical fibers are now proven, approved, and in reality a recognized technology. Optical fibers have a vast field of **study**. The understanding of optical segments, electronic and communications comes to be, very important to the study of optical structures.

History and Concepts:

1621: *Snell Willebrod found* when light passes through two means, direction changes (refraction).
1678: *Christian Huygens* modeling light as a wave.
1792: *Claude Chappe* invented a mechanical transmission to long distances B < 1 bps).
1800: *Sir William Herschel* discovered the infrared part of the spectrum.
1830: Telegraph Code *Morse* with repeaters got 1000 miles (B = 10 bps).
1866: The first transatlantic Telegraph cable transmission.
1876: Invention of the *Graham Bell* analog telephone.

1926: *John Logie Baird* patents a primitive color TV which used glass rods for transporting light.
1940: One coaxial cable carries up to 300 telephone calls or a TV channel with a 3 MHz carrier.

1950: Researchers begin to suggest the use of a shell around the fiber to guide the light. The first "fiberscope" was developed, but the cost was prohibitive.
1952: The Indian-born, American physicist, ***Narinder Singh Kapany*** invents the *optical fiber*. In 1960, he founded Optics Technology Inc. In 1973, Kapany founded the Kaptron Inc., and was President and CEO until 1990 when he sold the company to AMP Incorporated.

1964: *Kao* speculated if the fiber loss is only 20 dB/km, would be possible, at least theoretically, to transmit signals at long distances with repeaters, with only 1% of the light after 1 km of travel.
1968: The fibers had a loss of 1000 dB/km. *S*ponsors projects to obtain smaller glasses loss.
1970: *Corning Glass* produced some meters of optical fibers, with losses of maximum 20 dB/km.
1973: A fiber optic telephone link was installed in the USA.
1976: *Bell Laboratories* installed a telephone link in Atlanta of 1 km and proved to be possible the fiber optic for telephony, mixing with conventional techniques of transmission. The first link of cable with fiber optic was installed in *Hastings* (UK). Then, the *Traffic Rank Optics in Leeds* (UK) manufactured 110 mm fibers for lighting and decoration.
1978: At various points in the world, the optical fibers manufacturing starts, with losses smaller than 1.5 dB/km, for the most diverse applications.
1988: First optical fiber submarine cable plunged into the ocean and started the highest information system.

Nature of Light: The **light** can present characteristics of **particulates** (bodies endowed with mass) and waves (energy) or even, in some cases, appear as **photons**, which looks like a **beam** or electromagnetic particles that move at high speed. The theory of light as a **particle** can be described, when it is transmitted by the **photoelectric** effect, when the light hits the surface of certain solids and cause the emission of electrons.

Speed of Light: Galileo Galilei (1564 – 1642) the Italian astronomer made the first attempt to measure the **speed of propagation of light**, as follows: Galileo and his assistant went to the top of two hills on a distance of about a mile, **each** armed with a **flashlight** and a bulkhead to cover it. Galileo was intended to measure the **time needed** for light to **travel** twice the distance between **two observers**. The initial time of his vision of light with the other observer would be the time required for the light come and go between the two observers. But Galileo was not able with this, and **get no value** for the speed of light, because the speed is too great and the time **interval** to be measured is much **smaller** than the fluctuations of the response time of the observers.

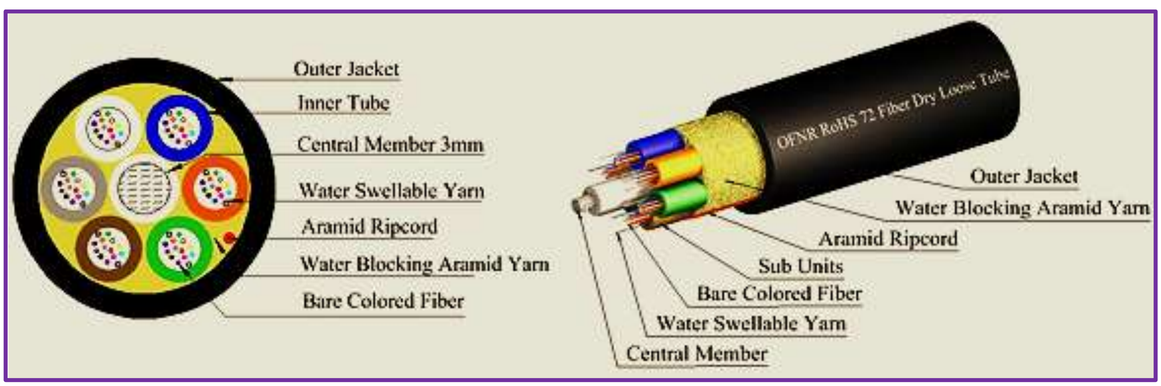
In 1675, the Danish astronomer Ole Christensen Rømer (1644 – 1710), through their astronomical observations about the period of **one rotation** of the Jupiter's moons, obtained the **first** real indication of **speed of light** greatness. In 1849, the French physicist Armand Hippolyte Louis Fizeau (1819 – 1896) made the **first** astronomical **measurement** of the speed of light, perfected by his fellow physicist Jean Bernard Léon Foucault (1819 – 1868), in 1850, and after between 1880 and 1930, by physicist Albert Abraham Michelson.

Electromagnetic Waves: James Clerk Maxwell (1831 – 1879), a Scottish scientist, developed the electromagnetic theory that treats light as an **electromagnetic wave**. He describes that the **speed** of an electromagnetic wave in **vacuum** is related to an electric constant, which can be determined by a measurement of a capacitor with parallel flat plates, and a magnetic constant. The electromagnetic waves that are generated by the **acceleration** of electric charges, include visible light, radio waves and gamma rays, radar, microwave and other, involving wave propagation of electrical and magnetic fields through space. Precisely, this is **speed of 299.792.500 m/s** for most practical applications this number is approximate to **300,000,000 m/s**. Each measure has its own unit of measure, whether it is energy, wavelength or frequency. Internationally, the most used is the wavelength measured in metric units, micrometric (10 less 6 m high) and in total (10 minus 9 m high). The frequency is measured in Cycles per Second (CPS) or **Hertz** (Hz).

For example, the **speed of light** is a function of **wavelength** and **frequency**. Using the photon energy (E) for fibers is, Plank law - **E = h x v**, where (H) is the Plank constant and (v) the frequency. The frequency **spectrum** has only a small region called optical region, in which **optical fibers** work. This region includes a light visible to **human eyes** with wavelength ranging between **400** and **700 nm** (nanometer), near infrared and ultraviolet region. Refractive index is less **than 1**, when we measure the speed of light in that material is always **less than the speed of light** in vacuum.

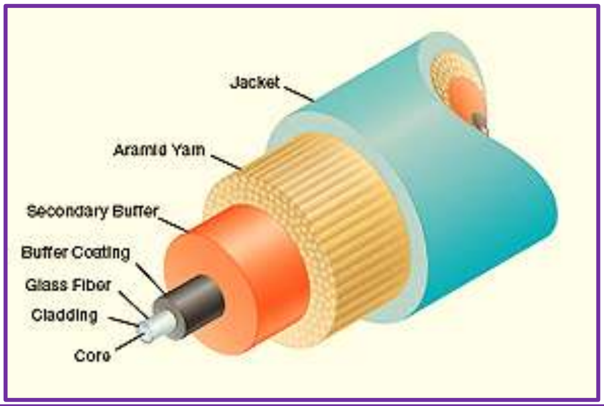
Snell's Law: The phenomenon of total internal reflection, which sustains and maintains light confined in **fiber optics**, is explained as follows: the internal reflection must be provided with all the energy, causing light rays **jump** to the inside of the fiber, according to **Snell's law**. The transmission of a **beam** of light directly in rows of optical materials arise certain situations. The angles of incidence and **refraction** measured are not in the same plane of the surface, but in a standard line, i.e. perpendicular to the face. The relationship is known as **Snell's law**, where the indices of refraction and the refractive medium are the **angles** of the light incidence and its refraction.

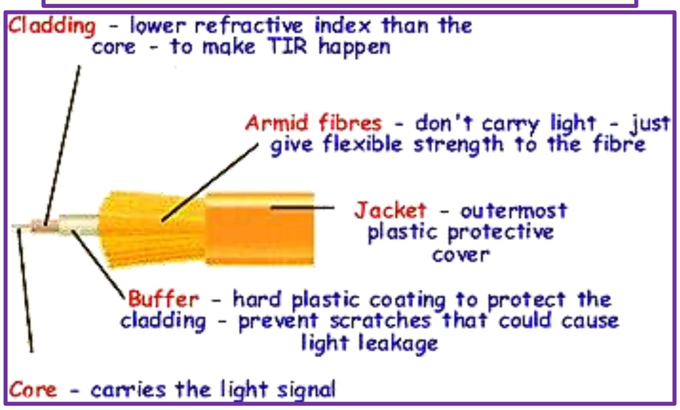
Optical Fiber Cable: The fiber optic technology *uses **light*** as its main information **carrier**. The cable consists of a core, a single continuous strand of glass or plastic that's measured in microns (μ) by the size of its outer diameter. This is the pathway for light rays carrying data signals. Fiber is the preferred cable for applications that require high bandwidth, long distances, and immunity to electrical interference.



Fiber Working Principle: The **light** propagates inside an optical fiber based on total reflection of light. The light is injected into the fiber for one of their ends under a cone of acceptance, in which it determines the angle by which the light beam must be injected, so that it can propagate along the fiber optic. The basic composition of optical fiber is a cylindrical structure with dielectric materials, composed of a central region, which is called **core**, which is where the light travels, and a peripheral region, named shell, which surrounds the nucleus. The core dimensions vary depending on the type of fiber, which can be from **8 microns to 200 microns**, and the diameter of **125 microns** up to **240 microns**. So, the basic composition of an optical fiber is:

- ✓ Core (fiberglass);
- ✓ Shell that surrounds the nucleus (fiberglass);
- ✓ Film that covers the shell, called acrylate;
- ✓ A tube where the fibers are behaved, cartridge calls;
- ✓ Aramid yarns, to act as protection and traction;
- ✓ Kevlar stick, used to provide mechanical strength to the cable;
- ✓ Cover; consisting of a polymer.





Types of Optical Fibers: The **main types** of optical fibers are: ***Singlemode and Multimode***. The choice of any type will depend on the application. *Multimode fibers* are most frequently used in ***local networks*** (LANs), while *Singlemode fibers* are used in ***wide area networks*** (WANs).

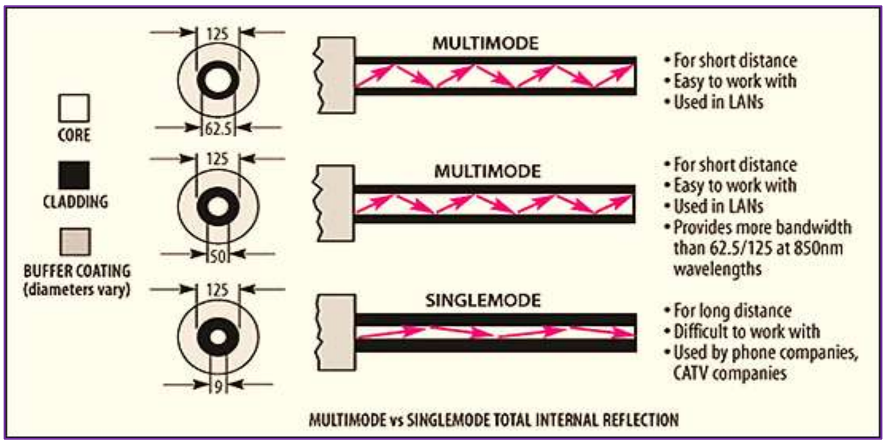
- **Singlemode, 8 - 10 µm Fiber Cables:** Also known as **SMF** - Singlemode Fiber Cables have a small 8 - 10 micron ***glass core*** and only **one** pathway of light, that is, only **one single** wavelength of light passing through its core, Singlemode cables realign the light toward the center and can provide **50 times** more effective **distance**, than **multimode** cables. Consequently, singlemode cables are typically used in **long network** connections, including cable television and campus **backbone** applications. This type of fiber differs also on the variation of the refractive index of the core, classified as a "***step-index standard***" with dispersion shifted to non-zero dispersion. Singlemode cables are traditionally *yellow*.

- **Multimode, 50/125 µm or 62.5/125 µm Fiber Cables:** Also known as **MMF** - Multimode Fiber Cables are commonly used for general data and voice applications. Both 50 and 62.5-micron cables feature the same cladding **diameter** of **125-microns**. The *50-micron fi-*

ber cable features a smaller core (the light-carrying portion of the fiber) and provides longer link lengths and/or higher speeds, particularly in the **850 nm** wavelength. The 50-micron cable is recommended for backbone, horizontal, and intra-building connections optimized for **10-Gigabit** applications. Multimode fiber cables are traditionally *orange*. Multimode fibers are classified in **two types**: *Multimode Step-Index fibers or Graded-Index fibers*.

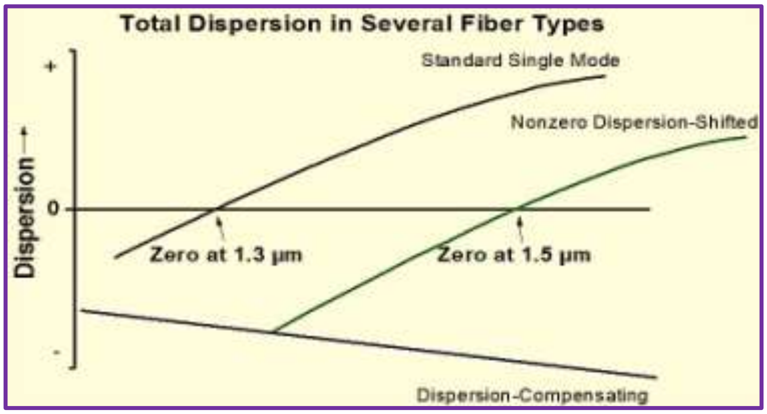
Multimode Step-Index: Have a nucleus consisting of a material with constant refractive **index**. One of the disadvantages is the pass band that is **too narrow**, which restricts the ability of fiber transmission. The **attenuation** is quite **high** when compared to singlemode fibers, which **restricts** applications in relation to the distance and transmission capacity.

Multimode Graded-Index: Have a nucleus consisting of a variable refractive index, which allows the **reduction** of the luminous impulse. The refractive index with different dosages in the fiber core decreases gradually from the center of the core to the crust. This index causes the light rays travel in different paths, with different speeds and reach the other end of the fiber at the same time virtually, increasing the bandwidth and, therefore, the fiber optic transmission capacity.



Plastic Optical Fiber Cables: Are used on short distance applications, such as in cars, airplanes and audio equipment such as DVD players, CD players and MP3 and DAT recorders. The low cost and ease of connectorization make *plastic optical fiber* the logical choice for short distance applications. Plastic optical fiber, like glass fiber is immune to lightning, and EMI and RFI.

Dispersion-Shifted Fiber Cables: Are singlemode optical fiber cables with a core-clad index profile **tailored to zero-dispersion** wavelength, which depends on the diameter of the **nucleus** and the variation of the refractive index. The dispersion-shifted fiber cables have a modern design and present characteristics with many advantages, such as **low attenuation**. When used for long distances, high-speed transmission, and for transmitting **multiple** channels (WDM) provides **greater bandwidth** than Multimode fibers. However, manufacturing requires advanced techniques and difficult handling, with much higher costs when compared with type Multimode fibers. It is designed to operate with a minimum dispersion from the natural **1300 nm** in silica-glass fibers up to the minimum-loss, at **1550 nm** (nanometer).



Note: The characteristics of these fibers are far superior to Multimode, mainly regarding to wider passing bands, which increases the transmission capacity. Its lower attenuation facilitates **longer** distances without the use of **repeaters**. The links generally exceed **50 miles** between repeaters, depending on the quality of the optical fiber.

Parameters Values: Parameters values defined for the main fiber cables, the **singlemode** fiber cables **8-10/125** and the **multimode** fiber cables **62.5/125**, as shown in the table below:

Fiber Performance Standards

Fiber Type	Wavelength	Attenuation (dB/km) Max.	Bandwidth (MHz/km)	Distance Gigabit Ethernet	Distance 10-GbE
Multimode					
50-/125-Micron	850 nm	3.5	500	500 m	300 m
	1300 nm	1.5	500	500 m	300 m
62.5-/125-Micron	850 nm	3.5	160	220 m	300 m
	1300 nm	1.5	500	220 m	300 m
Single-Mode 8–10-/125-Micron					
Premises	1310 nm	1.0	—	2–5 km*	10 km*
	1550 nm	1.0	—	50–100 km*	40 km*
Outside Plant	1310 nm	0.5	—	2–5 km*	10 km*
	1550 nm	0.5	—	50–100 km*	40 km*

Attenuation and Bandwidth of Optical Fibers: As the light propagates through the fiber optic, loses part of power by the absorption of **light** with imperfections of the material employed in manufacturing (silica) within the **fiber** (wave guide), by a process called **attenuation** of the signal that is measured in **dB/km**. The degree of attenuation depends on the wavelength of the transmitted light. The main characteristics are:

- **Greater Bandwidth:** Optical fibers provide far greater bandwidth than copper cables and have proven real performance at rates up to 10 Gbps, giving network designers future-proofing capabilities. Optical fibers can carry much more information with greater fidelity than copper cables.

- **Low Attenuation and Greater Distances:** Since the fiber optic signal is made of light, very little signal loss occurs during transmission, then, data can move at high speeds and greater distances. Distances can range easily from 300 meters (984.2 ft.) to 40 kilometers (24.8 mi.), depending on the style of cable, wavelength, and network. (Fiber distances are usually measured in metric units).

- **Immunity:** Optical fibers provide extremely reliable data transmission, and are completely immune to many environmental factors that affect copper cable, such as EMI/RFI, cross-talk, impedance, and are also much less susceptible to temperature fluctuations.

- **Design:** Optical fibers are lightweight and more durable and have pulling specifications up to **10 times** greater than copper cables. Its small size makes it easier to handle, and takes up less space in cabling ducts. Fiber also is available with PVC and plenum jackets.

Fiber Pulse Dispersion: Is the difference between the **bandwidth** of the input pulse to the corresponding **output** signal pulse (the distance traveled by light). The dispersion is an **effect** in which the generation of waves is separated when the light travels by fiber optic, which brings about the arrival of the other end scattered in relation to time. This phenomenon is specified per unit length in **ns/km**, in a digital broadcast, which comes to hinder the signal reception in the receiver circuit and its subsequent decoding. Pulse dispersion is responsible for limiting the **bandwidth** of the transmitted signal resulting in superposition of several signal pulses.

We can classify the pulse dispersion in **two ways**: *Intermodal Dispersion and Multimode Dispersion*. The geometry of the waveguide and refractive indexes that allow the fiber to **propagate** several modes or rays of light, defines the **intermodal** or **multimode** dispersion. In every fiber is present the material dispersion, intermodal or chromatic, because it's due to the dependence of the **refractive** index of the fiber material with respect to the wavelength. With only **one light** source, there is no chromatic dispersion, which generates a light purer and less spectral width, commonly better than a conventional LED. Multimode fibers are more susceptible to intermodal dispersion.

For the purpose of **measuring**, in a **standard** silica optical fiber, the dispersion coefficient is **null** for a wavelength close to **1,300 nm** (nanometers). **Multimode** fibers are more susceptible to intermodal dispersion. **Singlemode** fibers have band dispersion wavelength with minimum values, but **not zero**, where optical amplifiers work. This allows **higher** transmission rates and smaller spacing between channels of communication. Optical dispersion-shifted fibers (Dispersion Shifted "DS") meet **minimum** dispersion and attenuation.

Fiber Modulation: Modulation is the process by which a **signal** is transmitted with change of amplitude, frequency or phase, instead of being passed in its original form. A sinusoidal modulation is most used today in **radio systems** to convert a signal in a frequency band, in which the receivers can better detect it and separate the different waves. The signal can be recovered by absorption detection of changes of amplitude, frequency or phase, depending on the type of modulation. This type of transmission is called **analog** transmission. Modulation techniques are **rarely** used with **optical fibers**, and are only applied when the analog transmission offers an advantage in cost or signal format. The PCM (*Pulse Code Modulation*) is a common **modulation technique** employed in optical fiber communications systems.

Note: A pulse is formed by switching the source in the well-defined states, ***on and off***. For both analog modulation and pulse code modulation, the optical transmitter (LED or LASER) transmits the signal to the variation of output power, represented by a proportional variation in the optical output power. However, in **digital** systems, a pulse can be represented by a light burst, **1** (*for logical level-on*) and by the absence of a light burst, **0** (*for logic level-off*).

Multiplexing: Is different types of signals that can be transported by an **optical** transmission system, in which is possible to transmit **two or more** channels of information simultaneously. The three defined types of multiplexing are; Time Division Multiplexing (TDM) at different times; Frequency Division Multiplexing (FDM) in different frequencies; Wavelength Division Multiplexing (WDM) by wavelength. Other multiplexing methods are:

- **TDM (Time Division Multiplexing):** Is the multiplexing of **multiple** channels into a **single** channel for transmission of a group of bits, only with **binary** signals from the Pulse Code Modulation (PCM), no matter if the signal is analog or digital. This association of ranges is stored in a memory buffer called "*Timing Block*". The bit on the receiver side of the *demultiplexers* can identify the channels, which are **separated** and rebuilt. By not using the guard band TDM becomes much more efficient than the FDM (described below). The only inefficiency is that a small number of bits is **added** to the pulses (data) transmitted, to provide an error detection on the multiplexer and demultiplexer timing.

- **FDM (Frequency Division Multiplexing):** Is when **various** information channels are multiplexed into a **single** channel, the way that each source modulates a different frequency in amplitude, frequency or phase, referred to as an intermediate channel. This technique is used in the propagation of **radio and TV** signals. It is developed and manufactured for specific applications, such as cable TV. However, there is a disadvantage when applied to **optical fibers**, as the linearity of the optical sources, commonly between 0.001% and 0.1%, is not sufficient to prevent the generation of harmonic **distortion**.

- **WDM (Wavelength Division Multiplexing):** Is used to multiplex channels employed in stages where the signals to be transmitted are still electric. It multiplexes "*colors*" (wavelengths of light) in a **single fiber optic**, using sources of various wavelengths, like the FDM in an infrared portion of the electromagnetic spectrum. Each optical carrier can carry several channels that have been multiplexed electrical with FDM and TDM techniques. The WDM technique is not applied on local networks as transmission rates and distances make applications on LAN too much **single**, that is, not demanding complex optical systems.

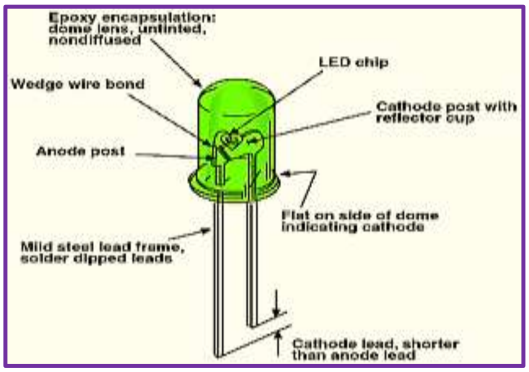
Optical Conversions: *In fiber optics a "**transmitter block**"* has the function to transform the **electrical** signal into **optical**, consisting of two basic components: the circuit *driver* and led circuit. The circuit *driver* has the function of electric polarization control and issuance of optical power. The led circuit is responsible for the conversion and the issuance of the optical signal. The "***receiver block***" has the **inverse** function, that is, converts the **optical** signal to **electrical**. It consists of a photo detector that performs the conversion through a filter-amplifier circuit, where the signal receives a treatment suitable for reading. The physical medium is naturally composed of optical fibers as a guide, in whose interior the light travels from the end station to the receiving end.

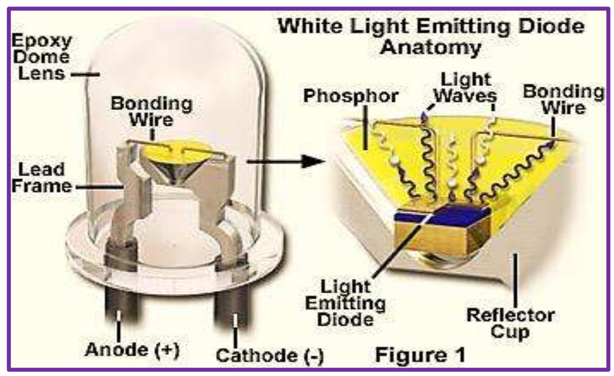
Light-Emissions Devices: Are **diodes** used for **light sources**, but only two devices are commonly applied to **fiber optic** transmission: *the **LED** (Light Diode Emission) and the **ILD** (Injection Laser Diode)*, both directly modulated semiconductors by variation of the input current, consisting of *gal-*

lium arsenide and aluminum (GaAIAs), *phosphate and aluminium gallium arsenide* (GaAIAsP) or *phosphate of gallium arsenide and Indium* (GaInAsP).

LEDs (Light Emission Diodes): Are the most common ***light sources*** for **fiber-optic** communication systems, because they ***emit light near invisible infrared***. A small voltage is applied between the diode terminals, in order to **emit light** (red or blue light-emitting diodes (LEDs) and can have values of **1.4 V** and **4.0 V**, making a small current flowing through the junction. These diodes are formed by **two types** of semiconductor material, impurities-doped ***P-type*** *and* ***N-type***.

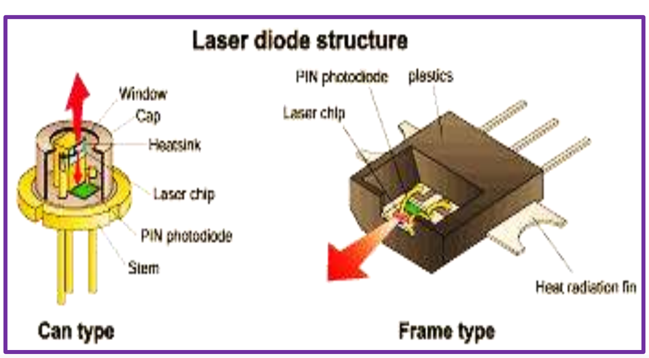
The ***P-type*** is the one that has fewer electrons than atoms, which implies in gaps where there are spaces for electrons in the crystalline structure. The ***N-type*** is characterized by presenting electrons more free than gaps. The wavelength emitted by the LED depends on the internal semiconductor's energy levels. The wavelengths used in fiber optic applications are of **820 and 850 nm**, at room temperature typically **3 dB** bandwidth, at **40 nm**, approximately.



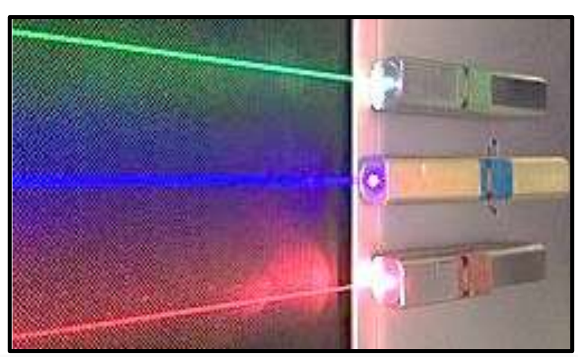


Note: There are two types of LEDs used in optical fiber communication systems; ***edge emitters and surface emitters****. Surface emitters* are most commonly used, because offer better emission of light. However, coupling losses are greater in *surface emitters* because exhibit minor modulation bandwidths than *edge emitters*.

ILDs (Injection Laser Diodes): There are **three basic types**; gas, solid laser or semiconductor, but only the ***semiconductor laser*** finds practical application in **optical fiber** communication systems due to cost, size and supply voltage, and is more suitable for long distance systems for attaching higher powers in optical fibers. The operation is very **similar** to LEDs and possesses the same materials in its constitution, arranged differently. The ILD **behaves** like an LED, and presents a **broader** light irradiation. The laser oscillates in **445 nm**, **520 nm** and **635 nm**.



Laser diodes types



Semi-conductor lasers (445 nm, 520 nm, 635 nm)

Optical Connectors: The optical connectors are accessories for **fixing** fiber cables at the **end** of a bolt. The detection of increasing **attenuation** has basically, two types of losses; *the insertion loss and return loss*. The concepts are:

- ***Insertion loss*, or attenuation:** Is the luminous power loss that occurs on passage of light in connections, usually caused by irregularities in the alignment of the connectors and the intrinsic optical fiber irregularities.

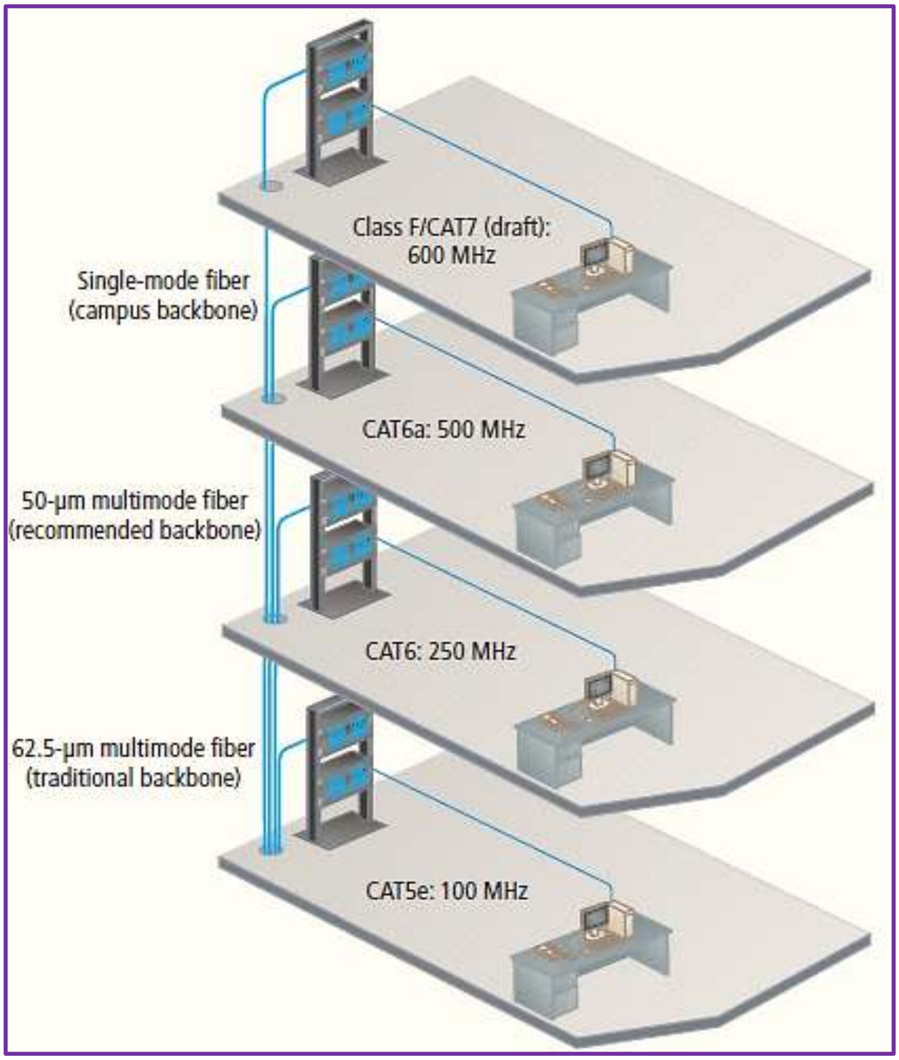
- ***Return loss*, or reflectance:** Is the amount of optical power reflected on the connection, and the reflected light returns to the light source, on the face of the connector bolts, which reflect part of the light that enters the fiber optic connector inside the opposite side. This loss does not influence directly the total attenuation, however, can degrade the operation of the light source and thus affect communication.

Optical Connection Types: There are various types of connectors, according to application. The **most common** are: *optical or extensions pig-tail; optical cord; multicord cables*. The basic, consists of a **bolt** with a polished face, where is made the **fiber alignment**, and a substrate provided with a plastic cover. The **EIA/TIA-568** standard recommends the use of certain optical cables, with main parameters that involve cables and optical accessories. This standard recommends the use of connectors **ST** and **SMA**, and attenuation for insertion must be lower than the **0.75 dB** per connector. The return loss should be above **20 dB** for **multimode** fiber cables and **26 dB** for **singlemode** fiber cables. All connectors must have lifespan of **1000** operations.

Optical Fusion: Or fiber cable optic **splicing** is the process of **joining** two or more fibers together. There are **two** types of fiber splicing – **mechanical** and fusion splicing. The maximum attenuation standard for optical fusion or mechanical seams **cannot** exceed the value of **0.3 dB**.

Layers: The fiber optic cables, which carry internet traffic around the world, are protected by a series of layers to protect against impact and from movement that could break the glass fibers. Fiber optic cables carry data across continents, through the sea and are the backbone of the internet. Each cable is made of many individual optical fibers, which can transmit data at up to around 1 Gigabit per second or around 100 times faster than copper cables.

Optical **repeaters** are generally placed along fiber cables for amplifying the wavelength signal at some distances, typically **100 km**. Most cables are shielded to specifically **prevent** electrical transmission **outside** the protective layers. Below is shown how a structured cabling system with fiber optic cables (mixed media) can be installed in a building:

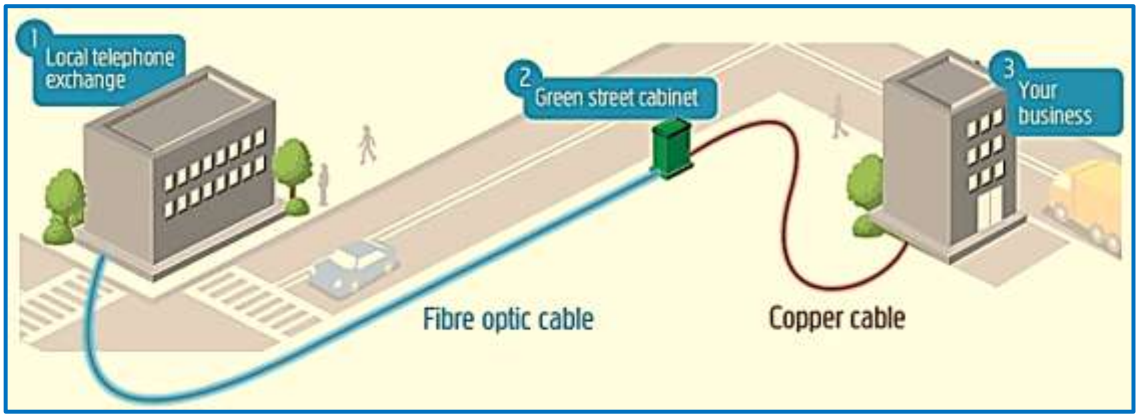


Optical Telephone Cables: In the 1980s, fiber optic cables were developed. The first transatlantic **telephone cable** that used **optical fibers** was TAT-8, which went into operation in **1988**. As described, fiber optic cables comprise **multiple pairs** of fibers. Each pair has one fiber in each direction. The TAT-8 had **two** operational pairs and one **backup** pair. Modern optical fiber repeaters use solid-state optical **amplifiers**, usually Erbium-doped fiber amplifiers. Each repeater contains separate equipment for each fiber.

Optic fibers are used in **undersea** cables, designed for exceptional clarity, permitting runs of more than ***100 kilometers*** using ***repeaters*** to minimize the number of amplifiers and distortions. Originally, submarine cables were simple **point-to-point** connections. With the development of submarine branching **units** (SBUs), more than one destination could be served by a single cable system. In 2012, operators had "*successfully*" demonstrated error-free transmission at **100 Gbps** across the **Atlantic** Ocean routes of up to **6,000 km** (3,700 mi), meaning that a typical cable can move **tens of terabits per second** overseas. Speeds improved rapidly in the last few years, with 40 Gbit/s having been offered on that route only three years earlier, in 2009.

Amplifiers or **repeaters** are used in various fiber cable length applications, commonly more than **100 km**. These repeaters are **powered** by a constant direct current passed down the conductor near the center of the cable. Power feed equipment is installed at the **terminal** stations. A solid-state **laser launches** the signal into the next length of fiber and excites a short length of doped fiber that acts as a **laser amplifier**. As the light passes through the fiber, it is **amplified**. This system also permits wavelength-division multiplexing, which increases the capacity of the fiber.

Typical applications take **signals** from Cell Towers to Central Offices, multiplexing links between PBX's, and adding **Ethernet**, Analog, Data or Telephone service to existing **fiber** optic links. Analog channels can be used for **wireless** applications. Bidirectional fiber optic option, doubles existing fiber optic cable capacity. Service Providers use a cost effective method to provide their customers with Ethernet (100Mbps) for data and voice.



Note: The Round Trip Delay (RTD) or latency standard for transatlantic **connections** is less than **60 ms** (milliseconds), maximum for a sea route. Switching and sea routing commonly **increases** the distance and the round trip **latency** by more than **50%**. The great circle route between **London** and **New York** is only **5,600 km** (3,500 mi). In theory, using this partly land route could result in round trip times below **40 ms**, not counting the switching (speed of minimum light).

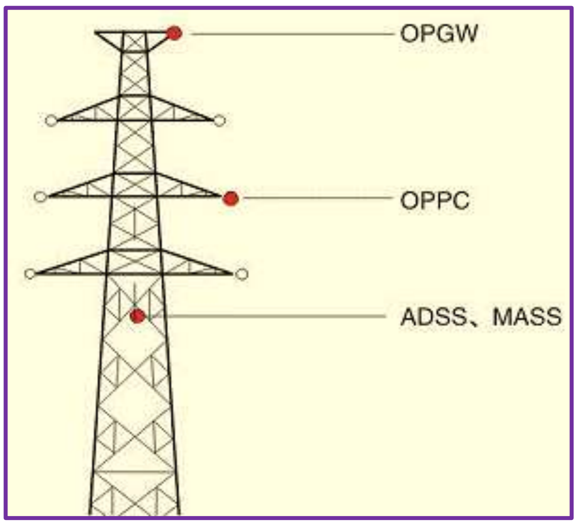
Pre-installation Testing: Typically consists of **using** an ***OTDR*** *(Optical Time Domain Reflectometer)* test commonly performed at **1550 nm**. All optical fiber cables must be **bi-directionally** OTDR-**tested** prior to **shipment**, and the **test** report must be **attached** to the cable **reel**. Bi-directional testing is important to **verify** results and to make certain that no potential problems were missed. The **data** can flow in two directions on the fiber strand.

OPGW (Optical Ground Wire) Cable: Is one of the **special** *optical fiber cables* that are installed at the **towers or poles** of aerial **electrical power transmission** lines, combining the functions of **grounding** and **communications**. The OPGW fiber cables can be used for **high-speed** transmission of data, protection and control of the transmission line, or may be leased to **third parties** to serve as a high-speed fiber interconnection between cities. The OPGW cables typically contain **8** and **48** glass **optical fibers** placed in a plastic tube for **low** transmission loss, allowing long distance transmission at high speeds, similar to ACSR cables. The ACSR (Aluminium Conductor Steel-Reinforced) is a specific type of high-capacity, high-strength stranded **conductor** typically used in **overhead** power lines. The optical fiber is also an insulator to protect against power transmission line and lightning induction, external noise and cross-talk.

OPPC (Optical Phase Conductor Cable): Is used as an **alternative** telecommunications solution when OPGW is not a viable option. The basic construction is **similar** to conventional OPGW; however, OPPC is energized along high voltage power lines. Therefore it requires specially adapted splice boxes and insulators to accommodate the live line conditions.

ADSS (All-Dielectric Self-Supporting) Cable: Is a type of optical fiber cable also used as an **alternative** to OPGW with **lower** installation cost, designed to be light weight and small in diameter to reduce the load on tower structures. It is used by electrical utility companies as a communications medium, installed along existing overhead transmission lines and often sharing the same support structures.

MASS (Metallic Aerial Self-Supporting) Cable): Is another **alternative** solution used for installing optical fiber cables on medium and high voltage power lines, designed to provide a telecommunications path without **interfering** with the existing power lines or infrastructure, typically installed in "*under build*" applications beneath the live phases.



XVI. FIBER OPTICS TESTING STANDARDS:

Standard Test Procedures: Most test **procedures** for fiber optic cable components were defined by national and international **standards**, as **TIA** in the US and **ISO/IEC** internationally. Procedures for **testing** optical power, instrumentation cabling, connector loss and the effects of many environmental factors (such as temperature, pressure, flexing, etc.) are described. In order to perform **basic tests**, are commonly used the power **meter test** source, the OTDR, (Optical Spectrum Analyzer) and an Inspection Microscope, as described below:

Fiber Optic Testing: The most common measurement parameters are listed in the table below. Measuring source power, receiver power and loss or attenuation, are the most important testing required for almost every optical fibers. The backscatter and wavelength measurements are the next most important and bandwidth or dispersion are of lesser importance.

Test Parameters	Applied Instrument
Optical Power (Source Output, Receiver Signal Level)	Fiber Optic Power Meter
Attenuation or Loss of Fibers, Cables & Connectors	Power Meter & Source or OLTS (Optical Loss

(Insertion Loss)	Test Set)
Source Wavelength, Spectral Width	Spectrum Analyzer
Backscatter For Loss, Length and Fault Location)	Optical Time Domain Reflectometer (OTDR)
Fault Location	OTDR, Visual Cable Fault Locator
Bandwidth / Dispersion (MM: Modal & Chromatic, SM: Chromatic and Polarization Mode)	Dedicated Bandwidth Testers
Reflectance	OTDR, OCWR (Optical Continuous Wave Reflectometer)
Fiber Geometry (Core and cladding diameter, concentricity, etc.)	Various mechanical and optical inspection tools

Fiber Optic Power Meters: These devices **test** the average **power** out of an optical fiber cable. Typically consist of a **solid state detector** (silicon for short wavelength systems, germanium or InGaAs for long **wavelength** systems), signal conditioning circuitry and a digital display of power. The power meters are calibrated to **read** in **dB** referenced to **one milliwatt** of optical power. Some meters offer a relative dB scale also, useful for **loss** measurements, since the reference value may be set to "*0 dB*". Occasionally, lab meters may also measure in linear units (milliwatts, microwatts and nanowatts.) Typical **wavelengths** used for **optical fiber cables** are; **850, 1300 and 1550 nm**. Plastic Optical Fibers (POF) are usually calibrated at **650 and 850 nm**, wavelengths.

Adapter Fiber Optic Test Shirt-Pocket Fiber Meter

For instance, the small Shirt-Pocket Fiber Meter is a simple and reliable **power meter** recommended for testing **fiber optic cables** where a **large** area detector is required. Two types of 5 mm detector are offered; **Si and Germanium**. These meters are commonly used for measuring up to **3 mm core** diameter POF / PCS / HCS fiber, MTRJ connectors, and MPO / MP / MTP™ ribbon fiber connectors up to **72 fibers**. Typical application areas include; Audio, Profibus, LAN and Telecom.

Power meters cover a very broad dynamic range, over **1 to 60 dB**. Although most fiber optic power and loss measurements are made in the range of **0 dBm to -50 dBm**, some power meters offer much wider dynamic ranges. For testing analog CATV systems or **fiber amplifiers**, are necessary special meters with extended high power ranges up to **+20 dBm** (100 mW). Although no fiber optic systems operate at very l**ow** power (below about **-50 dBm**), some lab meters offer ranges to **-70 dBm** or more, which can be useful in measuring **optical return loss** or spectral loss characteristics with a monochromator source.

The test source must be chosen for **compatibility** with the type of fiber in use (singlemode or multimode with the proper core diameter) and the **wavelength** desired for performing the test. Most sources are either LED's or lasers of the types commonly used as transmitters in actual fiber optic systems, making them representative of actual applications and enhancing the usefulness of the testing. Some tests, such as measuring **spectral** attenuation of **fiber**, require a variable wavelength source, usually a **tungsten lamp** with a monochromator to vary the output wavelength.

Typical wavelengths of sources are **650 or 665 nm** (plastic fiber), 820, 850 and 870 nm, (for glass fiber short wavelength) and **1300** or **1310 nm** and **1550 nm** (glass fiber long wavelength). LED's are typically used for testing **multimode** fibers and **lasers** are used for **singlemode** fibers, but there is some crossover, especially in **high speed** LANs, which use multimode fiber with **lasers** and testing of short singlemode jumper cables with **LED's**. The source wavelength can be critical in making accurate loss measurements. Thus all test sources should be calibrated for wavelength.

Optical Loss Testers: Are instruments formed by the **combination** of a fiber optic power **meter** and a **source** used to measure the **loss** of fibers, connectors and connectorized cables, also called attenuation meters, customized for a specific application, such as **testing** a LAN or CATV. For most loss measurements, a test source may be used with CW (steady state) or 2 kHz pulsed output. Other **testing instruments** are:

- ✓ **OLTS (Optical Loss Test Set):** May measure inputs as a separate power meter and test source, and have two wavelengths from one source output (MM: 850/1300, SM: 1310/1550.) Some offer bidirectional testing on a single fiber and some have two bidirectional ports. Some manufactures offer modules to convert these testers, allowing fiber and copper testing with one instrument, but may be less convenient than an individual source and power meter, since the ends of the fiber and cable are usually separated by long distances, which would require two OLTSs instead of one source and one meter.

- ✓ **OTDR (Optical Time Domain Reflectometer):** Uses the fiber **backscattering** to characterize fibers and installed cables, find **faults** and optimize splices. Since scattering is one of the primary **loss factors** in fiber (the other being absorption), the OTDR can send out into the fiber a **high** powered **pulse** and measure the light scattered **back**. The **pulse** is attenuated on the outbound leg and the backscattered **light** is attenuated on the return leg, so the returned signal is a function of **twice** the fiber loss and the coefficient of the fiber. OTDRs come in **three** basic versions. Full size OTDRs offer the highest performance and have a full complement of features like data storage, but are very big and high priced. Mini OTDRs provide the same type of **measurements** as a full OTDR, but with fewer features to trim the size and cost. Fault finders use the OTDR technique greatly simplified to provide the distance to a fault, to make the instruments easier to use.

Visual Fault Locators: Are simple instruments that **inject** a visible **light**, but since the light used in systems is invisible, it´s impossible to see the transmitter light. When injecting the light from a **visible** source, such as a LED or incandescent bulb, then is possible to see a visible trace in the fiber from the **transmitter** to **receiver**, and insure correct **orientation** and check **continuity** besides. Then, if a powerful enough visible light, such as a **HeNe** or visible diode laser is injected into the fiber, high **loss points** can be made visible.

Visual **cable tracers** work on buffered fiber and jacketed single fiber cable, if the jacket is not opaque to the visible light. The yellow jacket of the singlemode fiber and orange color of a multimode fiber usually passes the **visible** light. Most other colors, especially black and gray, will not work with this technique, even most multifiber cables. However, many cable breaks, bending losses, bad splices etc., can be **detected** visually. This instrument has a short range, typically 3-5 km.

Optical Time Domain Reflectometer; OLTS (Optical Loss Test Set); Visual Cable Tracers and Fault Locators

O/E and E/O Converters: Optical to electrical (O/E) and electrical to optical (E/O) **converters** have other uses besides testing fiber bandwidth, as described below:

- **O/E Converters:** Can be used with high speed oscilloscopes to analyze pulses in fiber optic links to see if the waveforms are of the proper shape. This means measuring rise and fall times of the pulse and the depth of modulation (difference between the highest power and the lowest power), also used for testing lasers and LEDs in transmitters and link dispersion in long links.
- **E/O Converters:** Are used to test receivers for bandwidth and margin, usually in conjunction with a bit error rate tester and attenuator.

OCWR (Optical Continuous Wave Reflectometer): The OCWR or reflectance **tester** is a special purpose instrument to measure the **reflectance** or optical **return loss** of connectors installed on **patch cords** or **jumpers**. Actual instruments are appropriate for the measurement uncertainty (0.01 dB resolution vs. 1 dB uncertainty), leading to much confusion, as to why measurements are not reproducible. Since OTDR is the **only way** to test installed cable plants for return loss, OCWR has little use in fiber optic testing.

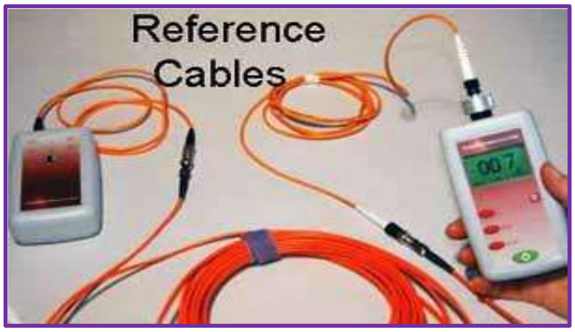
DWDM (Dense Wavelength Division Multiplexing): Is a technology that puts **data** from **different** sources **together** on an optical fiber, with each signal carried at the **same** time on separated light **wavelength**. Long distance fiber links may suffer from **chromatic** dispersion or polarization mode dispersion. Generally is used DWDM for testing **spectral** attenuation.

Fiber Identifiers: Are used to detect a **signal** in the fiber at normal **transmission** wavelengths. All technicians often need to **identify** a fiber in a **splice** closure or at a **patch panel**. If one carefully bends a singlemode fiber enough to **cause loss**, the light can be detected by a large area detector. These instruments usually function as receivers, at a high speed signal and a **2 kHz** tone. The instrument can identify a specific fiber in a **large** multifiber cable, especially useful to **speed up** the splicing or restoration process. Fiber identifiers can be used with **both** buffered fiber and jacketed singlemode fiber cable. With **buffered** fiber, is necessary to be careful to not **damage** the fiber, as any excess **stress** could result in stress cracks, and cause a failure in the fiber conduction.

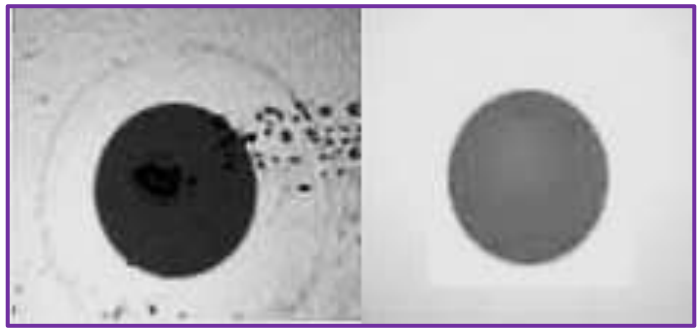
Measuring Fiber Bandwidth: Two **factors** limit multimode fiber bandwidth: **modal dispersion and chromatic dispersion**. Long singlemode links require concern over chromatic dispersion or polarization-mode dispersion. Specialized instruments are available for **testing** each of these bandwidth specifications, but are too expensive and rarely used outside the laboratory.

Optical Fiber Analyzers: The parameters for **testing** optical fibers include attenuation (as a function of wavelength), bandwidth/dispersion, numerical aperture and all the physical **dimensions**, such as **core** and **cladding** diameter, ovality, and concentricity. Cleaved fiber ends prepared for **splicing** and polished connector ferrules require **visual** inspection to find possible defects. This is accomplished using a **microscope**, with a modified stage to **hold** the fiber or connector in the field of view. Fiber optic inspection microscopes vary in **magnification** from 30 to 800 power, but **30-100** power range is the most widely used. Connectors are viewed at a small angle to find polishing **defects**, such as scratches.

Reference Test Jumper Cables and Mating Adapters: In order to **test** cables in an insertion loss, is necessary a **reference** launch jumper cable, to connect the test **source** to the cable under test, and to connect the fiber optic power meter. For accurate measurements, the launch and receive cables must **match**, to be tested and terminated carefully to ensure low loss, and performance. Connector adapters are used to **connect** the cables under test to the launch and receive cables, with bulkhead splices, checked regularly, for obtaining low loss connections.



Reference cables



Visual Inspection with Microscopes

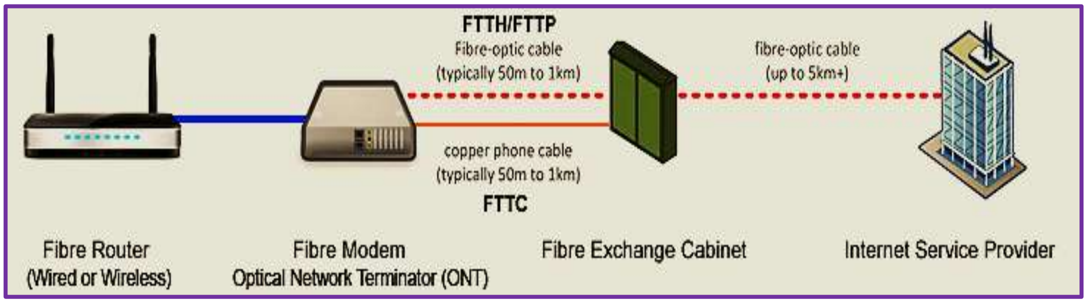
Fiber Optic Talksets: Are useful for **fiber installation and testing**, since **talksets** can **transmit voice** over fiber optic cables already installed, allowing technicians **splicing** or testing the fiber to communicate effectively. Talksets are especially useful, as in remote locations where splicing is being done, or in buildings where radio waves will not penetrate. There are no standards for the way **talksets** communicate, simply use AM transmission, some FM and some proprietary digital schemes. Thus no two manufacturers' talksets can communicate with each other. A technical advisory proposes a FM method at **80** and **120 kHz**, but it will take years before a standard has been set and manufacturers offer compatible instruments.

Optical Power Meter (OPM): Is a device used to measure the **power** in an optical signal. A typical optical power meter consists of a calibrated sensor, measuring amplifier and display. The sensor primarily consists of a **photodiode** selected for the appropriate range of wavelengths and power levels. On the display unit, the measured optical power and set wavelength is displayed. Power meters are calibrated using a **traceable** calibration standard.

Attenuators: Are used to **simulate** the **loss** of long fiber runs for **testing** link margin in network simulation in the laboratory. For loopback testing, an attenuator is used between a single piece of equipment's transmitter and receiver to test for operation under maximum specified fiber loss. Thus, many manufacturers of network equipment specify a loopback test as a **diagnostic** or troubleshooting procedure.

XVII. FTTH SYSTEMS:

FTTH (Fiber to the Home): Is the delivery of communications **signals** over optical fiber cables from an operator's switching equipment to a **home** or **business**, replacing existing copper infrastructure, such as telephone **wires** and coaxial cables. Connecting homes using fiber optic cables enable this technology to provide transmission **speeds of up to 100 Mb/s**. The Fiber to the Home Council was established in July 2001 as the result of efforts lead by Alcatel-Lucent, Corning Incorporated and Optical Solutions. The Council's continued mandate is the education, promotion and acceleration of fiber to the home throughout North America. Original membership included many companies from telecommunications, computing, networking, systems integration, as well as traditional telecommunications service providers, and real estate developers.



Network Architectures: New network architectures have been developed to reduce the cost of installing high bandwidth services to the home always using the acronym FTTx (Fiber to the x). The most used terms are:

- ✓ **FTTH (Fiber-to-the-Home):** Optical fiber connection, reaches the boundary of the living space, such as a panel box on the outside wall of a home. Passive optical networks and point-to-point Ethernet are architectures that deliver triple-play services over FTTH networks directly from an operator's central office.

- ✓ **FTTP (Fiber-to-the-Premises):** This term is used either as a term for both FTTH and FTTB, where optical fiber cables network, includes both homes and small businesses.

- ✓ **FTTN (Fiber-to-the-Node or Neighborhood):** Fiber is terminated in a street cabinet, possibly miles away from the customer premises, with the final connections being copper. FTTN is often an internal step to full FTTH, typically used to deliver an advanced triple-play telecommunications services.

- ✓ **FTTC / FTTK (Fiber-to-the-Curb/Cabinet or Kerb):** Very similar to FTTN. Fiber is terminated in a street cabinet (or curb) closer to the user's premises, typically within **1,000 feet** (300 m), within a range for high-bandwidth copper technology, such as wired Ethernet or IEEE 1901 power line networking and wireless Wi-Fi technology.

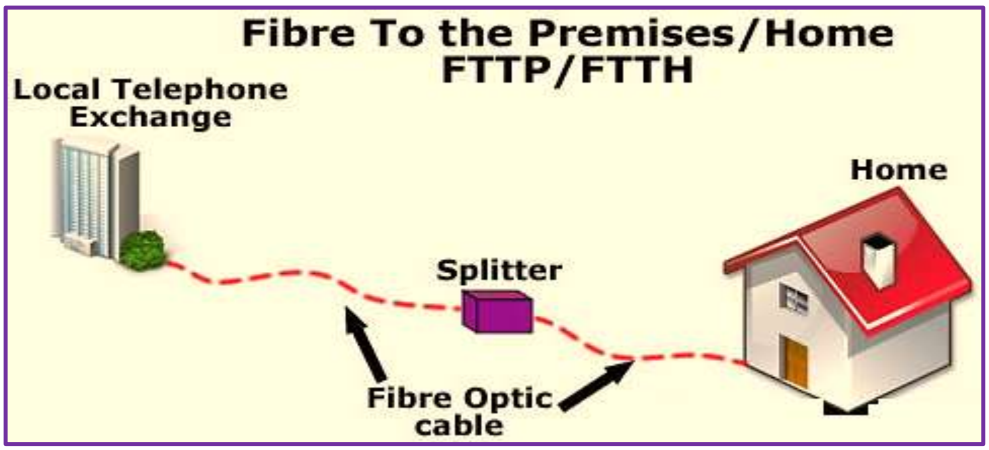
- ✓ **FTTB (Fiber-to-the-Building or Business):** Fiber reaches the boundary of the building, in a multi-dwelling unit, with the final connection to the individual living space being made via alternative means, similar to the curb or cabinet technologies.

- ✓ **FTTD (Fiber-to-the-Desktop):** Fiber connection is installed from the main computer room to a terminal or fiber media converter near the user's desk.

- ✓ **FTTE / FTTZ (Fiber-to-the-Telecom or Fiber-to-the-Zone):** Is a form of structured cabling typically used in enterprise local area networks, where fiber is used to link the main computer equipment room to an enclosure, close to the desk or workstation. FTTE and FTTZ *are not considered part of the FTTX* group of technologies, despite the similarity in name.

- ✓ **FTTW (Fiber to Wireless):** WiFi has become available inside businesses and in areas served by municipal networks, where distances are so large that cabling is unfeasible. Future options include WiMAX and Super WiFi-based wireless with longer ranges and higher bandwidth capability can be placed anywhere and connected with fiber and power.

FTTP (Fiber-to-the-Premises) or FTTH (Fiber-to-the-Home): Provides and end-to-end fiber optic connection to a **home or building** and can deliver faster speeds, since there is no copper leg at all. Fiber to the Home / Premises (FTTH / FTTP) and Fiber to the Cabinet (FTTC) services offer flexibility where is necessary to **share** a high speed fiber broadband with a **mixture** of wired and wireless connectivity or just pure wireless connectivity without the need of the main computer being switched on. A full fiber optic connection is shown below:



Fiber to the Premises (FTTP) is a **form** of fiber-optic communication delivery, where an optical fiber is installed in an optical distribution network, from the central office to the premises occupied by the subscriber. The term "*FTTP*" has become ambiguous and may also **refer** to ***FTTC**,* where the fiber terminates at a utility pole without reaching the premises. *FTTP* can be categorized according to where the optical fiber ends. Differences are as described below:

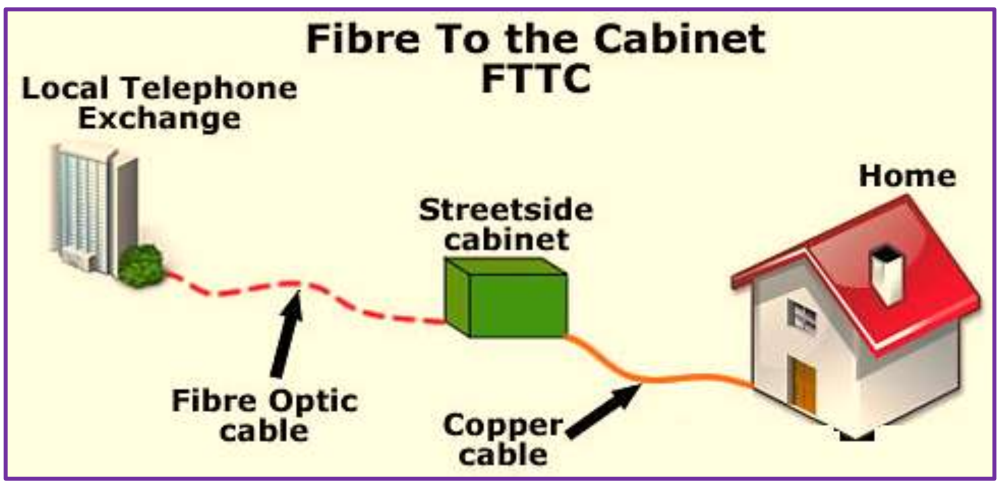
- ✓ **FTTH (Fiber to the Home):** Is a form of fiber-optic communication delivery that reaches one living or working space. The fiber **extends** from the central office to the subscriber's living or working space. The signal may be **conveyed** throughout spaces using any means, including twisted pair, coaxial cable, wireless, power line communication, or optical fiber.

- ✓ **FTTB (Fiber to the Building or Business):** Is a form of fiber-optic communication that applies only to those places that contain multiple living or working spaces. The optical fiber **ends in a box** before reaching the subscribers living or working space itself, but may be extended to other places. The signal is conveyed using **non-optical** means, which can be twisted pair cables, coaxial cables, wireless, or power line communication.

For phone systems, local area networks, and cable TV systems using **FTTH** and for some forms of **FTTB**, it is common to be connected directly to an **optical network terminal**. If any of these three systems cannot directly reach the unit, it is possible to **combine** signals and transport them over a common medium. Closer to the end-user the equipment, such as routers, modems, or network interface controllers, all signals can be converted into the appropriate user protocol.

FTTN Fiber to the Node or Neighborhood is sometimes **distinguished** from *FTTC (Fiber to the Cabinet*, which is a **telecom** architecture based on fiber-optic cables running from a **cabinet** to serve a neighborhood. Customers are typically **connected** to this cabinet using traditional **coaxial cables** or twisted pair wiring, *usually inside* a *radius area of **1 mile** (1.6 Km)*, and can contain several hundred customers. However, when the cabinet **serves** an area approximately of **1,000 ft** (300 m) in radius, this **architecture** is only called typically ***FTTC/FTTK***. The FTTN *often uses existing **coaxial or twisted-pair*** infrastructure, high-speed communication protocols, such as broadband cable access (typically DOCSIS) or some form of digital subscriber line (DSL).

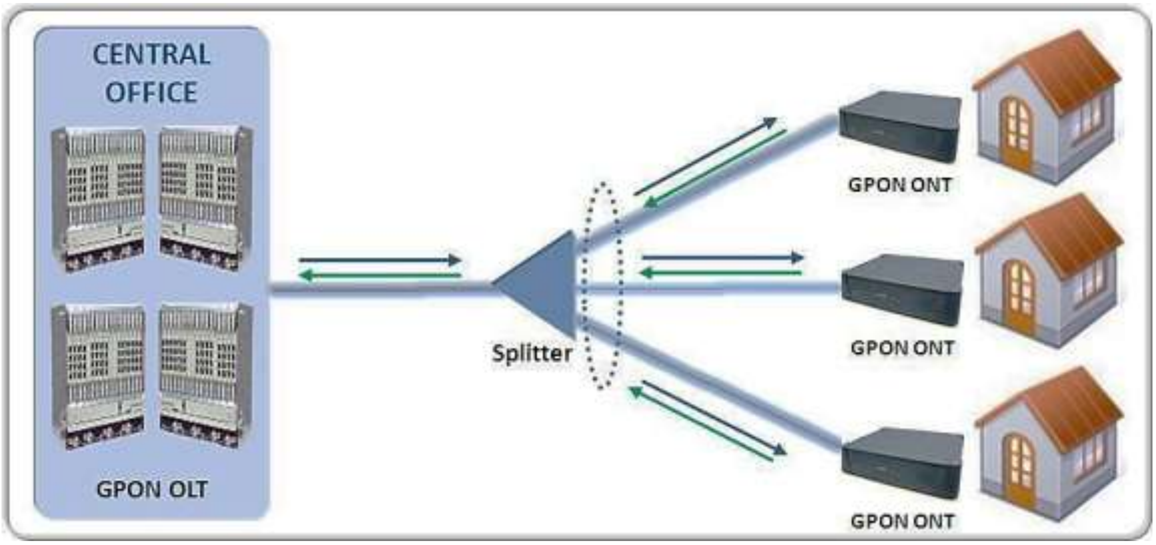
Fiber to the Cabinet (FTTC) or Fiber to the Curb is a telecom system based on **fiber-optic cables** installed on a platform that serves several customers. Each of these customers has a *connection to this platform via **coaxial cables or twisted pair cables***. The FTTC **isn't as fast** as a full FTTH connection. Where FTTC is available, a new **green** cabinet is commonly installed near or next an existing street side. The FTTC connection has fiber optic cable from the **telephone** exchange to this **green** street side cabinet. From there, copper network is used to deliver the broadband from the **cabinet to the premises**. An ADSL router with a built-in modem doesn't work with FTTC.



Copper ADSL Network: This type of network uses **copper cables** from the **telephone** exchange to the street **cabinet**, and then, from the street cabinet to the **premises**. The original telephone copper cables are the same, to deliver the line from the telephone exchange, to the green street cabinet, and then, more copper cable from there to the premises.

FTTH-PON (Passive Optical Network): The **PON system** allows sharing expensive and efficient components for FTTH, using **splitters**. PON splitters are bi-directional where **signals** can be sent from the **central office**. After signals are broadcasted to **all users**, these signals can be combined by ***only one fiber*** to communicate with the central office. A passive splitter (PON) that takes only one input, and **splits** it to many users. Some systems are designed for AM video and CATV systems, the non-reflective connectors (as SC-APC angle-polished connector) are generally used.

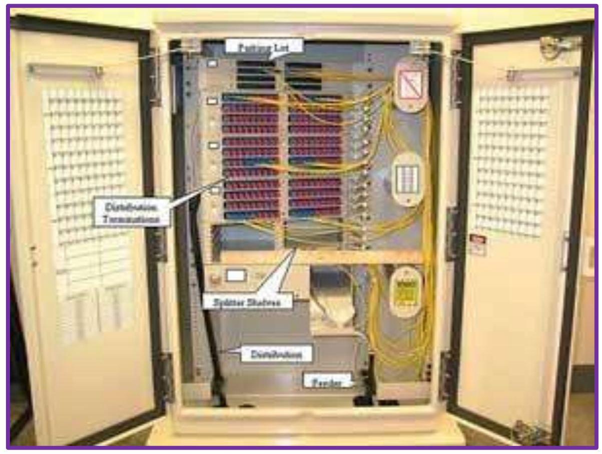
Below is shown the installation of a typical PON network with the equipment required at the CO (central office), fiber distribution hub, and shows the location of the hardware used in creating a complete PON network. A "*feeder*" cable extends from the **OLT** (optical line terminal) in the CO (central office) to a FDH (fiber distribution hub) where the PON (passive optical network) splitter is housed. It then connects to "*distribution*" cables that go out toward the subscriber location where "*drop*" cables will be used to connect the final link to the ONT (optical network terminal).



Cascaded **splitters** can be used to **reduce** the **amount** of fiber needed in a network by placing splitters nearer the user. So a 4-way splitter followed by a 8-way splitter would be a 32-way split. Most **PON splitters** are 1 X 32 or 2 X 32 or some smaller number of splits in a binary sequence (2, 4, 8, 16, 32, etc.). Couplers are basically symmetrical, such as, 32 X 32, but PON architecture needs only **one fiber** connection on the central office, or **maybe 2** for monitoring, testing and as a spare. Splitters add considerable loss to a FTTH link, limiting the distance of a FTTH link compared to typical point-to-point telecom link. The guidelines for loss in PON couplers are:

Splitter Ratio	**1: 2**	**1: 4**	**1: 8**	**1: 16**	**1: 32**
Ideal Loss / Port (dB)	3.0	6.0	9.0	12.0	15.0
Excess Loss (dB, max)	1.0	1.0	2.0	3.0	4.0
Typical Loss (dB)	4.0	7.0	11.0	15.0	19.0

Each home needs to be **connected** to the local **central office** with a **singlemode** fiber cable through an **optical splitter**. If the cable is underground, it will be pulled through a conduit to the distribution cable or the splitter to the home. The splitter can be **housed** in a central office or a pedestal in the neighborhood near the homes served. The advantage of PONs is that this pedestal is passive, that is, it does not require any power as would a **switch** or node for FTTC (Fiber to the Curb). Below is shown a **typical panel** that has connections from the CO (central office) to splitters and fibers out to each home, in a sealed enclosure. The incoming cable needs to be terminated at the house, tested, connected to the interface and the service tested.

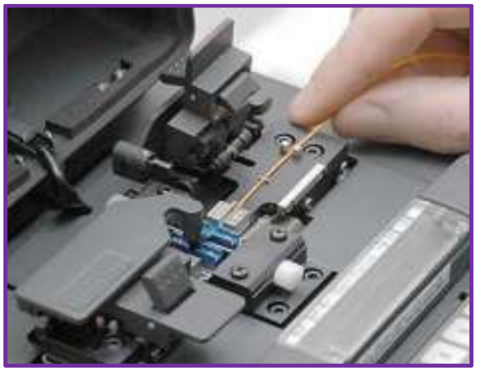


However, for FTTH/FTTC networks to take off, the **design** community first must **resolve** a key technical debate. Right now, both ATM-based PON (APON) and Ethernet-based PON (EPON) technologies are being pushed as the answer for delivering FTTH functionality. While EPON is in the early phases of development, EPON, faces challenges, the most noticeable is to handle the upstream traffic, moving away from the traditional, collision-based CSMA/CD Ethernet protocol.

	APON	EPON	Comments
Underlying technologies	ITU-T.983.x, ATM cells are of fixed-size packets (48 octets +5 header octets)	IEEE 802.3ah Ethernet standard expected Oct. 2003, Ethernet frames are of variable size (64 - 1,518 octets)	Fixed-size packets simplify PON upstream traffic protocol
PON data security	Yes. This is part of APON protocol, protection. Each ONT sets its own churning key and updates it regularly.	To be determined; whether and how to support data security for EPON is under discussion.	Applications may provide data security or data encryption at upper layers.

Fusion Splicing: Is the act of **joining two optical fibers** end-to-end using heat. The goal is to **fuse** the two fibers together, in such a way that **light** passing through the fibers is **not scattered** or reflected back by the splice, so that the **fusion** and the region surrounding it, become almost as **strong** as the original fiber itself. The **source** of fusion heat is usually an ***electric arc***, but can also be *a* ***laser***, or a ***gas flame***, or a *tungsten filament* through which current is passed.

Stripping the Fiber: Stripping is the act of **removing** the protective polymer **coating** around an optical fiber cable and prepares it for **fusion splicing**. Fiber stripping is usually carried out by a special preparation unit that uses **hot sulphuric acid** or a **controlled flow of hot air** to remove the coating. There are also **mechanical tools** used for stripping fibers, similar to copper wire strippers. Current **fusion splicers** are either core or cladding alignment, where both cleaved fibers are automatically **aligned** in the **fusion splicer**, and then fused together. Prior to removing the spliced fiber, a **proof-test** is performed to ensure that the splice is **strong** enough to survive handling, packaging and extended use. The bare fiber area is **protected** either by recoating or with a splice protector. A splice protector is a **heat** shrinkable **tube** with a strength membrane.




Point-to-Point Protocol over Ethernet (PPPoE): Is a common way of delivering triple and quad-play (voice, video, data, and mobile) services over both fiber and hybrid fiber-coaxial (HFC) networks. Active PPPoE uses dedicated fibers from an operator's central office to the subscribers' homes, while hybrid networks (often FTTNs) transport data via fiber to an intermediate point, to ensure sufficiently high throughput speeds over the last mile copper connections.

The migration of network technologies for higher speed protocols (Gigabit and 10 Gigabit Ethernet), popularizes the use of optical fibers for LAN applications. The common form of Gigabit Ethernet (1 Gbit/s) runs over an economical category, such as 5e, category 6, or augmented category unshielded twisted-pair copper cabling, but only inside a distance of 300 ft (~100 m). However, 1 Gbit/s Ethernet over fiber can easily reach *tens of miles*, thus, fiber is much better than copper.

XVIII. LINKS & REFERENCES:

https://www.isa.org/
http://www.nema.org/products/Pages/Power-and-Control-Cable.aspx
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IEEE Institute of Electrical and Electronics Engineers-Optical Fiber Technology
ANSI/TIA/EIA Building Telecommunications Wiring Standards
ANSI/TIA/EIA-568-A Commercial Building Standards for Telecommunications Cabling
TIA/EIA TSB-72 Centralized Optical Fiber Cabling Guidelines-Draft (September 1995).
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MURATA, Hiroshi; Handbook of Optical Fibers and Cables.