Chapter 2
Cabling Engineering

Generic cabling is a highly flexible modular information transmission pipeline within or between buildings, which can not only connect voice, data, image equipment or switching equipment with other information management systems, but also connect these equipment with the outside. It also covers all cables and associated connection components between connection points of network or telecommunication lines outside the buildings and application system equipment. Generic cabling systems can accommodate components of different series and specifications, including transmission mediums, connection hardware (such as distribution frames, connectors, sockets, plugs, adapters, etc.) and electrical protection equipment, etc. Although they work together to build various subsystems, they undertake different specific tasks. Therefore, the generic cabling system is not only easy to implement, but also can be upgraded smoothly as the demand changes.

Generic cabling schemes were first introduced in China in the 1990s. With China's continued efforts in infrastructure construction, the market demand continues to expand, which has contributed to the rapid development of the generic cabling industry. In particular, the GB 50311 - 2016 "Code for Engineering Design of Generic Cabling System" and GB/T 50312 - 2016 "Code for Engineering Acceptance of Generic Cabling System", which were implemented on April 1, 2017, have greatly driven the application and development of generic cabling system in China, which, as two national standards, put forward specific requirements and provisions for the design, construction, acceptance and management of the genetic cabling systems.

In order to endow readers with intuitive and quick understanding of genetic cabling, this chapter will follow the working process of cabling projects, first of all, taking the reader to know network cabinets from scratch, then looking into all kinds of communication cables and common connecting devices, cabling tools and instruments, and mastering their methods of use, and finally exploring the engineering technical standards of equipment room subsystems and acceptance of works.

Huawei Technologies Co., Ltd., *Construction, Operation and Maintenance of Network System(Junior Level)*, https://doi.org/10.1007/978-981-19-3069-0_2

By the end of this chapter, you will

(1) Get familiar with various network cabinets (2) Master the characteristics and identification methods of communication cables (3) Get familiar with common connecting devices of communication systems	(4) Understand tools and instruments commonly used in cabling engineering (5) Understand the engineering standards, technical requirements for installation and acceptance content of equipment room subsystems

2.1 Network Cabinet

Network cabinet is used to assemble panels, plug-ins, subracks, electronic components and mechanical parts and components into an integrated cabinet.

1. Classification by installation location: indoor cabinet and outdoor cabinet.
2. Classification by purpose: network cabinet, server cabinet, power cabinet, and passive cabinet (used to carry optical fiber distribution frame, main distribution frame, etc.).
3. Classification by installation method: ground mounting, wall mounting, pole installation.

We know network cabinets different styles are operating in various sites. With the continuous development of the ICT industry, network cabinets are taking in more and more powerful functions. These network cabinets are generally installed in cable distribution rooms, central equipment rooms, monitoring centers, shelters, outdoor stations and other places, as shown in Fig. 2.1.

Network cabinets are usually available in white, black and gray, They are classified by material as aluminum profile cabinet, cold-rolled steel cabinet or hot-rolled steel cabinet or other types; and by processing technology as ninefold profile cabinet or 16-fold profile cabinet or other types.

The basic structure of the network cabinet includes the top cover, fan, mounting beam, removable side door, aluminum alloy frame, etc., as shown in Fig. 2.2.

2.1.1 Network Cabinet with "U" as Unit

1. What does the unit "U" mean
   Before introducing various network cabinets, we need to understand the commonly used unit "U" that describes the size of a cabinet.
   "U" is an abbreviation for "Unit" that represents the external dimension (to measure the height or thickness of the cabinet) of the server. The specific dimension representation rules are determined by the Electronic Industries Association (EIA). In terms of thickness, 1 U is equal to the thickness of 4.445 cm, and

Fig. 2.1 Network cabinet

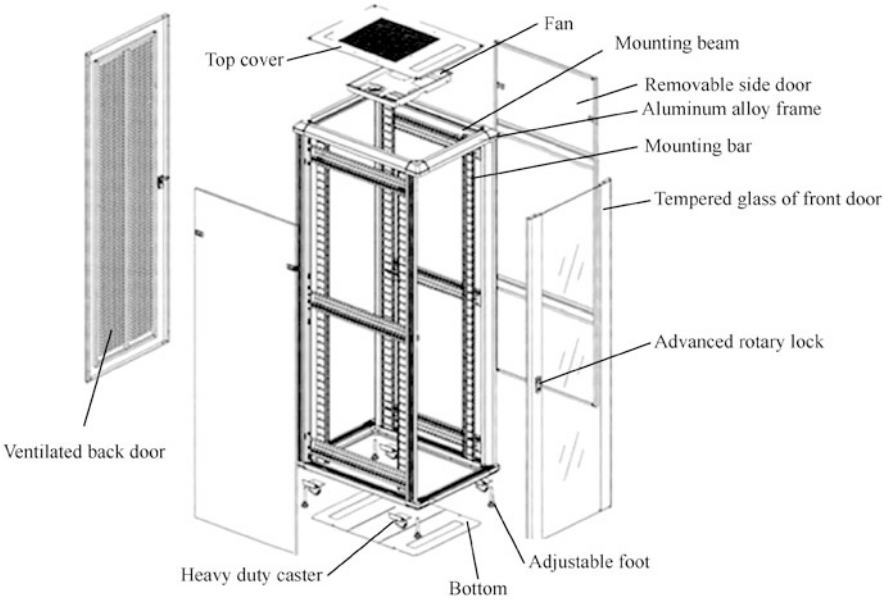


Fig. 2.2 Basic structure of network cabinet

Fig. 2.3 A 1 U server

2 U is 8.89 cm. The so-called "1 U server" refers to the server with the shape conforming to EIA standard and the thickness of 4.445 cm, as shown in Fig. 2.3.

2. Standard U-sized cabinet

Standard U-sized cabinet is widely used in computer network facilities, wired communications equipment, wireless communications equipment, electronic equipment, passive material stack, which features strengthened electromagnetic shielding, ability to block the working noise of the equipment to a certain extent, and reduced floor area occupied by equipment. Some high-end cabinets are equipped with air filtration function to improve the working environment for precision equipment.

Engineering equipment mostly employs panels that are 19 inches (about 48 cm), 21 inches (about 53 cm), 23 inches (about 58 cm), etc. in width, so there are 19-inch (about 48 cm), 21-inches (about 53 cm) and 23-inches (about 58 cm) standard cabinets and things like that. Among them, 19-inch standard cabinet ("19-inch cabinet" for short) is more common. For some equipment in non-standard dimensions, most can be installed and fixed in the standard shelf through the additional adaptive baffle.

The dimension of the cabinet is indicated by three general indicators, namely width, height and depth.

(a) Width: The standard width of a network cabinet is 600 mm or 800 mm. The server cabinet is mostly 600 mm wide; while the network cabinet is mainly 800 mm wide, because it carries more cables inside that the method of cabling on both sides should be facilitated. The 19-inch cabinet allows to install equipment with a width of 482.6 mm.

(b) Height: The cabinet height is generally in shown as "*n*U" ("*n*" for quantity) between 2 U and 42 U. In order to ensure heat dissipation, servers need to keep a certain distance between each other, so a cabinet cannot be fully loaded. For example, a 42 U cabinet typically hold 10 to 20 standard 1 U servers. The standard cabinet is 0.7–2.4 m in height, depending on the quantity and unified style of the equipment in the cabinet. Cabinets in special height are usually be customized by manufacturers. 19-inch cabinets are usually 1.6 m or 2 m high.

The mounting dimensions of the rack should meet the standard mounting requirements. The 1 U rack should has three holes, with the middle hole as the center and the distance between the two distal holes being 31.75 mm. The

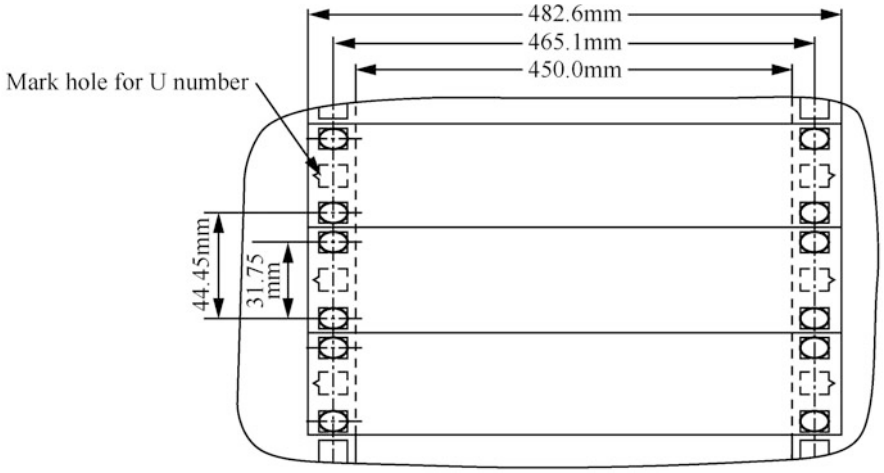


Fig. 2.4 The mounting dimensions of the 19-inch rack

mounting columns on both sides should be 465.1 mm apart, as shown in Fig. 2.4.

(c) The standard U-sized cabinet is 400–800 mm in depth, depending on the dimensions of the equipment in the cabinet. Cabinets in special depth are usually be customized by manufacturers. 19-inch cabinets are usually 500 mm, 600 mm or 800 mm high.

The standard U-sized cabinet is 600 mm in width, providing a width of 19 inches (about 48 cm) for internal mounting. In general, the depth of the server cabinet is no less than 800 mm, while that of the network cabinet is no more than 800 mm. The dimensions of 19-inch cabinet are shown in Table 2.1.

3. Server cabinet

Server cabinets are typically manufactured according to the rack-mounted server and following specific industrial standards and specifications. The following will introduce the server cabinet by comparing it with the network cabinet.

(a) Functions and internal composition

(i) Equipment installation in the network cabinet is generally carried out by the user, that is, the installation of panels, subracks, plug-ins, devices, electronic components, mechanical parts, etc., so that they constitute an entire shelf. At present, the capacity of network cabinet is generally 2–42 U.

(ii) The cabinets in the IDC machine room are collectively referred to as server cabinets, generally referring to the special cabinet used for carrying 19-inch (about 48 cm) standard equipment such as server, UPS and

Table 2.1 Dimensions of 19-inch cabinet

Type	Model	Height × Width × Depth (mm)
Standard Cabinet	18 U	1000 × 600 × 600
	24 U	1200 × 600 × 600
	27 U	1400 × 600 × 600
	32 U	1600 × 600 × 600
Standard Cabinet	37 U	1800 × 600 × 600
	42 U	2000 × 600 × 600
Server Cabinet	42 U	2000 × 800 × 800
	37 U	1800 × 800 × 800
	24 U	1200 × 600 × 800
	27 U	1400 × 600 × 800
	32 U	1600 × 600 × 800
	37 U	1800 × 600 × 800
	42 U	2000 × 600 × 800
Wall-mounted Cabinet	6 U	350 × 600 × 450
	9 U	500 × 600 × 450
	12 U	650 × 600 × 450
	15 U	800 × 600 × 450
	18 U	1000 × 600 × 450

display. It carries plug-ins, panels, electronic components and so on in the form of combination, so that they constitute an entire cabinet. The server cabinet provides the environment and safety protection necessary for the normal operation of electronic equipment.

(b) Conventional dimensions of the cabinet

(i) The network cabinet is generally 800 mm wide. In order to facilitate in-cabinet cabling, cabling devices are required on the mounting columns on both sides, such as vertical and horizontal cable troughs, cable panel, etc.

(ii) The width of the server cabinet is generally 600 mm or 800 mm, the height is 18 U, 22 U, 27 U, 32 U, 37 U, 42 U, or 47 U, and the depth is 800 mm, 900 mm, 960 mm, 1000 mm, 1100 mm or 1200 mm, as shown in Fig. 2.5.

(c) Requirements for load-bearing and heat dissipation

(i) The equipment in the network cabinet dissipates less heat and weighs less, so the requirements for heat dissipation and load-bearing are not high. For example, a load-bearing capacity of 850 kg and a through-hole rate of 60% are sufficient.

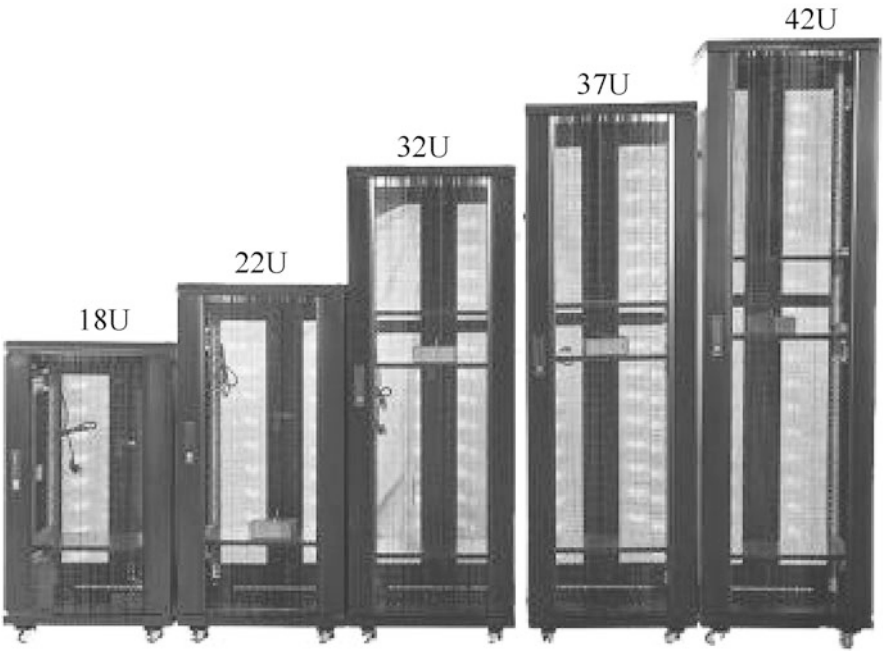


Fig. 2.5 Server cabinet

(ii) The server required enhanced heat dissipation capacity from the server cabinet as it dissipates more heat. For example, the front and back doors require 65–75% through-hole rate, and additional heat dissipation units were appreciated. The server cabinet is required to meet higher load-bearing requirement, such as the load-bearing capacity of 1300 kg.

The server cabinet can be installed along with the special fixing pallet, special sliding pallet, power socket, caster, base anchor, cabling unit, cable manager, L-style bracket, horizontal beam, vertical beam and fan unit. The frame, upper ledge, lower ledge, front door, back door and left and right side doors of the cabinet can be quickly disassembled and installed. The common internal layout of the server cabinet is shown in Fig. 2.6.

4. Fitted Screws

When installing network equipment in the cabinet, it is often necessary to use M6 × 16 screws specially designed for cabinet, including cross recessed pan head machine screws, buckle nuts and gaskets, as shown in Fig. 2.7.

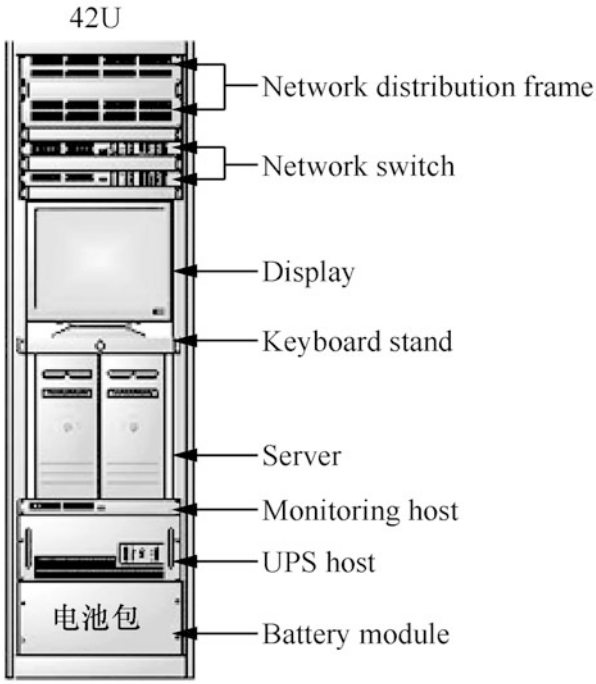


Fig. 2.6 Common internal layout of the server cabinet

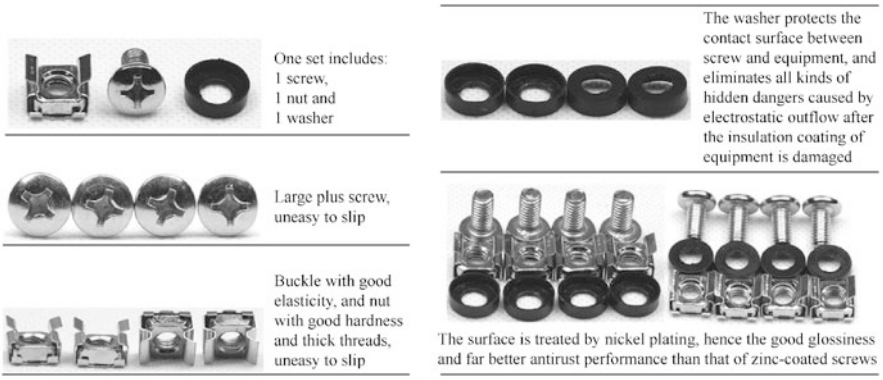


Fig. 2.7 M6 × 16 screws for cabinet

2.1.2 Cable Distribution Cabinet

The cable distribution cabinet is customized for the generic cabling system, which is special in that it adds some accessories peculiarly needed by the cabling system. The common cable distribution cabinet is shown in Fig. 2.8.

Fig. 2.8 Cable distribution cabinet in common use

Digital cable distribution unit, optical fiber cable distribution unit, power distribution unit, generic cabling unit and other active/passive equipment and accessories can be flexibly installed inside an generic cabling cabinet as needed. The common internal layout is shown in Fig. 2.9.

The cable distribution unit is the most important component in the management subsystem, which serves as the hub for cross-connecting the vertical subsystem and the horizontal subsystem, and also bridges the gap between the cables and the equipment. It features the advantages of convenience for cable management, less occurrence of fault, and neat and aesthetic cabling environment.

The following are some common distribution frames.

1. Twisted-Pair Distribution Frame

   Twisted-pair distribution frame, namely standard RJ-45 distribution frame, is the most commonly used distribution frame in network generic cabling engineering. The distribution frame is primarily used in modular devices that manage front-end information points from the local side. The cable for the front-end information point (Cat 5e or Cat 6 cable) enters the equipment room by first approaching the Copper Wire Distribution Frame B, after which it binds the wire to the Copper Wire Distribution Frame B, and then the Copper Wire Distribution Frame A is connected with the switch with a patch cord (with RJ-45 splice), as shown in Fig. 2.10.

   At present, the common twisted-pair distribution frame is compatible with Cat 5e or Cat 6 cable, or even the next-generation Cat 7. The physical appearance of the twisted-pair distribution frame is shown in Fig. 2.11.
2. Optical fiber distribution frame

   Optical fiber distribution frames are classified into unit type, drawer type and module type. An optical fiber distribution frame generally is used for proper and convenient patch cord connection, fixing and protection of optical fibers, which is composed of the identifiers, optical fiber coupler, optical fiber fixing device,

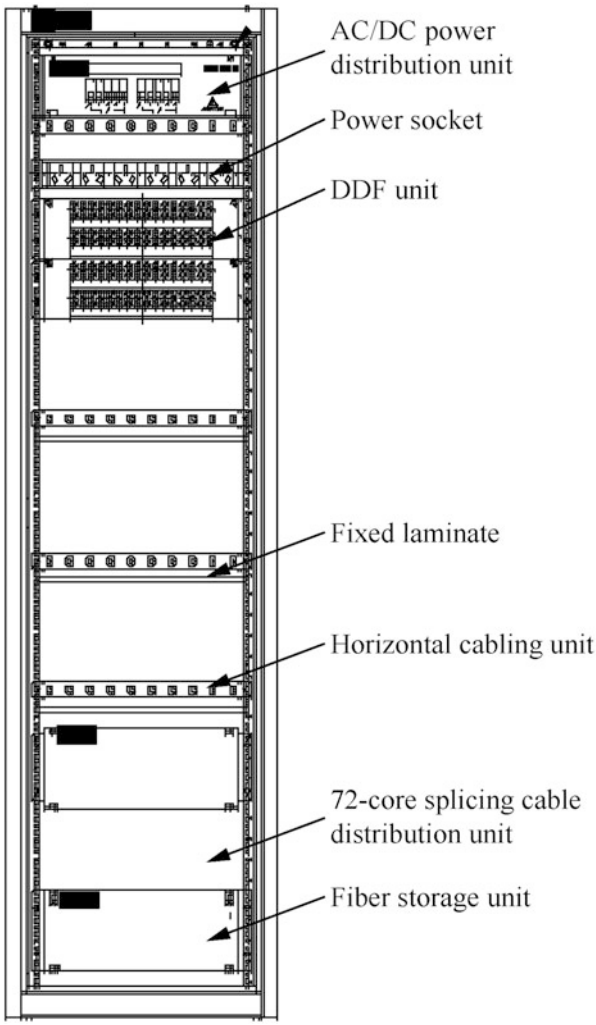


Fig. 2.9 Common internal layout of an integrated cable distribution cabinet

welding unit, etc. The physical appearance of the optical fiber distribution frame is shown in Fig. 2.12.

3. Digital distribution frame

The digital distribution frame (DDF), also known as high-frequency distribution frame, is available with 8-system, 10-system, 16-system, 20-system frames, etc. A DDF is used to connect the digital code stream of the digital communication equipment as a whole, presenting increasing importance and superiority in digital communication. The signal input and output with transmission rate of 2 to 155 Mbit/s can be connected to the DDF, which brings great flexibility and convenience for cabling, patching, reconnection and capacity expansion. The physical appearance of the DDF is shown in Fig. 2.13.

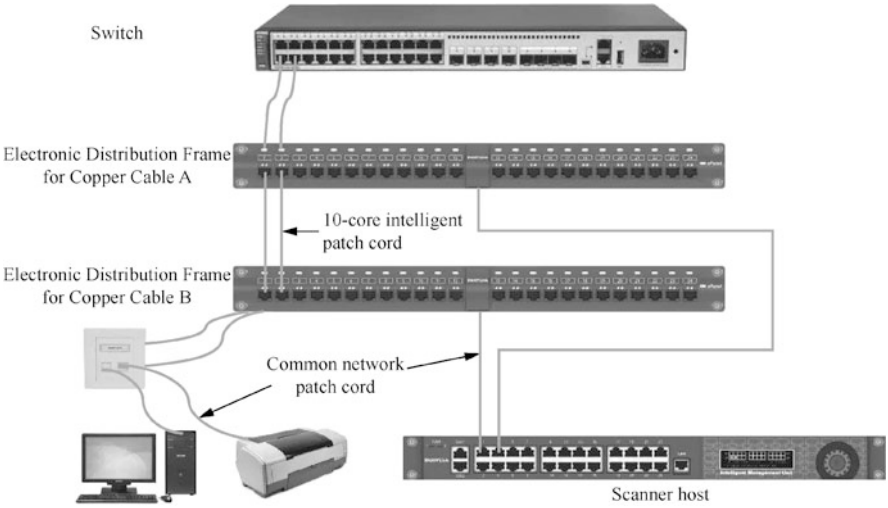


Fig. 2.10 Systematic connection of the twisted-pair distribution frame

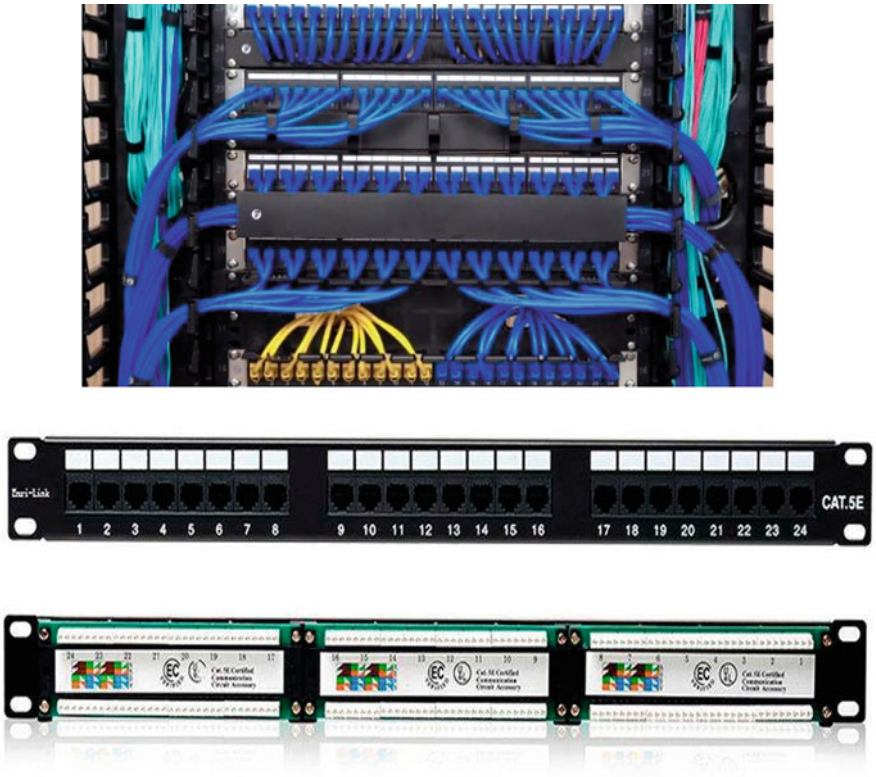


Fig. 2.11 Physical appearance of the twisted-pair distribution frame

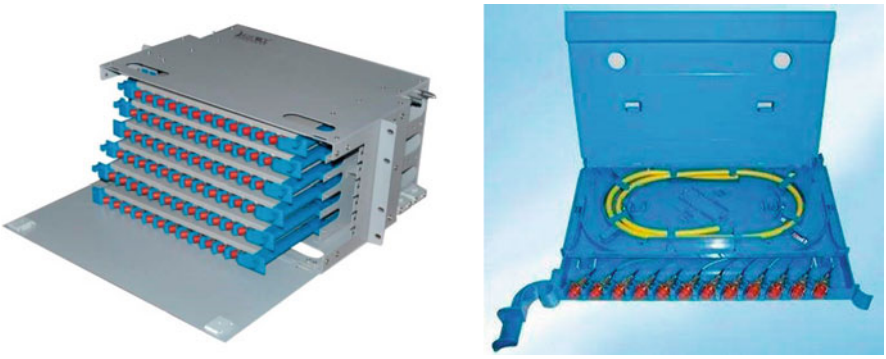


Fig. 2.12 Physical appearance of the optical fiber distribution frame

Fig. 2.13 Physical appearance of the DDF

4. Main distribution frame

   The main distribution frame (MDF) is an internal cable distribution frame that connects the cable from the outside of the switch on one side and the internal cables at the entrance and exit of the switch on the other side. The physical appearance of the MDF is shown in Fig. 2.14. The main distribution frame is designed to connect ordinary cables and transmit and test low-frequency audio signals or XDSL signals, while protecting the switch from over voltage and over current, and notifying the watchman through acoustics and optical alarm.
5. Intermediate distribution frame

   Intermediate distribution frame (IDF) is a secondary communication room in a building that uses a star network topology. The IDF relies on the MDF, where the latter stands for the main equipment room, and the IDF stands for the remote auxiliary equipment rooms serving as cable distribution rooms. IDF and MDF are both distribution frames, the only difference between whom is the position.

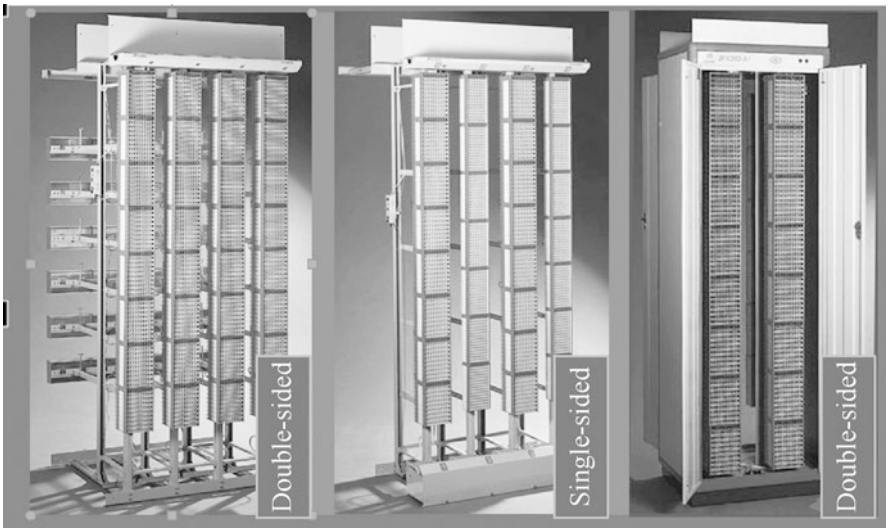


Fig. 2.14 Physical appearance of the MDF

Fig. 2.15 Wall-mounted cabinet

2.1.3 Wall-Mounted Cabinet

The wall-mounted cabinet can be fixed on the wall through different installation methods, and is widely used in cable distribution rooms and corridors with small space, thanks to their small profile, convenient installation and disassembly, easy management and anti-theft characteristics. When installing a wall-mounted cabinet, the installer will generally open 2 to 4 holes for wall mounting at the back of the cabinet, and then fix it on the wall or directly embed them into the wall with expansion screws, as shown in Fig. 2.15.

The wall-mounted cabinet is divided into standard model, non-standard model, and embedded model, with the common specifications including 6 U, 9 U, 12 U, and 15 U in height, 530 mm and 600 mm in width, and 450 mm and 600 mm in depth.

2.2 Communication Cables

The most important links in the communication network is the communication line and transmission. Communication is divided into wired communication and wireless communication. The signal sent and received in wired communication is mainly electrical signal and optical signal, the cables responsible for which are collectively referred to as communication cables. At present, the commonly used transmission media in communication lines are twisted pair (TP) and optical fiber.

2.2.1 TP

TP is the most commonly used transmission medium in network generic cabling, which is composed of several pairs of copper conductors with insulating protective layer. Compared with other transmission medium, TP has more restrictions in transmission distance, channel width and data transmission rate, etc., but is relatively low in price, as shown in Fig. 2.16.

1. Classification of TP
   (a) By availability of shielding
      (i) Shielded twisted pair (STP): A metal shielding layer is provided between the TP and the outer insulation sleeve, with the structure shown in Fig. 2.17. The shielding layer reduces radiation, prevents information from being eavesdropped, and also prevents the intrusion of external electromagnetic interference, so the STP, though at a higher cost, has higher transmission rates than comparable unshielded twisted-pair.
      (ii) Unshielded twisted pair (UTP): Unlike the STP, the UTP is not provided with a metal shielding layer, with the structure shown in Fig. 2.18. UTP is widely used because it is low in cost, light weight, easy to bend and easy to install.

Fig. 2.16 TP

Fig. 2.17 STP Structure

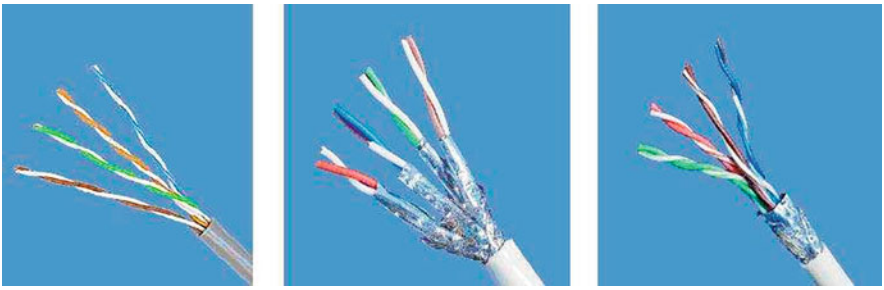


Fig. 2.18 UTP Structure

(b) By performance of transmission

(i) Cat 5: The cable provides a bandwidth up to 100 MHz and a maximum transmission rate of 100 Mbit/s, suitable for use in voice transmission and data transmission where the maximum transmission rate needs to reach 100 Mbit/s. Cat 5 is mainly used in 100Base-T and 1000Base-T Ethernet, with the maximum network segment length of 100 m, and adopts the RJ connector. Cat 5 is the most commonly used Ethernet cable.

(ii) Cat 5e: Cat 5e presents low attenuation and less crosstalk. Compared with Cat 5, Cat 5e has higher signal noise ratio (SNR) and smaller delay error, hence the greatly improved performance. The Cat 5e is primarily used in Gigabit Ethernet (GbE) applications. Its structure is shown in Fig. 2.19.

(iii) Cat 6: Cat 6 is far superior to Cat 5e in transmission performance and is most suitable for applications with transmission rates higher than 1 Gbit/s. Cat 6 differs from the Cat 5e mainly in its improved performance in terms of crosstalk and return loss, because Cat 6 has a cross skeleton structure, Its structure is shown in Fig. 2.20.

The larger the number indicating the category of cable, the later the version of the cable, the more advanced the technology adopted, and correspondingly the wider the bandwidth and the more expensive the

Fig. 2.19 Cat 5e Structure

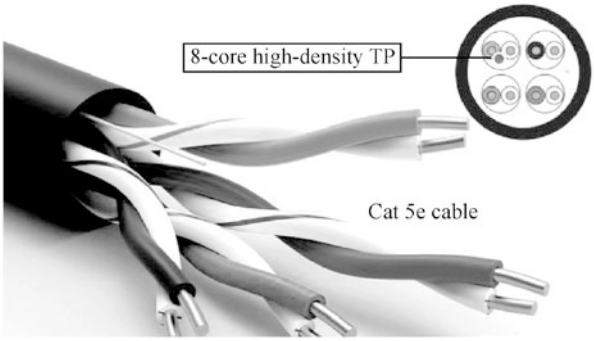
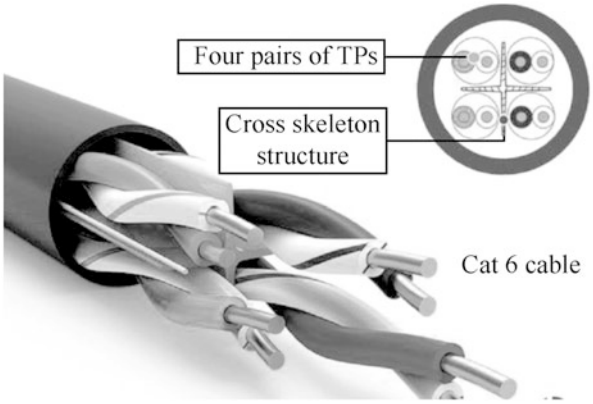


Fig. 2.20 Cat 6 Structure



cable. The following is a description of the marking methods for different categories of TPs. For the standard TPs, the format "Cat x" is adopted, for example, the word "Cat 5" or "Cat 6" on the sheath of the cable; the cables of advanced version is marked with "Cat xe", such as "Cat 5e", as shown in Fig. 2.21.

Cat 5 and Cat 5e cables were mainly used by 2005. Since 2006, Cat 5e and Cat 6 took over the dominant position, while Cat 6e and 7 began to serve in some critical projects.

2. Wire sequence standards

The three most influential generic cabling standard organizations in the world are the American National Standards Institute (ANSI), the Telecommunication Industry Association (TIA), and the Electronic Industries Alliance (EIA). The most widely used TP standards are ANSI/EIA/TIA-568A (T568A) and ANSI/EIA/TIA-568B (T568B), with the biggest difference in wire sequence.

The wire sequence of T568A is defined as the order of white green, green, white orange, blue, white blue, orange, white brown, brown; while that of T568b

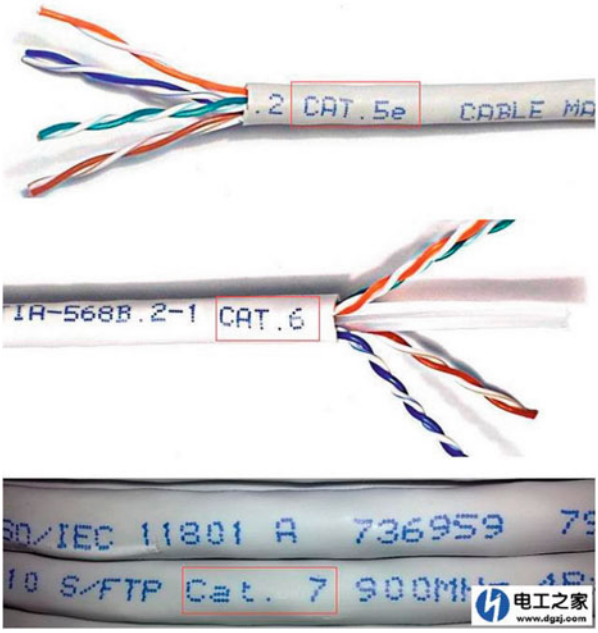


Fig. 2.21 Marking examples of different cable categories

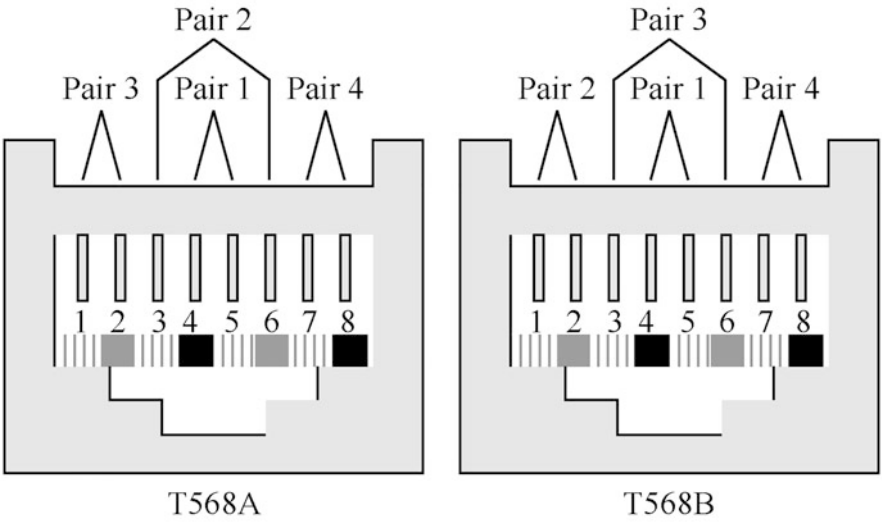


Fig. 2.22 Color labels and wire sequence of the TP

is in the order of white orange, orange, white green, blue, white blue, green, white brown and brown, as shown in Fig. 2.22.

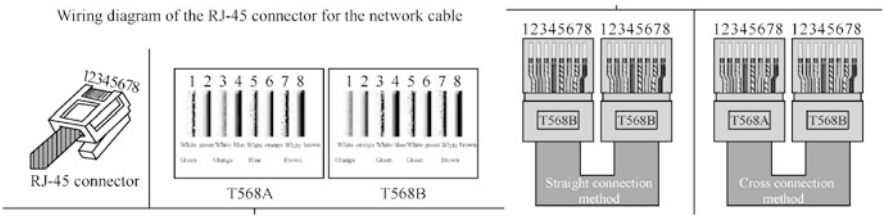


Fig. 2.23 Wiring diagram of the RJ-45 connector for the network cable

3. Connection methods of TPs

TPs can be connected by straight connection method or cross connection method, so when used as a network cable, a TP is usually called a straight-through cable or a crossover cable according to the connection method. The wiring of the RJ-45 connector for the network cable is shown in Fig. 2.23.

(a) Straight-through cable

(i) The registered jacks (RJs) at both ends of the cable are made in accordance with the T568B.

(ii) It is used for the connection between equipment at different levels, for example, the connection between the switch and the router, and between the switch and the computer.

(b) Crossover cable

(i) The RJs of the cable adopt the T568B standard at one end and T568A at the other end.

(ii) It is used for the connection between equipment at the same level, for example, the connection between computers, and between switches.

Nowadays, the RJ-45 connectors for communication equipment are mostly self-adaptive. When the cable does not match, the receiving port and transmitting ports can be automatically reversed to solve the problem. So now in the general application scenario, the straight-through cable is sufficient to meet the demand.

2.2.2 Cable

1. Structure and guiding principle of optical fiber

Optical fiber is short for optical waveguide fiber, a kind of fiber made of glass or plastic that can be used for optical conduction. The optical fiber used for communication is a kind of glass fiber slightly thicker than a human hair, with an outer diameter of 125 to 140 μm, as shown in Fig. 2.24.

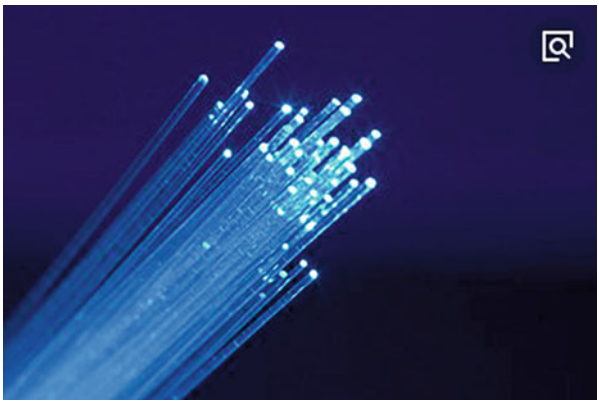


Fig. 2.24 Physical appearance of the optical fiber

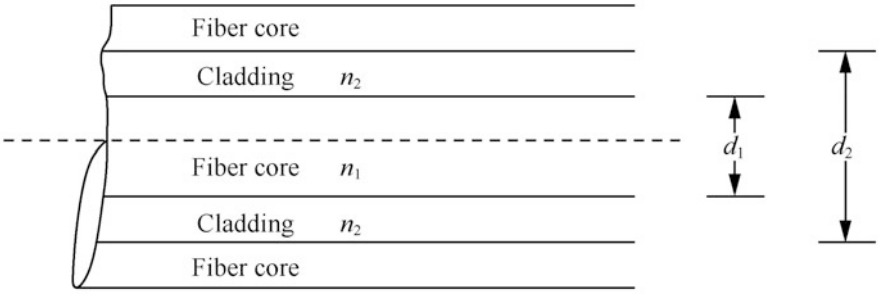


Fig. 2.25 Basic structure of the optical fiber

The basic structure model of optical fiber refers to the layered structure of optical fiber, consisting of fiber core, cladding and coating layer, which appears as a concentric cylinder, as shown in Fig. 2.25.

(a) Fiber core: located in the center of the optical fiber, mainly composed of high purity silicon dioxide (SiO_2), mixed with a small amount of dopant. The optical signal can be transmitted by increasing the optical refractive index n_1 of the fiber core. The diameter d_1 of the fiber core is generally 2 to 50 μm.
(b) Cladding layer: located in the middle layer, also composed of high purity silicon dioxide (SiO2), and mixed with some dopant. By reducing the optical refractive index n_2 of the cladding to less than n_1 to satisfy the total reflection condition, it achieves the purpose of confining the optical signal in the fiber core for transmission. The outer diameter d_2 of the cladding is generally 125 μm.
(c) Coating layer: located in the outermost layer, composed of acrylate, silicone rubber and nylon to protect the optical fiber from water vapor erosion and mechanical abrasion. It also enhances the mechanical strength and bendability of the fiber, playing the role of prolonging the service life of the fiber. The outer diameter of the coated fiber is generally 1.5 mm.

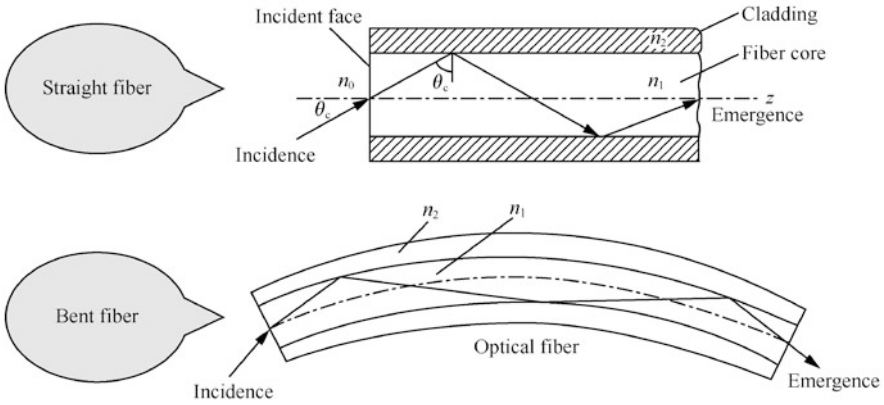


Fig. 2.26 Principle of optical fiber transmission

Optical fiber transmission is based on the principle of "total reflection of light", as shown in Fig. 2.26. According to the principle of geometric optical total reflection, when the angle of incidence is larger than the critical angle of total reflection, the total reflection will be generated at the interface between the fiber core and the cladding. So, in view of the premise of $n_1 > n_2$, as light travels from the fiber core to the cladding, the light is confined inside the fiber and propagates forward. This ensures that the light travels all the way through the fiber, even through a slightly curved route.

2. Classification of optical fibers

(a) By transmission mode

(i) Single-mode fiber: supports transmission in a single mode. The core diameter is 8 to 10 μm, the cladding diameter is 125 μm, and the commonly used diameter combination is 9/125 μm. This type of optical fiber achieves a transmission distance of more than 5 km, and the light is sourced from laser, which is suitable for long-distance transmission. It adopts a yellow outer sheath.

(ii) Multi-mode fiber: supports transmission in multiple modes. The core diameter is 50 μm or 62.5 μm, and the cladding diameter is 125 μm. The light is sourced from LED, which is suitable for short distance transmission, such as the optical fiber patch cord in the equipment room. It adopts an orange or aqua green outer sheath.

Comparison between single-mode fiber and multi-mode fiber is shown in Fig. 2.27.

(b) By definition of ITU-T

(i) G.651 fiber (graded index multi-mode fiber): mainly applied to the wavelength of 8500 nm and 1310 nm.

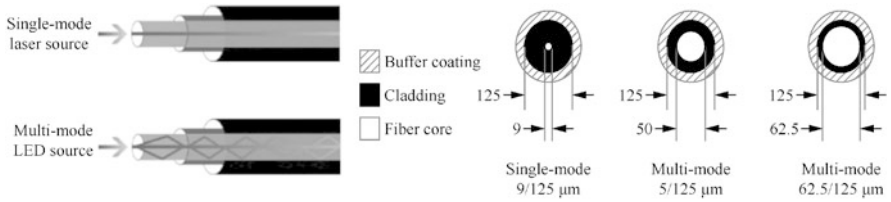


Fig. 2.27 Comparison of single-mode fiber and multi-mode fiber

(ii) G.652 fiber (conventional single-mode fiber): zero dispersion at the wavelength of 1310 nm, and lowest transmission loss at the wavelength of 1550 nm.
(iii) G.653 fiber (dispersion-shifted fiber): zero dispersion and lowest transmission loss at the wavelength of 1550 nm.
(iv) G.654 fiber (least attenuation fiber): minimum attenuation at the wavelength of 1550 nm, suitable for long distance submarine transmission.
(v) G.655 fiber (non-zero dispersion-shift fiber): suitable for long distance transmission.

3. Structure of optical fiber cable

Designed to meet specifications for optical, mechanical, or environmental performance, the optical fiber cable is a type of communication cable that can be used individually or in groups. It use one or more optical fibers enclosed in a sheath as the transmission medium. The appearance is shown in Fig. 2.28.

(a) Classification of optical fiber cables

(i) By transmission performance, transmission distance and use: long-distance cable, urban cable, submarine cable and household cable.
(ii) By type of optical fiber: multi-mode optical fiber cable and single-mode optical fiber cable.
(iii) By optical fiber overlaying method: tight-buffer optical cable, loose-buffer optical cable, beam-tube optical cable and ribbon multi-fiber cable.
(iv) By optical fiber number: single-fiber cable, dual-fiber cable, 4-fiber cable, 6-fiber cable, 8-fiber cable, 12-fiber cable, 24-fiber cable, etc.
(v) By laying method: duct optical cable, direct buried optical cable, aerial optical cable and optical cable for lake and river crossing.

(b) Indoor optical cable

The indoor optical cable is laid in the building. Due to the advantages of the indoor environment over the outdoor environment, which is not affected by mechanical stress and weather factors from nature, so the dry-type tight-

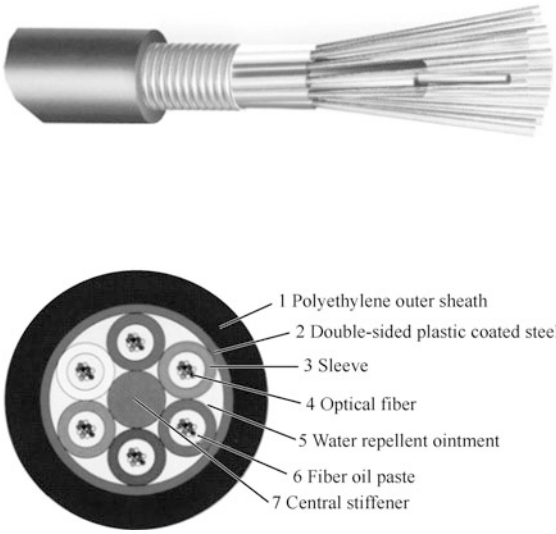


Fig. 2.28 Appearance of optical fiber cables

Fig. 2.29 Appearance of indoor optical cables

buffer optical cable that is flame retardant and flexible is adopted indoor. Its appearance is shown in Fig. 2.29.

Indoor optical cables are divided into single-fiber, dual-fiber and multi-fiber cables by fiber number.

They can also be divided into indoor main cable, indoor distribution cable and indoor trunk cable by service environment and location. The former is mainly used to provide a passageway between the inside and outside of the building; the latter two are used to deliver information to a specific location.

The indoor optical cable usually consists of the optical fiber, stiffener and sheath, with the structure shown in Fig. 2.30.

(c) Outdoor optical cable

The outdoor optical cable needs to expose to the weather, so thicker outer sheath, pressure resistance, corrosion resistance, tensile strength and other characteristics are essential. Armored cables (that is, wrapped with a metal skin) are commonly used for outdoor applications.

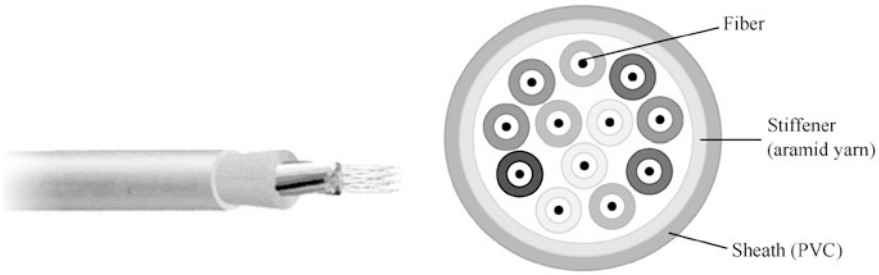


Fig. 2.30 Structure of indoor optical cables

Fig. 2.31 Structure of an outdoor optical cable

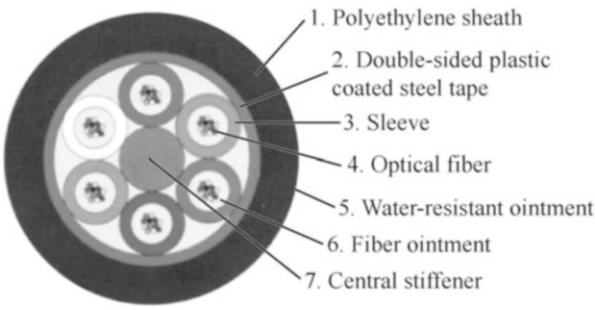


Fig. 2.32 Color spectrum and identification of optical fiber

The cable consists of cable core, reinforcing steel wire, filling material and sheath. The core is composed of a certain number of optical fibers in a certain way. In addition, the outdoor optical cable is also provided with waterproof layer, buffer layer, insulating metal wire or other components according to the need. Figure 2.31 shows the structure of an outdoor optical cable.

The color of the loose tube and the fiber in it are blue, orange, green, brown, gray, white, red, black, yellow, violet, pink, and dark green in turn. The color spectrum and identification of optical fiber are shown in Fig. 2.32.

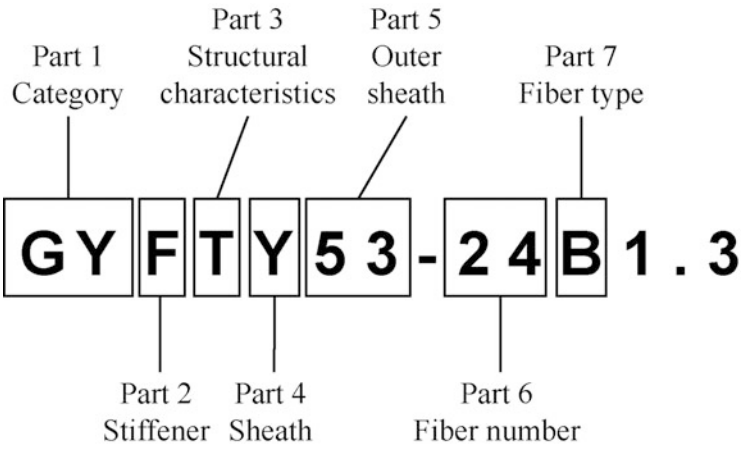


Fig. 2.33 Model of optical fiber cables

4. Identification of optical cable model

The optical cable is varied with the material, structure and use. In order to facilitate the distinction and use of optical cables, the models of optical cables are coded uniformly. The cable model is generally composed of seven parts, that is, category + stiffener + structural characteristics + sheath + outer sheath + fiber number + fiber type, as shown in Fig. 2.33.

(a) The first part represents the code for the category of the optical cable, as shown in Table 2.2.
(b) The second part represents the code for stiffener (reinforced core), as shown in Table 2.3.
(c) The third part refers to the code of structural characteristics of the optical cable. The code should reflect the main type of cable core and the derivative structure of the cable. When there are multiple structural characteristics that need to be reflected, combined codes can be used, as shown in Table 2.4.
(d) The fourth part represents the code for the sheath of the optical cable, as shown in Table 2.5.
(e) The fifth part represents the code for the armor layer of the optical cable, which includes one or more digits, as shown in Table 2.6.
(f) The sixth part represents optical fiber number, such as 2, 4, 6, 8, 12, 24, 36, 48, 72, 96, 144, etc.
(g) The seventh part represents the code for the fiber type, as shown in Table 2.7.

Table 2.2 Code for the category of the optical cable

Code	Optical cable category	Explanation
GY	Outdoor (field) optical cable for communication	The outer sheath is thick, with strong pressure resistance, corrosion resistance and tensile strength. It is suitable for the interconnection between outdoor buildings and between remote networks, and supports long-distance transmission
GJ	Indoor (local) optical cable for communication	Bending resistance, fire retardant, strong flexibility; applicable to communication equipment in buildings; suitable for short-distance transmission
GH	Submarine optical cable for communication	No need for tunnel or support, less investment, fast construction, less interference from the natural environment and human activities, good confidentiality, safety and stability; mostly used for long-distance international transmission
GT	Special optical cable for communication	The types of fiber used are dispersion-shifted fiber, non-zero dispersion-shift fiber, dispersion flattened fiber, etc.; also includes, among other things, all optical cables used for special purposes
GS	Optical cable inside equipment for communication	Adopting metal heavy stiffener and enveloping structure of loose tube; suitable for cabling in equipment
MG	Optical cable for coal mine	Flame retarding and rat proof; suitable for coal, gold, iron and other mining occasions
GW	Metal-free cable for communication	Using non-metallic materials; mainly used in areas with strong electromagnetic influence and lightning prone areas
GR	Soft optical cable for communication	Shorter outer diameter, good flexibility, easy to bend; suitable for indoor or small space; used in optical connectors, FTTH, sensors and other fields

Table 2.3 Code for stiffener (reinforced core)

Code	Stiffener	Explanation
None	Metal stiffener	Metal, non-metallic and metal heavy components are respectively used to strengthen the optical cable, in order to enhance the tensile strength and improve the mechanical properties of optical cables
F	Non-metallic stiffener	
G	Metal heavy stiffener	

2.3 Connection Devices Commonly Used in Communication Systems

In the last section we learned about communication cables. So how to connect the communication equipment with the cable? What we need is the connecting device. Communication connector is the interconnecting device for network transmission medium, whose performance may affect the whole communication system. There

Table 2.4 Code of structural characteristics of the optical cable

Code	Cable structure	Explanation
D	Fiber ribbon structure	Optical fiber units are accommodated into a large tube, offering small volume and high space utilization. The tube can accommodate a large number of optical fibers, and can complete the connection of all units at a time
None	Stranding structure	The bidirectional stranding technology realizes the water resistance for the whole section, and makes the additional attenuation of the fiber close to zero, thus obtaining excellent environmental performance. The structure is suitable for long-distance communication, inter-station communication and the occasions with higher requirements of moisture-proof and rodent-proof
S	Loose tube structure	The structure consists of multiple optical fibers, fiber ointment and PBT loose tube, which is mainly used for outdoor laying. The tube is filled with multiple optical fibers in a free state
J	Tight buffer structure	The structure is composed of the optical fiber and the PVC tight-buffer layer on the fiber surface, forming a soft, easy-to-peel tight-buffer fiber, generally used in indoor optical cable or special optical cable
X	Central tube structure	The structure takes loose tube as the cable core, and the stiffeners are arranged around the loose tube. It has the characteristics of shorter diameter, light weight and easy laying
G	Skeleton structure	The structure can be used for taking out the required optical fiber and butting it with the access cable. With good side compression resistance, it can protect the optical fiber well
B	Flat structure	The flat cable has a soft structure on the core to ensure the softness of the cable. Due to its relative thin depth, small size, and easy connection and disassembly, it is suitable for data transmission or power transmission in electrical equipment
T	Fill-in structure	The structure keeps the round and normal shape of the cable by filling the inside of the optical fiber, playing a role in fire, water, pressure resistance and so on
Z	Flame retardant structure	The structure is low in cost, and can delay the spread of the flame along the cable, And improve the fire protection level of the cable line to avoid the expansion of the fire and the major disaster caused by the cable fire
C	Self-supporting structure	The structure is characterized by low transmission loss, low dispersion, light weight due to non-metallic structure, convenient laying, strong anti-electromagnetic interference, and excellent mechanical and environmental properties, and is suitable for high voltage transmission lines

are various types and standards of communication connectors, mainly including those for power cables and those for optical cables.

Table 2.5 Code for the sheath of the optical cable

Code	Sheath	Explanation
L	Aluminum	The sheath is made of varied materials to protect the cable core from external mechanical action and environmental conditions
G	Steel	
Q	Lead	
Y	Polyethylene sheath	
W	Steel wires reinforced polyethylene sheath	
A	Aluminum-polyethylene sheath	
S	Steel-polyethylene sheath	
V	PVC sheath	
F	Fluoroplastic	
U	PU	
E	Polyester elastomer	

Table 2.6 Code for the armor layer of the optical cable

Code	Armor layer	Explanation
0	Non-armored	A layer of metal protection is added to the outside of the cable to protect the internal utility layer from damage during transportation and installation
2	Double steel strip	
3	Small-gauge round steel wire	
4	Large-gauge round steel wire	
5	Corrugated steel strip	
6	Double-layer round steel wire	
23	Armored polyethylene sheath wrapped with steel strip	
33	Armored polyethylene sheath wrapped with small-gauge steel wire	
53	Armored polyethylene sheath longitudinal-wrapped with corrugated steel strip	
333	Armored polyethylene sheath wrapped with double-layer small-gauge steel wire	
44	Double-layer large-gauge round steel wire	

Table 2.7 Optical fiber type

Code	Fiber type	Explanation
A	Multi-mode fiber	Supporting multi-mode transmission, with high dispersion and loss, suitable for short- and medium-distance transmission and low-capacity optical fiber communication system
B	Single-mode fiber	Only supporting single-mode transmission, with low dispersion, suitable for long-distance transmission

2.3.1 Cable Connection Devices

1. Network jumper
   Jumper is also called patch cord. Jumpers are usually used for patch cord connection between distribution frames, cabling units and switches. The paths are mostly curved and the cables knot easily, so in order to facilitate the cabling of patch cords in the complex path, without damaging the structure, the patch cord itself must be made soft. One of the advantages of a patch cord made from multiple strands of fine copper wire is that it is much softer than a hard patch cord made from a single strand of hard wire. The appearance of a network patch cord is shown in Fig. 2.34.

   The patch cord is mainly composed of cable conductor, RJ and protective sleeve.
2. Network registered jack

   Registered jack (RJ) is a standardized telecommunications network interface that is crystal clear in appearance, for the transmission of voice and data.

   It is suitable for field termination of equipment room subsystem or horizontal cabling subsystem. Its housing is made of high density polyethylene. Each TP is connected to a network card and hub (or switch) via a port made with a RJ.

   In the RJ model number, the letter "RJ"represents the registered jack, and the following number represents the serial number of the interface standard; *x*P*y*C means that the RJ has *x* slot positions and *y* metal contacts.

   There are two kinds of common network RJs: RJ-45 and RJ-11. They are all composed of PVC shell, shrapnel, chip and other parts, as shown in Fig. 2.35.

   The corresponding interfaces of these two RJ types are RJ-45 interface and RJ-11 interface, as shown in Fig. 2.36.

   (a) RJ-45

      (i) RJ-45 is a type of modular jack or plug following the IEC (60) 603-7 connection standard, with 8 plots defined in accordance with the international standard for connectors. The RJ-45 includes two types: 8P8C and 8P4C, whose structure is shown in Fig. 2.37.

Fig. 2.34 Appearance of a network patch cord

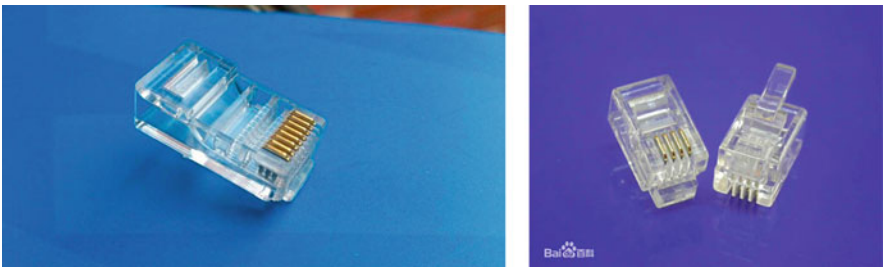


Fig. 2.35 Appearance of the two types of RJs

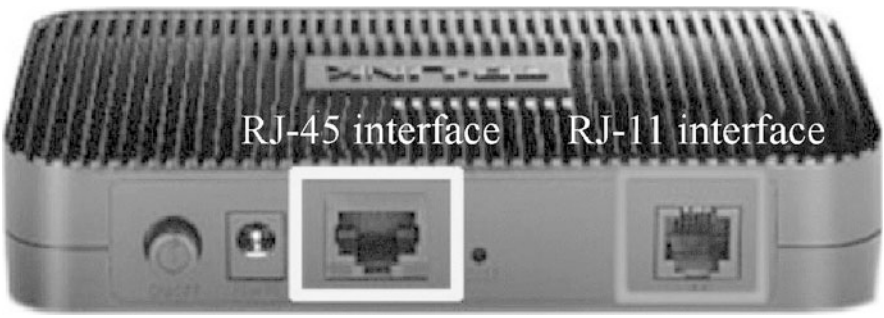


Fig. 2.36 Appearance of the two types of interfaces

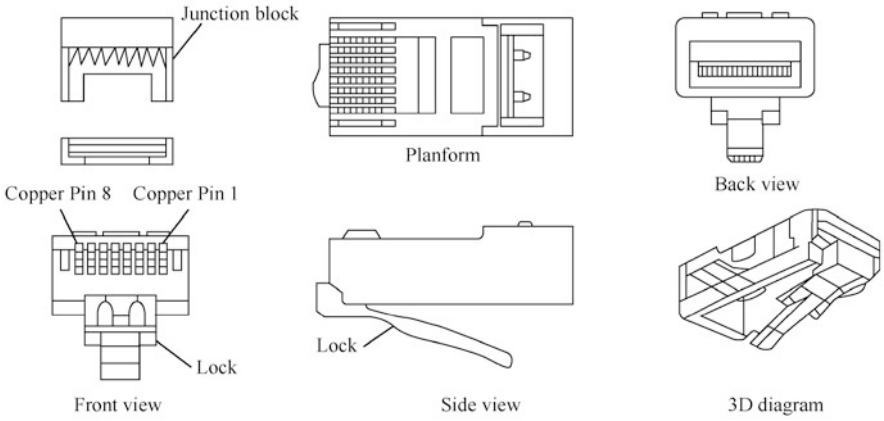


Fig. 2.37 Structure of the RJ-45

(ii) The RJ-45 is often used for data transmission in monitoring projects, generic cabling in equipment rooms and other scenarios. It is an indispensable link in the Ethernet. It is usually installed on both ends of the network cable, used to connect computers, routers, switches and other network equipment.

(iii) The wiring of the RJ-45 is allowed to follow T568A and T568B wire sequence standards. According to the standard adopted, the finished cables can be divided into straight-through cables and crossover cables. However, due to the new generation of switches, network adapters and other devices with automatic reversal function, most network cables are now made in accordance with the T568B standard.

(b) RJ-11

(i) The RJ-11 does not follow the international standard, which is a type of connector usually with only 6 plots and 4 or 2 pins, that is, 6P4C and 6P2C.
(ii) The RJ-11 is often used to connect the telephone with the modem. For example, a telephone cable use the four-core (4C) RJs.
(iii) The RJ-11 is smaller in volume than the RJ-45. These two types of RJs differ in size, wiring standards and application scenarios and are not compatible with each other.

(c) Other types of RJs

The RJ-12 is also commonly used for voice communications. It has 6 pins (6P6C), and is also derived in the types with 6 slots and 4 pins (6P4C) and with 6 slots and 2 pins (6P2C).

(d) Types, appearance and features of commonly used RJs.

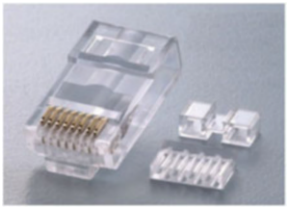
The types, appearance and features of the commonly used RJ at present are shown in Table 2.8.

3. Information outlet

Chapter 7 of the GB 50311 - 2016 “Code for Engineering Design of Generic Cabling System” puts forward specific requirements on the installation process of the information outlets in work areas. The information outlet box hidden on the ground should meet the requirements of waterproof and compression. It is advisable for the bottom surface of the information outlet bottom box mounted on the wall or column to be 300 mm away from the ground, as shown in Fig. 2.38. The bottom surface of the information outlet box mounted on the side plate of the workbench and on the adjacent wall is recommended to be 1.0 m away from the ground.

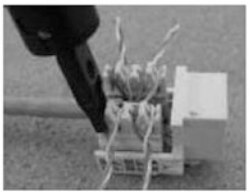
The number of information outlet modules (for power cable or optical cable) in each work area should not be less than two, and should meet the needs of various businesses. Therefore, under normal circumstances, it is appropriate to use the bottom box with 2-port panel, and the number of ports should match the number of ports set on the outlet box panel. The number of information points supported by each bottom box should not be more than twp. The information outlet module in the work area should support the access of different terminal devices. Each 8-position modular outlet should be connected to a cable containing 4 TPs.

Table 2.8 Types, appearance and features of commonly used RJs

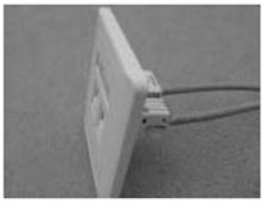
Type	Appearance	Feature
Unshielded RJ		Common RJ, without a metal shield
Shielded RJ		With a metal shield and immunity to interference superior to the unshielded RJ
Cat 5e RJ		Widely used, suitable for the Cat 5 TP, but also compatible with the Cat 5e TP
Cat 6 RJ		Suitable for the Cat 6 TP (also compatible with the Cat 5 TP and Cat 5e TP), with the eight wires being arranged into two rows, four in the upper row and the other four in the lower row

The information outlet is usually composed of the bottom box, panel and module, and is generally mounted on the wall, or on the desktop or ground, mainly for the convenience to move the computer or other equipment, and maintain neat cabling.

(a) Bottom box: Classified into metal bottom box and plastic bottom box by material; or classified into open-mounted bottom box and conceal-mounted bottom box by installation method, as shown in Fig. 2.39.
(b) Panel: It must be waterproof, compression resistant and dustproof, in line with the GB 50311 - 2016 "Code for Engineering Design of Generic Cabling System". For the information module, the standard 86 panel should be adopted, as shown in Fig. 2.40.
(c) Module: Information module, also known as information outlet, is an extremely important component in generic cabling. It realizes the physical connection between equipment area and work area through terminal



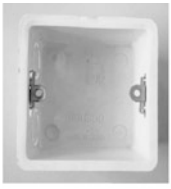
Seat the wire according to T568B



Install on the panel

Fig. 2.38 Information outlet mounted on the wall

(1) Open-mounted bottom box



(2) Conceal-mounted plastic bottom box

(3) Conceal-mounted metal bottom box

Fig. 2.39 Bottom box

(1) 2-port panel

(2) Ground-mounted metal panel

(3) Multi-functional desktop panel

Fig. 2.40 Panel

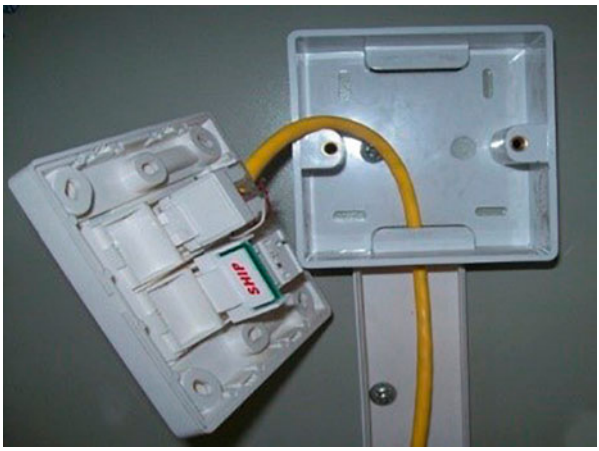


Fig. 2.41 Information module fixed on the back of the panel

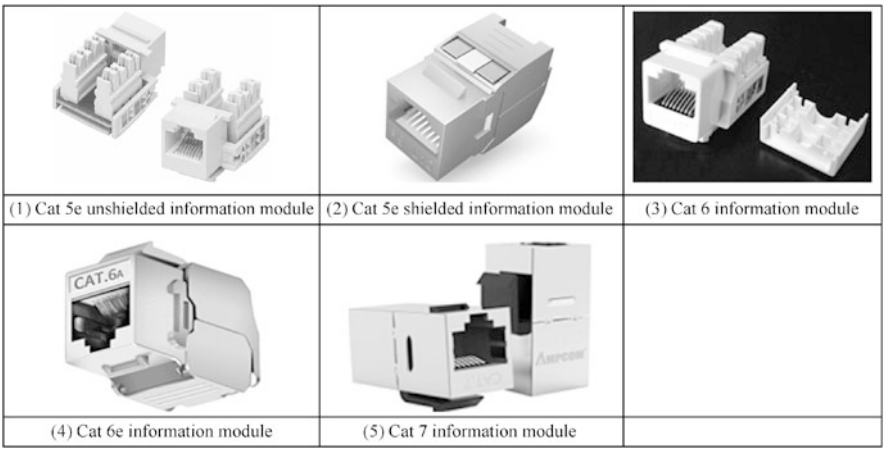


Fig. 2.42 Information modules

connection (or clamping). The information module is fixed on the back of the panel to achieve cable crimping, as shown in Fig. 2.41.

By tested performance, the information modules are classified into Cat 5e information module, Cat 6 information module and Cat 6e information module, and are classified into unshielded information module and shielded information module by occasions of use, as shown in Fig. 2.42.

2.3.2 Optical Cable Connection Devices

Optical cable connection device refers to the connector installed at the end of the optical cables for optical signal transmission between two optical cables. It is responsible for making the optical energy outputted from the transmitting optical fiber coupled to the receiving optical fiber to the maximum extent, and minimizing the impact on the system caused by its access to optical link.

1. Optical fiber splice

   An optical fiber splice connects two optical fibers permanently or detachably together, with a junction can protecting components. As the terminal device of the optical fiber, it serves as the physical interface to connect optical fibers. The common types of optical fiber splices are shown in Table 2.9.

   Splice types include: FC (round threaded style, typically used for distribution frames), ST (round clamping style), SC (square clamping style, typically used for routers and switches), PC (with micro spherical section, employing the grinding and polishing process), APC (with micro spherical section in an angle of 8°, employing the grinding and polishing processes), MT-RJ (square style, featuring two fibers integrated into a single design that supports both single receiving and transmitting), etc.

   Optical fiber splices mainly adopt three section processes (i.e., grinding process): PC section (physical contact), UPC section (ultra physical contact) and APC section (Angled Physical Contact). PC section is flat (actually employs micro-spherical grinding and polishing process). The signal attenuation of the UPC section is smaller than that of the PC section. The APC section is at an 8°, with the micro-spherical grinding and polishing process. The performance of these three sections from high to low is APC, UPC and PC. The APC section is green.

   The splice labeling format is "splice type/section process". For example, "FC/PC" indicates that it is a round threaded splice with a micro-spherical section employing the grinding and polishing process, and the section is flat.

2. Optical fiber patch cord/cable

   Optical fiber patch cord, also known as optical fiber connector, is a patch cord from equipment to optical fiber cabling link, which is applied to optical fiber communication system, optical fiber access network, optical fiber data transmission, local area network, etc. The plugs of the optical fiber patch cord is connected with the connectors installed on both ends of the optical cable, which can realize the active connection of the optical circuit. An optical fiber patch cord with only one end fitted with a plug is called a tail fiber. The core of the optical fiber patch cord is optical fiber, and there is a thin plastic sleeve outside the cable core to protect the sheath. Common optical fiber patch cords are shown in Fig. 2.43.

   (a) Classification of optical fiber patch cords

      (i) Single-mode patch cord: yellow sheath, and relatively longer transmission distance.

Table 2.9 Common types of optical fiber splices

SpliceType	Connection Method	Material	Advantages	Defects	Context of Use	Appearance
SC	Square snap-in splice	Engineering plastics	Easy-plug, and high installation density	Easy to be pulled out, and prone to damage under high temperature	100BASE-FX	
LC	Small rectangle plug-in splice	Engineering plastics	Half of the size of the FS and FC, easy-plug, and high installation density	Complex manufacturing process	On the high-density optical interface unit, and for Gigabit interface	
FC	Round-head threaded splice	Metal	Firm and dustproof	When installing, the splice should be aligned before tightening. It is not convenient for high-density installation.	100BASE-FX(phasing out)	
ST	Round-head snap-in splice	Metal	Easy to install	Prone to break-off	10BASE-F	

(continued)

Table 2.9 (continued)

SpliceType	Connection Method	Material	Advantages	Defects	Context of Use	Appearance
MT-RJ	Square clamping splice, equivalent to the telephone wire plug in volume	Engineering plastics	Small profile, featuring two fibers integrated into a single design that supports both single receiving and transmitting; lower insertion loss	Not widely used in China	For application from optical fiber to desktop, and for Gigabit interface	E2000/APC 
E2000	Slide splice	Engineering plastics	The spring lock protects the pins from wearing and pollution	Not widely used in China	On the high-density Gigabit optical interface unit	

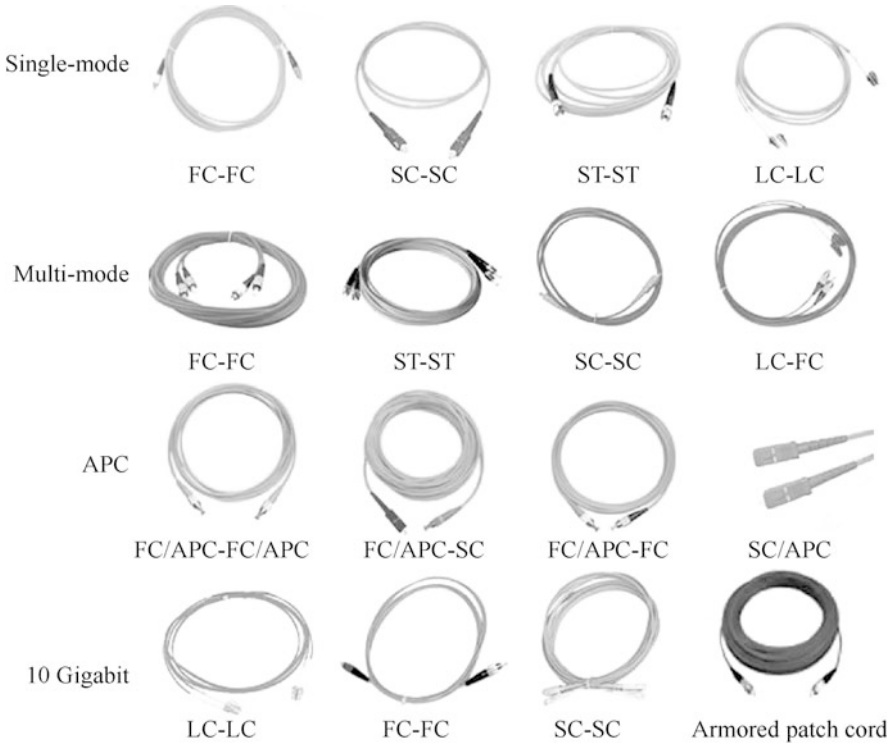


Fig. 2.43 Common optical fiber patch cords

(ii) Multi-mode patch cord: orange or gray sheath, and relatively shorter transmission distance.

(b) Common optical fiber patch cords

(i) FC patch cord: The patch cord adopts the FC splice, generally used for the optical distribution frame side, most used for the distribution frame. The FC splice is generally used by telecommunications networks, screwed on to the adapter through a nut. It features firmness and dustproof design, but takes more time to install.

(ii) SC patch cord: The patch cord adopts the SC splice, most used in routers and switches for 100BASE-FX connection. The SC splice is easy-plug and easy to use, but prone to falling off.

(iii) ST patch cord: The patch cord adopts the ST splice, often used as the 10BASE-F connector for optical fiber distribution frame.

(iv) LC patch cord: the LC splice is similar to but smaller than the SC splice. The LC splice can be used to connect the SFP optical transceiver, often

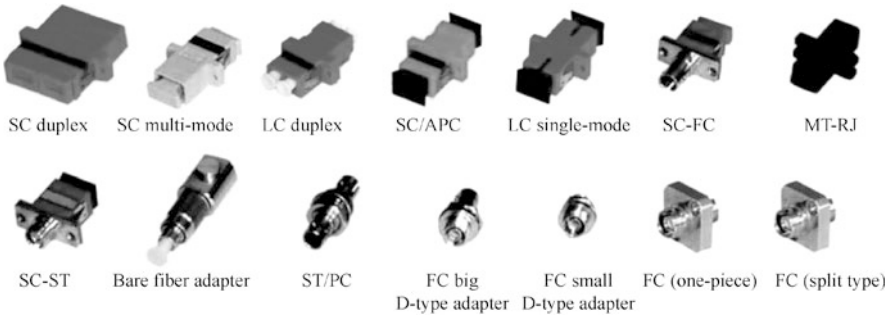


Fig. 2.44 Common optical fiber adapters

used in routers, and can increase the density of optical fiber connectors in optical fiber distribution frame to a certain extent.

(v) MT-RJ patch cord: The patch cord adopts the MT-RJ splice that features two fibers integrated into a single design that supports both single receiving and transmitting, which is suitable for indoor applications in telecommunications and data network systems.

3. Fiber optic adapter

The fiber optic adapter, also known as fiber optic connector, fiber coupler and flange, is the most widely used optical passive devices in fiber communication systems, supporting the removable (active) connection between fibers. It precisely mate two end faces of the optical fibers to make the optical energy outputted from the transmitting optical fiber coupled to the receiving optical fiber to the maximum extent, and minimizing the impact on the system caused by its access to optical link. Optical fiber adapters may affect the reliability and performance of optical transmission systems to a certain extent.

Common optical fiber adapters are shown in Fig. 2.44.

4. Fiber optic information outlet

The fiber optic information outlet is a socket for optical fiber splice. The structure is similar to that of TP information outlet, as shown in Fig. 2.45.

2.4 Common Tools for System Cabling

Communication network cabling must be inseparable from the relevant tools. The following examples are Xiyuan generic cabling toolbox (KYGJX-12) and Xiyuan optical fiber toolbox (KYGJX-31).

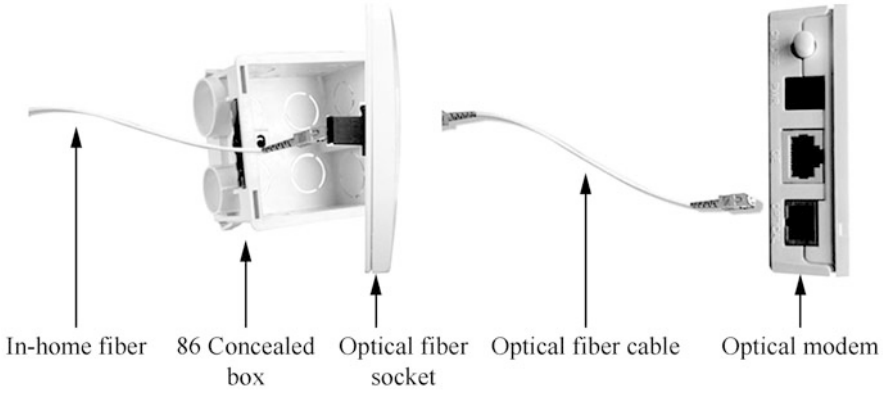


Fig. 2.45 Fiber optic information outlet

Fig. 2.46 Xiyuan generic cabling toolbox

2.4.1 Communication Cable Toolbox

This section takes the Xiyuan generic cabling toolbox (KYGJX-12) as an example to illustrate the composition of the communication cable toolbox, as shown in Fig. 2.46 and 2.47.

1. RJ-45 crimping pliers: used for clamping the RJ-45 and helping striping wires.
2. Single-port pliers: mainly used for seating wires on the distribution frame. Check the condition of the tool head before seating the wire. If it is in good condition, then align the wire with module and lay it down quickly with appropriate strength. The tool head is consumable that it should be replaced in time once the strokes made by exceed 1000 times.
3. Steel tape measure (2 m): an consumable tool mainly used for measuring consumable materials, cables, etc.

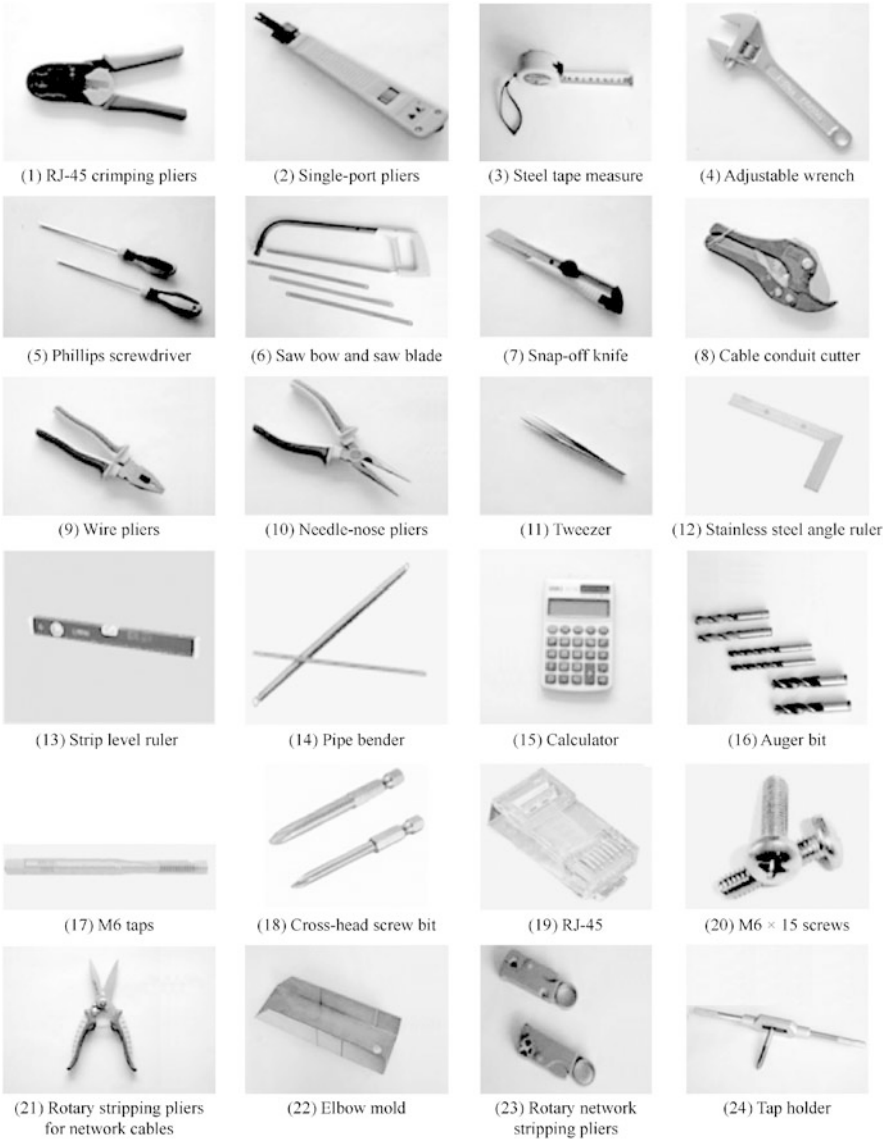


Fig. 2.47 Tools in the Xiyuan generic cabling toolbox

4. Adjustable wrench (150 mm): mainly used for fastening nuts. When using, adjust the jaw to match the nut specification, and exert the appropriate force to prevent the wrench from slipping.
5. Phillips screwdriver (150 mm): mainly used for the disassembly and assembly of cross-slot screws. When using, the cross head of the screwdriver should be tightly clamped into the screw slot with appropriate force.

6. Saw bow and saw blade: mainly used for sawing PVC conduits and troughs.
7. Snap-off knife: mainly used for cutting materials and stripping wire sheaths.
8. Cable conduit cutter: mainly used for cutting PVC cable conduits.
9. Wire pliers (8-inch): mainly used for plugging or unplugging the connecting blocks, clamping cables and other devices, cutting steel wires, etc.
10. Needle-nose pliers (6-inch): mainly used for clamping cables and other objects, cutting steel wires, etc.
11. Tweezers: mainly used to clamp small items. Prevent the sharp end from hurting people when using.
12. Stainless steel angle ruler (300 mm): mainly used for measuring, drawing right-angled lines, etc.
13. Stripe level ruler (400 mm): mainly used for measuring whether the cable conduits, troughs, etc. are level.
14. Pipe bender (Φ20): mainly used for cold-bending PVC pipes.
15. Calculator: mainly used for numerical calculation during operation.
16. Auger bit (Φ10, Φ8, Φ6): mainly used for drilling holes in the material where holes are required. Drill bits of appropriate specifications should be selected according to the size of drilling holes. When drilling, the drill chuck should clamp the drill bit, with the electric drill keeping perpendicular to the drilling surface, and the appropriate force being exerted to prevent the bit from slipping.
17. M6 tap: mainly used to pass the wire through the thread hole.
18. Cross-head screw bit (150 mm): mainly used with the electric screwdriver for the disassembly and assembly of cross-slot screws. Make sure the cross-head screw bit is well installed when using.
19. RJ-45: practical consumable items.
20. M6 $\times$ 15 screw: practical consumable items.
21. Cable trough cutter: mainly used for cutting PVC troughs or cords and pull wires. When using, the hand should be away from the edge of the cutter blades. When the material is about to be cut off, the force should be strengthened appropriately.
22. Elbow mold: mainly used for sawing cable conduits and troughs at a certain angle. When in use, place the cable conduits and troughs horizontally into the inner groove of the elbow mold.
23. Rotary stripping pliers for network cables: mainly used for stripping the sheaths of the network cables. When in use, rotate the tool clockwise to strip the sheaths.
24. Tap holder: mainly used with the tap to pass the wire through the thread hole.

2.4.2 Communications Optical Cable Toolbox

This section takes the Xiyuan optical fiber toolbox (KYGJX-31) as an example to illustrate the composition of the communications optical cable toolbox, as shown in Fig. 2.48 and 2.49.

Fig. 2.48 Xiyuan optical fiber toolbox

Fig. 2.49 Tools in the Xiyuan optical fiber toolbox

1. Pipe-binding pliers: mainly used for cutting the steel wires in the cables.
2. Multi-purpose shears (8-inch): mainly used for cutting relatively soft objects, such as pull wires; not suitable for cutting hard objects.

3. Wire stripper: mainly used for shearing and striping sheaths of optical cables and tail fibers; not suitable for cutting the steel wires in outdoor cables. When in use, choose the jaw of the right specification.
4. Snap-off knife: mainly used for patch cords, pull wires in TPs, etc. Never use it for cutting hard objects.
5. Needle-nose pliers (6-inch): mainly used for stripping cable sheaths and clamping small objects.
6. Wire pliers (6-inch): mainly used for clamping objects and cutting steel wires.
7. Diagonal pliers: mainly used for cutting cable sheaths; not suitable for cutting steel wires.
8. Optical fiber stripper: mainly used for stripping each layer of protective sleeve of optical fibers. Its 3 jaws can shear and strip tail fiber sheaths, middle protective sleeves and resin protective films respectively. When in use, choose the jaw of the right specification.
9. Adjustable wrench (150 mm): mainly used for fastening nuts.
10. Transverse cable cutter: used for cutting the black sheaths of outdoor optical cables.
11. Cleaning ball: used for removing dust.
12. Alcohol pump: used for holding alcohol. To prevent alcohol volatilization, it must not be tilted and the lid must not be removed.
13. Red light pen: used for simply check of the break-make of optical fibers.
14. Alcohol cotton ball: used for dipping in alcohol to wipe the bare fiber, which should be kept dry when idle.
15. Composite screwdriver: combined screwdriver, used for fastening the corresponding screws.
16. Miniature screwdriver: used for fastening the corresponding screws.
17. Steel tape measure (2 m): an consumable tool mainly used for measuring consumable materials, cables, etc. (omitted in Fig. 2.49).
18. Tweezers: mainly used to clamp small items. Prevent the sharp end from hurting people when using (omitted in Fig. 2.49).
19. Straps: for easy carrying of the toolbox (omitted in Fig. 2.49).
20. Marker pen: for marking (omitted in Fig. 2.49).

2.5 Common Instruments for System Cabling

In equipment installation, cabling construction, troubleshooting, inspection and testing, engineering acceptance, etc., dedicated test instruments are essential. This section is a brief introduction some commonly used instruments, such as Nengshou Network Tester, network tester for TPs, optical fiber light pen, optical power meter, optical time-domain reflectometer, and optical fiber fusion splicer.

2.5.1 Nengshou Network Tester

Nengshou Network Tester is a network cable tester, suitable for simple tests of links, such as for 8-core network cables and 4-core telephone cables. It consists of two units: the host as the sending unit, powered by a 9 V laminated battery with a power switch and a green power indicator; the remote terminal as the receiving unit, with indicators displaying the cable connection status. It provides an RJ-45 interface for network cables, and an RJ-11 interface for telephone cables. The appearance of the Nengshou Network Tester is shown in Fig. 2.50.

During measurement, first turn off the power supply of the tester, and then connect one end of a network cable to the network cable interface of the host, and the other end to the network cable interface of the remote terminal. Turn on the host and check whether the numbers above the indicators of the host and the remote terminal are flashing synchronously from 1 to 8. The synchronous display indicates the good condition of the network cable. If they are not displayed synchronously or any indicator does not flash, it means that the cable fails to connect or some wires are wrongly arranged when making the RJ.

2.5.2 Network Tester for TPs

Network tester, also known as network detector, is a type of portable intelligent testing equipment with visual display. It can test the status of the physical layer, data link layer, and network layer defined by the 7-layer model of open system

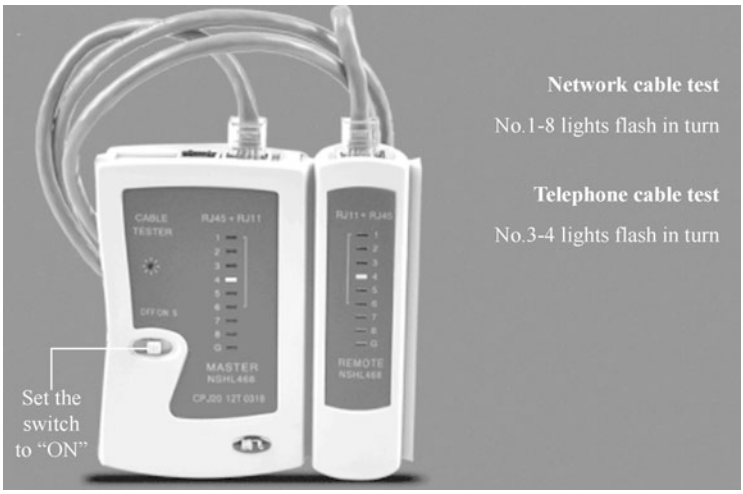


Fig. 2.50 Appearance of the Nengshou Network Tester

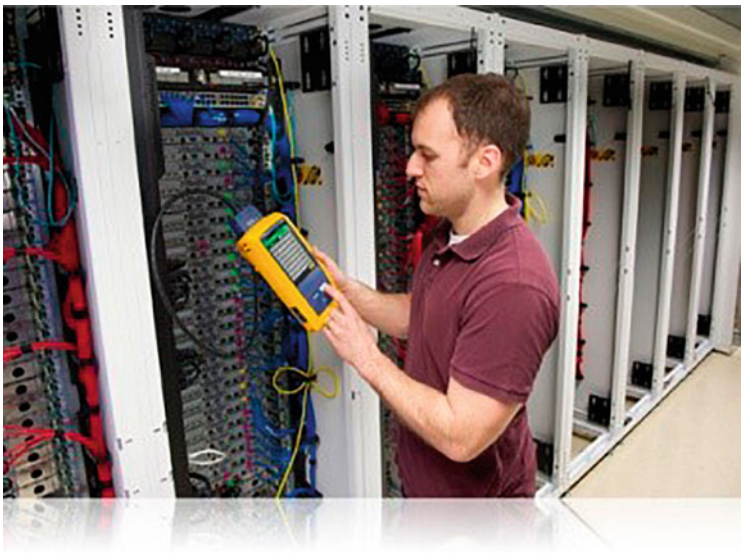


Fig. 2.51 Troubleshooting using a network tester

interconnection (OSI), mainly used for fault detection and maintenance of the LAN and generic cabling.

With the popularization and complexity of the network, the rational setting up and normal operation of the network is becoming more and more important. To ensure the normal operation of the network, we must proceed from two aspects. First, the network construction quality which directly affects the subsequent use of the network can not be ignored, so strict requirements and careful inspection must be in place, in order to nip the faults in the bud. Second, troubleshooting of network faults is crucial, because network faults will directly affect the operating efficiency of the network. Therefore, efficient and time-saving investigation must be guaranteed. This is one of the reasons why auxiliary equipment for network detection is increasingly important in network construction and maintenance. With the help of network tester, network administrator can greatly reduce the time of troubleshooting, helping the construction personnel of generic cabling improve work efficiency and quality, and speed up the construction, as shown in Fig. 2.51.

Well-known network tester manufacturers include Fluke, Agilent, Ideal, etc., there are also China's Xinertel, ZCTT, Ntooler, etc. This section will provide a brief introduction with the Fluke DSX2-5000 CableAnalyzer as an example.

Fluke has developed network testers for wired transmission medium, including network testers for optical fibers and network testers for TPs, as shown in Fig. 2.52. The network tester for optical fibers is not commonly used, so the term "network tester" is generally used to refer to the network tester for TPs.

The Fluke Network Tester DSX2-5000 CableAnalyzer (see Fig. 2.53) has been certified by Intertek (ETL). The certification is based on the Level IV accuracy

Fig. 2.52 Fluke network testers

Fig. 2.53 DSX2-5000 CableAnalyzer

specified in the IEC-61935-1 standard and the Level V accuracy in the draft standard, as well as the Level IIIE accuracy specified in the ANSI/TIA-1152. DSX2-5000 CableAnalyzer can test CAT 5E, 6, 6A and Class FA TPs with an accuracy of up to 1000 MHz, helping speed up the copper cable certification tests. For CAT 6A and FA cables, it realizes unmatched test efficiency, meeting even the more stringent accuracy requirements of the Level V in the IEC draft.

With the built-in Projx management system, existing project settings can be invoked on each operation, helping to track the progress from project setup through system acceptance. The Versiv platform, which is easy to upgrade and supports future standards, comes with optical fiber testing (OLTS and OTDR modules), Wi-Fi analysis, and Ethernet troubleshooting. In addition, the Taptive user interface helps speed up troubleshooting by graphically displaying the fault sources, including the exact locations of crosstalk, return loss and shielding fault. Finally, in order to

analyze test results, LinkWare management software can be used to generate a professional test report.

The parameters required for testing depend on the testing standard employed, which include the Wire Map, Loop Resistance, Impedance, Length, Propagation Delay, Delay Skew, Insertion loss/Attenuation, the return loss (RL, @host, @remote), near-end crosstalk (NEXT, @host, @remote), Power Sum near-end crosstalk (PS NEXT, @host, @remote), attenuation-to-crosstalk ratio—near-end (ACR-N, @host, @remote), PS ACR-N (@host, @remote), attenuation-to-crosstalk ratio—far-end (ACR-F, @host, @remote), and PS ACR-F (@host, @remote).

2.5.3 Optical Fiber Light Pen

Optical fiber light pen is also called optical fiber fault locater, optical fiber fault detector, visual red light source, light pen, red light pen, optical fiber pen, laser pen, etc. It uses a semiconductor laser with a wavelength of 650 nm as a light-emitting device, driven by a constant current source, and emits stable red light to the multi-mode or single-mode fiber through the optical interface connected with it, so as to realize fiber fault detection, as shown in Fig. 2.54.

The optical fiber light pen is a pen-type red light source specially designed for field construction personnel to perform tasks such as locating optical fiber faults, inspecting optical fiber connectors, optical fiber tracing, etc. As an ideal choice for on-site construction personnel, it features stable output power, long detection distance, solid and reliable structure, longer service time, and multi-functions. The

Fig. 2.54 Optical fiber light pen

optical fiber light pen can be divided into models of 5 km, 10 km, 15 km, 20 km, 25 km, 30 km, 35 km, 40 km, etc. by minimum detection distance. The longer the detection distance, the higher the price.

2.5.4 Optical Power Meter

With the rapid development of optical fiber communication technology, it has become the major way of data transmission in various communication networks. As the most fundamental measurement parameter in optical fiber communication system, optical power is an important indicator to evaluate the performance of optical terminal equipment and the transmission quality of optical fiber. The optical power meter is specially used to measure the absolute optical power or the relative loss of the optical power passing through a segment of optical fiber. It is widely used in the laying of network backbone, equipment maintenance, scientific research and production, as shown in Fig. 2.55.

In optical fiber measurement, the optical power meter is a commonly used instrument that carries a heavy load. An optical power meter can evaluate the performance of an optical device by simply measuring the absolute power of the transmitting terminal or optical network. When used in combination with a stable light source, it can measure joint losses, verify continuity, and help evaluate transmission quality of optical fiber links.

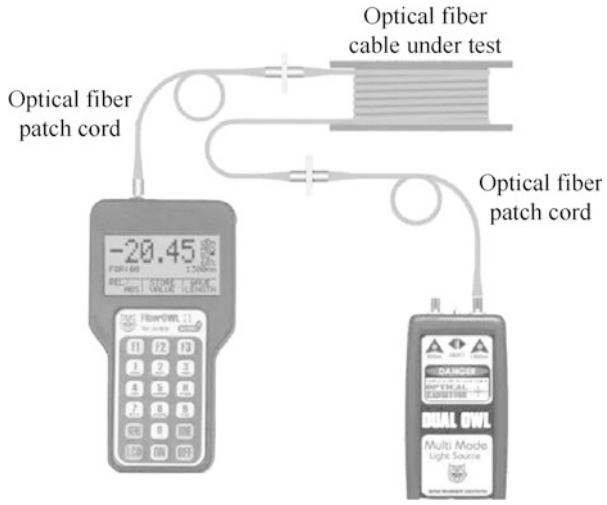


Fig. 2.55 Optical power meter

2.5.5 *Optical Time-Domain Reflectometer*

Optical time-domain reflectometer (OTDR) is used to follow the uniformity, defect, fracture, coupling and other properties of optical fiber by analyzing the measured curve. It is designed based on the principle of backscattering of light and Fresnel inversion principle, utilizing the backscattered light generated when the light propagates in the fiber to obtain information about attenuation. As an essential tool in optical cable construction, maintenance and monitoring, it can be used to measure optical fiber attenuation and joint losses, locate optical fiber fault points, and find out the distribution of losses along the fiber, as shown in Fig. 2.56.

The OTDR is an optical fiber tester used to determine the characteristics of optical fiber and optical network, for the purpose of detecting, locating and measuring events at any location of an optical fiber link. One of the main advantages of OTDR is its ability to act as a one-dimensional radar system to learn the characteristics of an entire optical fiber from only one end. The resolution of OTDR is 4 to 40 cm.

OTDR testing is a very effective means of maintaining and repairing optical fiber links. The basic working principle is to measure the distance in accordance with the time difference between the incoming light and the reflected light so as to accurately determine the location of a fault. The OTDR injects probe pulses into the fiber and then estimates the length of the fiber based on the reflected light. OTDR testing is

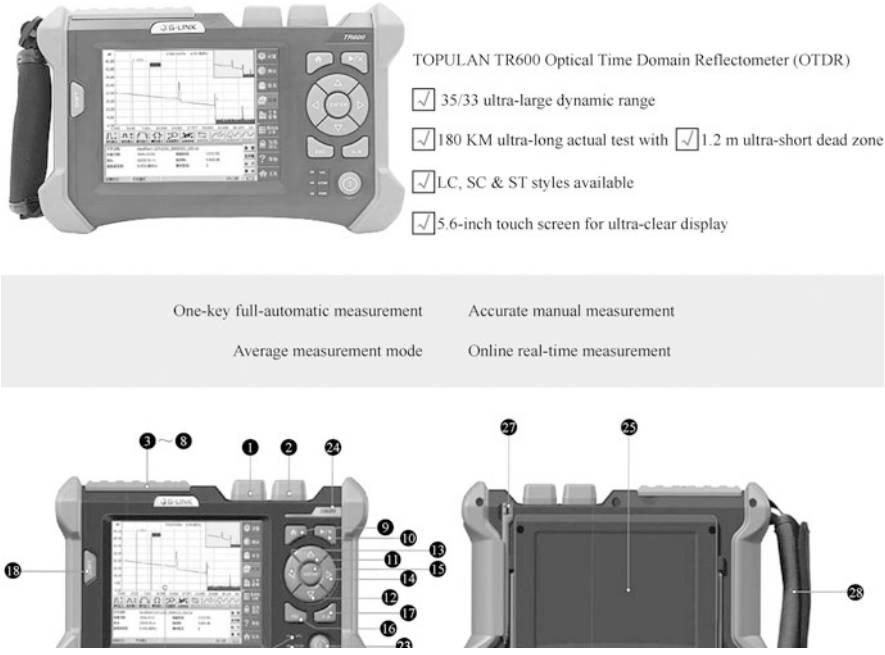


Fig. 2.56 OTDR

suitable for fault location, especially for determining the location of a broken or damaged cable. OTDR testing documentation provides technical personnel with a graphical representation of fiber characteristics, as important data for network diagnostics and network expansion.

2.5.6 *Optical Fiber Fusion Splicer*

The working principle of fiber fusion splicer is that two fiber sections are melted at a high temperature above 2000 °C produced by high-voltage arc discharge. At the same time, the two fibers are gently advanced by a high-precision motion device, so that the two fibers are fused into one, realizing the coupling of fiber mode field. Fiber splicing is one of the most widely used connection methods in fiber engineering. Fiber fusion splicer is mainly used in optical cable line construction, maintenance and emergency repair and production and testing of optical fiber devices by telecom operators, engineering companies and public institutions, as well as research and teaching in scientific research institutes, as shown in Fig. 2.57.

Tools necessary for fiber splicing include the optical fiber fusion splicer, incision knife, optical fiber stripper, alcohol pump (for 99% industrial alcohol), cotton ball, and heat-shrinkable sleeve. From stripping, cleaning, cutting to final welding, these tools can help users complete a qualified fiber splicing. The toolbox of optical fiber fusion splicer is shown in Fig. 2.58.

Well-known brands of fiber fusion splicer include Fujikura, Sumitomo and Furukawa from Japan, Comway from the US, South Korea's Inno, Dark horse,

Fig. 2.57 Optical fiber fusion splicer

Fig. 2.58 Toolbox of optical fiber fusion splicer

and Ilshin. There are also China's CETC 41st, Signal Fire, Jilong, Ruiyan, SHINHO, Eloik, etc.

2.6 Engineering Technology of Equipment Room Subsystem

The equipment room subsystem is a centralized equipment area that connects common equipment of the system and connect to the management subsystems (such as LAN, mainframe, and building automation and security systems) through the backbone subsystem.

The equipment room subsystem is the place where the backbone subsystems for data and for voice are connected in the building, the place where the cables from the building complex are connected to the building, and the place where all kinds of mainframes and protection facilities for data and voice are installed. It is generally located in the middle or on the first or second floor of the building; it should not be located in the top floor or basement, nor be far away from the elevator; space should also be reserved for future expansion, as shown in Fig. 2.59. The cables from the building complex should be provided with corresponding over-current and over-voltage protection while entering the building.

Space design of the equipment room subsystem should comply with ANSL/TLA/ELA-569 requirements. This space is used for installation of telecommunication equipment, connection hardware, connector sleeve, etc., providing control environment for grounding and connection facilities and protection devices as a place for

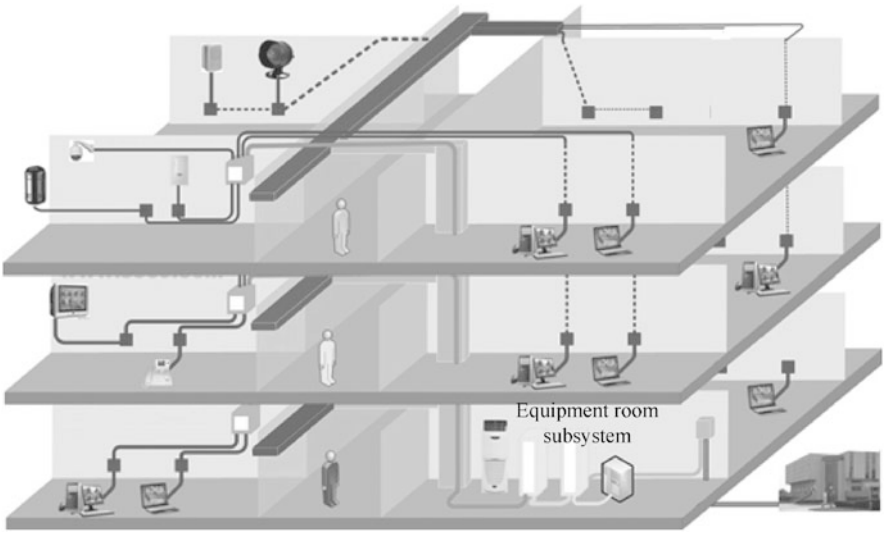


Fig. 2.59 Location of the equipment room subsystem in a building

system management, control and maintenance. In addition, the space should also meet the requirements of doors and windows, ceiling, power supply, lighting, and grounding.

2.6.1 Standard Requirements

1. Standard requirements of equipment room subsystem
   Chapter 7 of the GB 50311 - 2016 "Code for Engineering Design of Generic Cabling System" puts forward specific requirements on the installation processes in equipment rooms.

   (a) Each building should be equipped with not less than one equipment room.
   (b) The equipment room should not be located directly under or adjacent to the toilet, bathroom or other wet and water-prone areas.
   (c) The equipment room should be away from dust, lampblack, harmful gases and places with corrosive, flammable and explosive items.
   (d) The available space in the equipment room should not be less than 10 m^2.
   (e) The net height under the beam in the equipment room should not be less than 2.5 m.
   (f) The room temperature of 10 °C to 35 °C and relative humidity of 20% to 80% should be maintained in the equipment room, and good ventilation should be provided.

Table 2.10 Installation requirements of cabinets for equipment room

Project	Requirements
Installation position	Design requirements should be followed. The cabinet should be 1 m away from the wall for easy installation and construction. All screws installed should not be loose, and the protective rubber pad should be firmly installed
Base	The base should be firmly installed, and the construction should be carried out according to the shockproof requirements of the design drawing
Placement	The cabinet should be placed vertically, with the top keeping level. The vertical deviation should not be more than 1‰, and the horizontal deviation, no more than 3 mm. The gap between the cabinets should be no more than 1 mm
Surface	The surface should be intact, free of damage, and the screws should be tightened. The surface convexity per square meter should be less than 1 mm
Connection	The connection should meet the design requirements and keep in good condition, with complete terminal signs
Distribution Equipment	The grounding body, protective grounding, cross-section of wires, and cable color should meet the design requirements
Grounding	Grounding terminals should be provided and well connected to building grounding terminals
Cable reservation	(1) There should be no visible reserved cable in the cabinet fixed. The cable should be reserved in a place where it can be concealed, with a length of 1 to 1.5 m (2) For all cables connected to the movable cabinet, at least 1 m should be reserved at the entrance of the cabinet, and the length difference of various reserved cables should not exceed 0.5 m
Cabling	The cables in the cabinet should be all fixed and kept horizontal and vertical

(g) The equipment room should be opened with double fire doors with a net height not less than 2.0 m and a net width not be less than 1.5 m.
(h) The cement floor of the equipment room should be no less than 100 mm higher than the ground of the floor where the room is located, or a waterproof threshold should be installed.
(i) No less than two 220 V/10A single-phase AC power socket boxes should be installed in the equipment room, and the distribution lines of each power socket should be equipped with protectors. The power supply of the equipment should be separately configured.

2. Installation requirements of cabinets for equipment room

The installation requirements of cabinets for equipment room are shown in Table 2.10.

3. Distribution requirements

The power supply of the equipment room is provided by the mains electricity of the building, which goes into the special distribution cabinet of the equipment room. The dedicated underfloor socket for UPS should be installed in the equipment room. In order to facilitate maintenance, maintenance sockets should

be installed on the wall. Other rooms should be equipped with corresponding maintenance sockets according to the quantity of equipment.

In addition to meeting the power supply demand of the equipment in the equipment room, the distribution cabinet shall also reserve redundant space for future capacity expansion.

4. Requirements for installation of lightning protector in equipment room

   According to the relevant provisions of GB 50057-2010 "Design Code for Protection of Structures against Lightning", the power supply system of computer network center equipment room should adopt three-stage lightning protection design.

   Lightning protection in the equipment room is especially important. Perfect lightning protection system is not only the basis of protecting expensive and important network exchanges and servers and other important equipment and maintaining the normal operation of the network system, but also can avoid personal injury incidents and protect personal safety.

5. Grounding requirements for equipment room

   Equipment grounding in the equipment room cannot be ignored. DC and Ac working grounding resistance should not be greater than 4 Ω commonly, lightning protection grounding resistance should not be greater than 10 Ω. There should be a grounding network set in the building to ensure that an equipotent reference for all equipment is established. In order to achieve a good grounding state, it is recommended to adopt the joint grounding mode, that is, the lightning protection grounding, AC working grounding, DC working grounding, etc. are connected to the common grounding device.

2.6.2 Installation Technology

1. Installation and construction of cabling channel

   The laying of all kinds of cable bridges, pipelines and other cabling channels in the equipment room shall meet the following requirements.

   (a) The cabling should be horizontal and vertical, with lateral deviation no more than 10 mm for the horizontal cabling and vertical deviation no more than 5 mm for the vertical cabling.
   (b) When the cabling channel is installed onto a pipe rack together with other pipes, the cabling channel should be arranged on one side of the pipe rack.
   (c) When the cable is laid vertically in the cabling channel, the upper end of the cable should be fixed on the channel support, and the body of the cable should be fixed on the support at 1.5 m intervals. When laying horizontally, the cable should be fixed at its head, end and turnings and at 3 to 5 m intervals.
   (d) The cable laid on the cable bridge should be bound to the bridge and keep straight and tidy, with even-spaced and moderate-tightened buckles.

(e) AC and DC power cables and signal cables should be laid on their respective bridges; if laid in a metal groove, a metal plate shall be used to separate the cables. If the cables are laid in the same groove, the spacing between them should be ensured.
(f) The cables should keep straight without crossing, and should be bound to be fixed at turnings.
(g) The cables laid in the cabinet should not be tightened, with an appropriate amount of redundancy, and with even-spaced and moderate-tightened buckles. The cables should keep straight and tidy without crossing.
(h) When laying Cat 6e UTP network cables, the filling rate in the cabling channel should not exceed 40%.

2. Cable termination

There are a lot of patch cords and cables need to be connected and terminated in the equipment room. The termination should meet the following basic requirements.

(a) When cross-connecting, the redundancy and length of patch cords should be minimized to keep them tidy and artistic.
(b) The bending radius of the cable shall be met.
(c) The cable shall be connected to the connecting hardware with the same performance level.
(d) The backbone cable and the horizontal cable shall be terminated on different distribution frames.
(e) The outer sheath of the TP should be stripped as shortly as possible.
(f) The length the separated wires of the TP shall not exceed 13 mm.
(g) The Cat 6e network cable should not be bound tightly.

3. Installation and construction of open network bridge

(a) Ground-based installation

The network bridge in the equipment room must be connected to the building's vertical subsystem and the main bridge in the management room. In the equipment room, ground brackets or supports shall be installed at 1.5 m intervals and fixed with bolts and nuts. Common installation methods include bracket-based installation and support-based installation, as shown in Figs. 2.60 and 2.61.

In general, the support-based installation is feasible. The height above ground of the bracket or support may depend on the actual situation of the site, but the bottom of it should be at least 50 mm from the ground.

(b) Ceiling-mounted installation

When installing the bridge on the ceiling, the ceiling-mounted method should be adopted. The bridge can be suspended above the cabinet with U-steel support or reinforcement reinforcing steel suspending lever, combined with the horizontal bracket and M6 bolts. When laying the cables in the

Fig. 2.60 Bracket-based installation

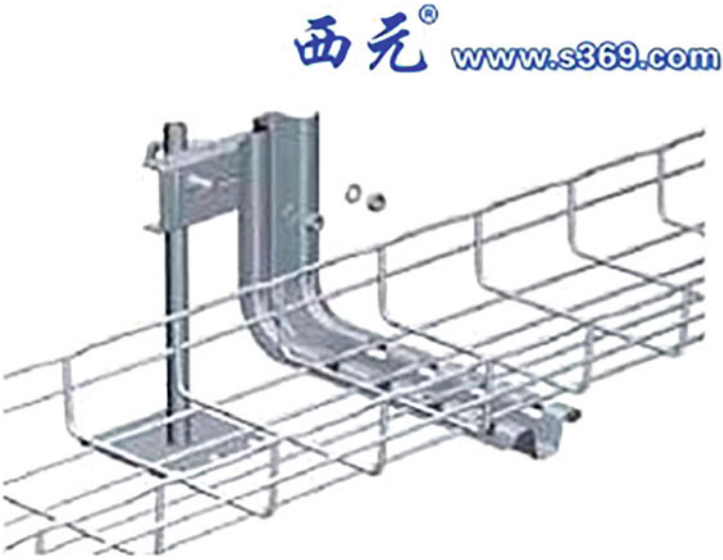


Fig. 2.61 Support-based installation

cabinet, the cables should be arranged and bound with a cabling unit in the cabinet, as shown in Fig. 2.62.

(c) Special installation methods

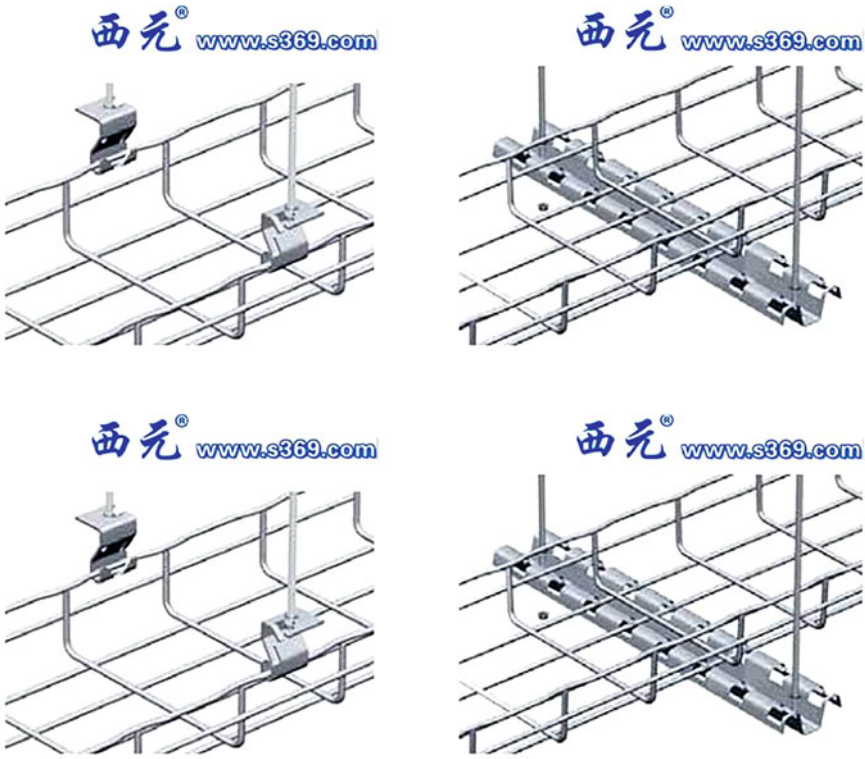


Fig. 2.62 Ceiling-mounted installation

(i) Layered installation: This method allows for laying of more cables, easier maintenance and management, as well as the aesthetically pleasing site, as shown in Fig. 2.63.

(ii) Installation of supporting bridge for rack: With this new installation method, the installer does not need to drill holes into the ceiling or climb high during installation and cabling, which saves time and effort and is very convenient, as shown in Fig. 2.64. This method not only gives the user more intuitive control of the entire installation engineering, but also provides natural ventilation and heat dissipation conditions for the cables, which is convenient for the maintenance and upgrading of the equipment room in the future.

4. Grounding connection in the equipment room

(a) Grounding connection of the cabinet and rack

The cabinet and rack in the equipment room must be grounded reliably, which generally uses self-tapping screws for connection with the steel plate of the cabinet. If the cabinet surface has been painted, the electrical connection

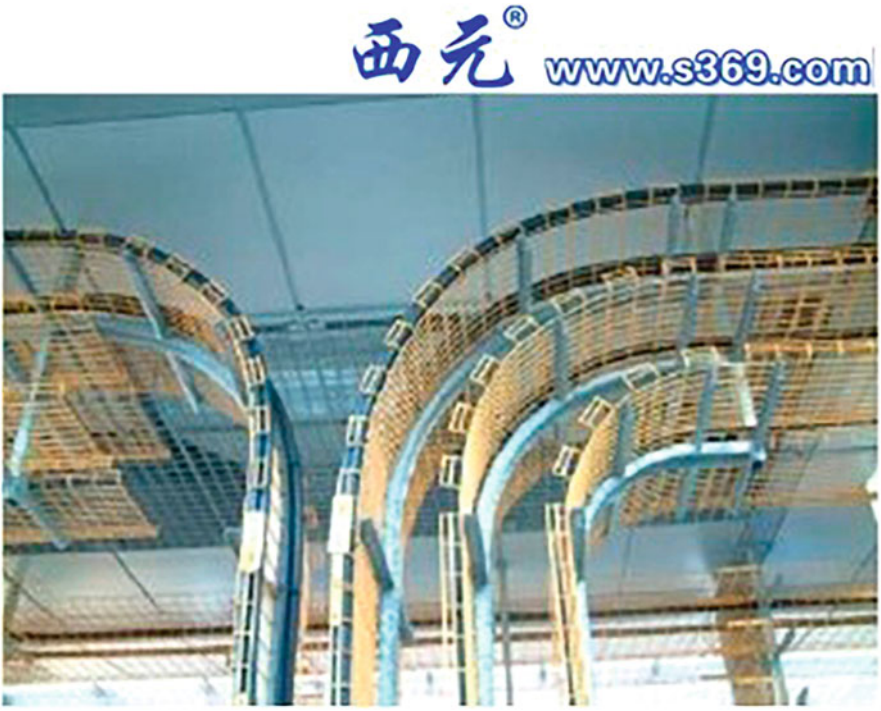


Fig. 2.63 Layered installation of bridges

can be made by using a paint removal solvent or an electric drill to direct the grounding facility to the metal surface of the cabinet.

(b) Grounding connection of the equipment

The server, switch and other equipment installed in the cabinet or on the rack must be reliably grounded through the grounding bar.

(c) Grounding connection of the bridge

The bridge must be grounded reliably, and the open bridge grounding method is often employed, as shown in Fig. 2.65.

5. Design and installation of aisles and channels in the equipment room

(a) Personnel aisles

(i) The width of the aisles for transport equipment shall not be less than 1.5 m.

(ii) The distance between the fronts of the cabinets or racks arranged face to face should not be less than 1.2 m.

(iii) The distance between the backs of the cabinets or racks arranged back to back should not be less than 1 m.

Fig. 2.64 Installation of supporting bridge for rack

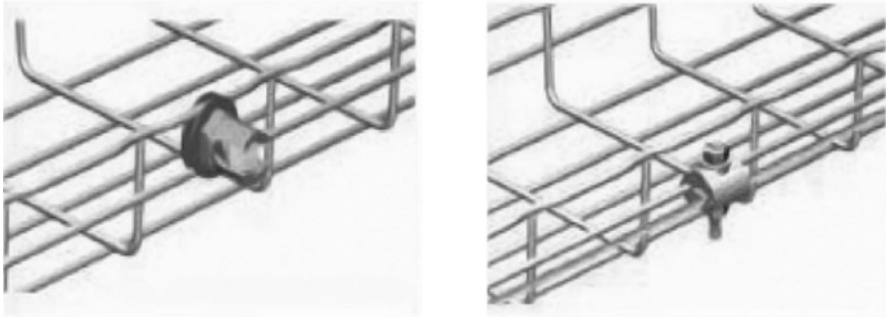


Fig. 2.65 Open bridge grounding method

(iv) When maintenance or testing is performed on the side of the cabinet, the distance between the cabinets, and between the cabinet and the wall should not be less than 1.2 m.

(v) When the total length of a row of cabinets exceeds 6 m, there should be an aisle at both ends. When the distance between two such aisles exceeds 15 m, aisles shall be added between them. The width of each

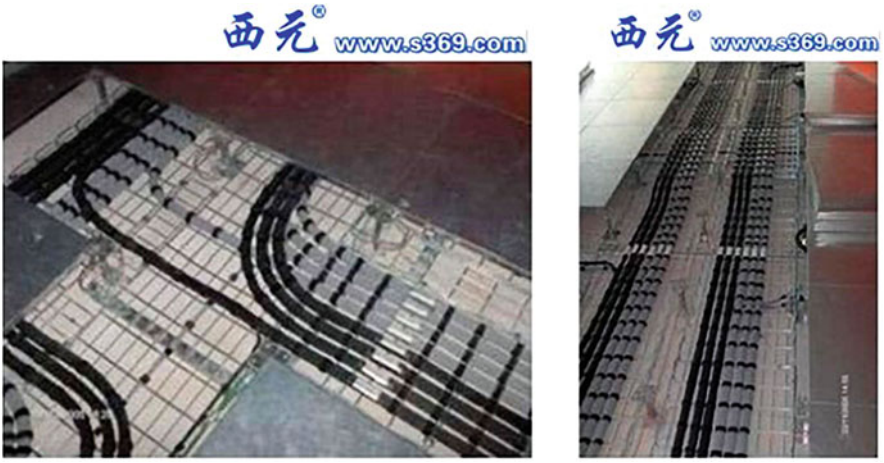


Fig. 2.66 Cabling channels under the raised floor

aisle should not be less than 1 m, but the local width of the aisle may be contracted to 0.8 m.

(b) Cabling channels under the raised floor

The ground of the raised floor plays an anti-static role. The space under the floor can be set with channels for heating, ventilation and cooling, as well as grooves and pipes for laying cables.

When cabling under the raised floor of the equipment room, the cables shall not be placed under the floor at will, but shall be laid in the cabling channels. The channels may be set separately for each category of cable and installed in multiple layers, but the height of the cable bundle should not exceed 150 mm. In architectural design, cabling channels under the floor should be coordinated with other equipment pipelines (such as those for air conditioning, fire protection, electricity, etc.), and corresponding protective measures should be in place.

According to the international standards, if the space under the raised floor is only used for laying communication cables, the net height under the floor should not be less than 250 mm; if the space also serves as a static pressure box for the air conditioning, the net height under the floor should not be less than 400 mm. The cabling channels under the raised floor are shown in Fig. 2.66.

According to the Data Center Design and Implementation Best Practices published by the BICSI, the net height under the raised floor shall be at least 450 mm, and the net height of 900 mm is recommended. The distance between the bottom of the floor plate and the top of the cabling channel should be at least 20 mm. If there is an outlet for cable bundles or pipes or

Table 2.11 Net heights under the ceiling of the equipment rooms

	Tier 1	Tier 2	Tier 3	Tier 4
Net height under the ceiling	At least 2.6 m	At least 2.7 m	At least 3 m; not less than 0.46 m from the ceiling to the top of the highest equipment	At least 3 m; not less than 0.6 m from the ceiling to the top of the highest equipment

grooves, the distance should be increased to 50 mm to meet the needs of cable placement and air distribution of the air conditioning.

(c) Cabling channels under the ceiling

(i) Requirements for net height

Commonly used cabinets are usually 2 m high. In view of the need of air distribution, the top surface of the cabinet and the ceiling are generally 500 to 700 mm apart. This distance should be as close as possible to the net height under the raised floor, so the net height of the equipment room should not be less than 2.6 m.

According to the international standard for data center tier rating, the net heights under the ceiling of the equipment rooms of Tier 1 to 4 data centers are shown in Table 2.11.

(ii) Channel style

The ceiling-mounted cabling channel is composed of open bridges or groove-style closed bridges and corresponding accessories for installation. The open bridge is widely used in new data centers because of its convenience in cable maintenance.

The cabling channel shall be installed in the upper spaces of the aisles in the equipment room and other public areas, above 2.7 m from the floor, otherwise the bottom of the cabling channels installed on the ceiling shall be laid with solid material to prevent personnel from touching it and accidental or intentional damage to the cables. The ceiling-mounted cabling channels are shown in Fig. 2.67.

(iii) Requirements for channel location and dimensions

- The top of a channel should be no less than 300 mm from the ceiling or other obstacles.
- The width of a channel should not be less than 100 mm, and the height should not exceed 150 mm.
- The filling rate in the cross section of a channel should not exceed 50%.
- Multiple ceiling-mounted cabling channels may be installed in layers, if any. The optical cables are preferably laid above the copper cables. In order to facilitate construction and maintenance, the copper cable link and optical fiber link should be laid separately.
- The sprinklers of fire extinguishing devices shall be placed between the cabling channels, instead of being placed directly on the channels.

Fig. 2.67 Ceiling-mounted cabling channels

Where the pipe-style gas fire-extinguishing system is adopted in the equipment room, the cable bridge shall be installed above the fire-extinguishing gas pipeline, without blocking the sprinkler or gas.

2.7 Acceptance of Cabling Engineering

Acceptance is the final part of the whole project, which also marks the completion of the project. In order to ensure the quality of the whole project, it is necessary to employ relevant industry experts to participate in the acceptance. The acceptance process generally includes pre-construction inspection, follow-up acceptance, preliminary acceptance and completion acceptance.

2.7.1 Completion Documents

After the completion of the project, the construction organization shall deliver the completion documents to the development organization before the acceptance of the project. The completion documents of the generic cabling system project shall include the installation bill of quantities, project specifications, equipment list, as-built drawings, test records, engineering change records, inspection records, design changes during construction, negotiation records of construction, design and construction units regarding relevant measures, follow-up acceptance records, concealed work confirmation and final project accounts.

2.7.2 *Project Contents*

Generic cabling system engineering shall be accepted according to Table 2.12. The acceptance conclusion shall be an integral part of the completion documents and serve as a proof in the project acceptance.

2.8 Summary

Based on the demand of primary standards, this chapter guides the reader along the basic workflow of cabling engineering to understand the engineering technical standards and installation specifications for equipment room subsystem, covering network cabinets, communication cables, cable connection devices and optical cable connection devices commonly used in communication systems, common tools and instruments for system cabling, etc., and introduces the completion documents involved in project acceptance and items subject to the acceptance.

Upon the study of this chapter, the reader should get familiar with various network cabinets; master the characteristics and identification methods of TPs and optical fibers; have the ability to skillfully identify and use connection devices commonly used in communication systems; understand common tools and instruments for system cabling; and understand the engineering standards, technical requirements for installation and items subject to the acceptance of the equipment room system.

2.9 Exercise

1. The wire sequence of T568B is ().
   A. White orange, orange, white green, blue, white blue, green, white brown, brown
   B. White orange, orange, white green, green, white blue, blue, white brown, brown
   C. White green, green, white orange, blue, white blue, orange, white brown, brown
   D. White green, green, blue, white blue, white orange, orange, white brown, brown
2. The basic structure of a bare fiber is ().
   A. Fiber core, reinforced layer and sheath
   B. Cladding, sleeve and central stiffener
   C. Fiber core, shielding layer and coating layer
   D. Fiber core, cladding and coating layer.

Table 2.12 Acceptance checklist

Stage	Items for acceptance	Content	Acceptance method
Pre-construction inspection	1. Environmental requirements	(1) Civil construction conditions, floors, walls, doors, power sockets and grounding devices; (2) Civil engineering technology, equipment room area and reserved holes; (3) Construction power supply; (4) Laying of floors; (5) Inspection of facilities at the entrance to the building	Pre-construction inspection
	2. Equipment inspection	(1) Appearance; (2) Model, specification and quantity; (3) Electrical performance test of cables and accessory connecting devices; (4) Performance test of optical fibers and accessory connecting devices; (5) Inspection of test instruments and tools	
	3. Safety and fire protection requirements	(1) Fire equipment; (2) Placement of dangerous materials; (3) Fire prevention measures for reserved holes	
Equipment installation	1. Telecom room, equipment room, equipment cabinet, and rack	(1) Specifications and appearance; (2) Perpendicularity and levelness of installations; (3) Good condition of painted surfaces, and comprehensiveness and completeness of signs; (4) Screw fastening; (5) Reinforcing measures for earthquake resistance; (6) Grounding measures	Follow-up acceptance
	2. Cabling module and 8-position modular outlet	(1) Specification, location and quality; (2) Screw fastening; (3) Comprehensiveness and completeness of signs; (4) Compliance with installation process requirements; (5) Reliable connection of the shielding layer	
Layout of cables and optical cables(in the building)	1. Arrangement of cable bridges and grooves	(1) Correct installation position; (2) Compliance with installation process requirements; (3) Compliance with	Follow-up acceptance

(continued)

Table 2.12 (continued)

Stage	Items for acceptance	Content	Acceptance method
		cabling process requirements; (4) Grounding	
	2. Concealed laying of cables (including hidden pipes, grooves, underfloor cabling, etc.)	(1) Cable specification, routing and location; (2) Compliance with cabling process requirements; (3) Grounding	Concealed work confirmation
Layout of cables and optical cables(between buildings)	1. Aerial cables	(1) Suspension specifications, positions and installation specifications; (2) Perpendicularity of the cables; (3) Cable specifications; (4) Buckle intervals; (5) Compliance of cable introduction process	Follow-up acceptance
	2. Duct cables	(1) Locations of duct holes; (2) Cable specifications; (3) Cable direction; (4) Quality of cable protection measures	Concealed work confirmation
	3. Buried cables	(1) Cable specifications; (2) laying position and depth; (3) Quality of cable protection measures; (4) Quality of cable burial	
	4. Channel cables	(1) Cable specifications; (2) Installation location and routing; (3) Compliance with civil construction requirements	
	5. Others	(1) Distance between communication lines and other facilities; (2) Installation and construction quality of the facilities in the cable entry room	Follow-up acceptance and concealed work confirmation
Cable termination	1. 8-position modular outlet	Compliance with process requirements	Follow-up acceptance
	2. Optical cable connection devices	Compliance with process requirements	
	3. Patch cords/cables	Compliance with process requirements	
	4. Distribution modules	Compliance with process requirements	
System test	1. Electrical performance test	(1) Wire Map; (2) Length; (3) Attenuation; (4) NEXT; (5) PS NEXT; (6) ACR;	Completion acceptance

(continued)

Table 2.12 (continued)

Stage	Items for acceptance	Content	Acceptance method
		(7) PS ACR; (8) FEXT; (9) PS FEXT; (10) RL; (11) Propagation Delay; (12) Delay Skew; (13) Insertion Loss; (14) DC Loop Resistance; (15) Tests specially specified in the design; (16) Conducting of the shielding layer	
	2. Optical fiber characteristic test	(1) Attenuation; (2) Length	
Management system	1. Management system level	Compliance with design requirements	Completion acceptance
	2. Layout of signs and labels	(1) Type and composition of the special signs; (2) Label setting; (3) Label material and color code	
	3. Records and reports	(1) Records; (2) Reports; (3) Engineering drawings	
General acceptance	1. Completion documents	Checking and handover of completion documents	
	2. Project acceptance evaluation	Project quality assessment and acceptance result confirmation	

3. The optical fiber splice () is typically used for distribution frames and shows as a round threaded splice with a micro-spherical section employing the grinding and polishing process.

   A. FC/APC
   B. FC/PC
   C. SC/APC
   D. SC/PC

4. [Multi-choice] An information outlet consists of ().

   A. Panel
   B. Bottom box
   C. Module
   D. RJ

5. [Multi-choice] Network tester can be used to test ().

   A. Wire Map
   B. Length
   C. Propagation Delay
   D. Insertion Lose