Connector

Contents

Chapter 1

Phone connector (audio)

"Phone plug" redirects here. For the plugs used to connect landline telephones, see telephone plug. For the connector sometimes called a phono connector, see RCA connector.

In electronics, a **phone connector** is a common family of connector typically used for analog signals, primarily audio. It is cylindrical in shape, typically with two, three or four contacts. Three-contact versions are known as **TRS connectors**, where **T** stands for "tip", **R** stands for "ring" and **S** stands for "sleeve". Similarly, two- and four-contact versions are called **TS** and **TRRS connectors** respectively.

A 6.35 mm ($\frac{1}{4}$ inch) two-contact phone connector used for various signals including electric guitar, loudspeaker, microphone and line-level audio.

*A pair of **phone connectors**: A **phone plug** (right) is inserted in a **phone socket** (left). For terms, see section Other connectors, other terms.*

The phone connector was invented for use in telephone switchboards in the 19th century and is still widely used. In its original configuration, the outside diameter of the "sleeve" conductor is $\frac{1}{4}$ inch (exactly 6.35 mm). The "mini" connector has a diameter of 3.5 mm (approx. $\frac{1}{8}$ inch) and the "sub-mini" connector has a diameter of 2.5 mm (approx. $\frac{3}{32}$ inch).

1.1 Other connectors, other terms

It is also termed an **audio jack**, **phone jack**, **phone plug**, and **jack plug**. Specific models are termed **stereo plug**, **mini-stereo**, **mini jack**, **headphone jack**, **microphone jack**, *tiny telephone connector*, *bantam plug*.[1]

In the UK, the terms **jack plug** and **jack socket** are commonly used for the respective male and female phone connectors.[2] In the US, a stationary (more fixed) electrical connector is called a "jack".[3][4] The terms *phone plug* and *phone jack* are sometimes used to refer to different genders of phone connectors,[5] but are also sometimes used colloquially to refer to RJ11 and older telephone plugs and the corresponding jacks that connect wired telephones to wall outlets. Phone plugs and jacks are not to be confused with the similar terms *phono plug* and *phono jack* (or in the UK, *phono socket*) which refer to RCA connectors common in consumer hi-fi and audio-visual equipment.

1.2 Modern connectors

Modern phone connectors are available in three standard sizes. The original $\frac{1}{4}$ in (6.35 mm) version dates from 1878, when it was used for manual telephone exchanges, making it possibly the oldest electrical connector standard still in use. The 3.5 mm or *miniature* and 2.5 mm or *sub-miniature* sizes were originally designed as two-conductor connectors for earpieces on transistor radios. The 3.5 mm

Phone connectors:

- *2.5 mm mono (TS)*
- *3.5 mm mono (TS)*
- *3.5 mm stereo (TRS)*
- *6.35 mm ($^{1}/_{4}$ in) (TRS)*

and 2.5 mm sizes are also referred to as $^{1}/_{8}$ in and $^{3}/_{32}$ in respectively in the United States, though those dimensions are only approximations. All three sizes are now readily available in two-conductor (unbalanced mono) and three-conductor (balanced mono or unbalanced stereo) versions.

Four- and five-conductor versions of the 3.5 mm plug are used for certain applications. A four-conductor version is often used in compact camcorders and portable media players, and sometimes also in laptop computers and smartphones, providing stereo sound plus a video signal. Proprietary interfaces using both four- and five-conductor versions exist, where the extra conductors are used to supply power for accessories. The four-conductor 3.5 mm plug is also used as a speaker-microphone connector on handheld amateur radio transceivers from Yaesu[6] and on some mobile phones – see below for details.

The most common arrangement remains to have the male plug on the cable and the female socket mounted in a piece of equipment: the original intention of the design. A considerable variety of line plugs and panel sockets is available, including plugs suiting various cable sizes, right-angle plugs, and both plugs and sockets in a variety of price ranges and with current capacities up to 15 amperes for certain heavy duty $^{1}/_{4}$ in versions intended for loudspeaker connections.[7]

1.2.1 Tiny telephone

The professional audio field and the telecommunication industry use *tiny telephone* (TT) connectors in patch bays. These are mid-size TS or TRS phone plugs with a 4.40 mm (0.173 in) diameter shaft and a slightly different geometry. In the telecommunications field this is termed a "bantam" plug. The three-conductor (TRS) versions are capable of handling balanced line signals and are used in professional audio installations. Though unable to handle as much power, and less reliable than a 6.35 mm (0.250 in) jack,[8] TT connectors are used for professional console and outboard patchbays in studio and live sound applications, where large numbers of patch points are needed in a limited space. The slightly different shape of bantam plugs is also less likely to allow shorting as they are plugged in.

1.2.2 Less common

Less commonly used sizes, both diameters and lengths, are also available from some manufacturers, and are used when it is desired to restrict the availability of matching connectors, such as 0.210 inch inside diameter jacks for fire safety communication jacks in public buildings, the same size found in discontinued Bell & Howell 16 mm projector speaker jacks.[9]

A dual 310 patch cable, two-pin phone plug

- A two-pin version, known to the telecom industry as a "310 connector" consists of two phone 6.35 mm phone plugs at a centre spacing of 0.625 inches. The socket versions of these can be used with normal phone plugs provided the plug bodies are not too large, but the plug version will only mate with two sockets at 0.625 inches centre spacing, or with line sockets, again with sufficiently small bodies. These connectors are still widely used today in telephone company central offices on "DSX" patch panels for DS1 circuits. A similar type of 3.5 mm connector is often used in the armrests of older aircraft, as part of the on-board in-flight entertainment system. Plugging a stereo plug into one of the two mono jacks typically results in the audio coming into only one ear. Adapters are available.
- A short-barrelled version was used for 20th century high-impedance mono headphones, and in particular those used in World War II aircraft. It is physically possible to use a normal plug in a short socket, but a short plug will neither lock into a normal socket

nor complete the tip circuit. These have become rare.

1.3 Mono and stereo compatibility

Old-style male tip-sleeve ("pin" or "jack") connectors. The left-most plug has three conductors; the others have two. At the top is a three-conductor jack from the same era.

Modern profile 2-conductor male 1⁄4 in TS connectors.

In the original application in manual telephone exchanges, many different configurations of 6.35 mm (1⁄4 in) phone plugs were used, some accommodating five or more conductors, with several tip profiles. Of these many varieties, only the two-conductor version with a rounded tip profile was compatible between different manufacturers, and this was the design that was at first adopted for use with microphones, electric guitars, headphones, loudspeakers, and many other items of audio equipment.

When a three-conductor version of the 6.35 mm (1⁄4 in) jack was introduced for use with stereo headphones, it was given a sharper tip profile in order to make it possible to manufacture jacks (sockets) that would accept only stereo plugs, to avoid short-circuiting the right channel of the amplifier. This attempt has long been abandoned, and now the normal convention is that all plugs fit all sockets of the same size, regardless of whether they are balanced mono, unbalanced mono or stereo. Most 6.35 mm (1⁄4 in) plugs, mono or stereo, now have the profile of the original stereo plug, although a few rounded mono plugs are also still produced. The profiles of stereo miniature and subminiature plugs have always been identical to the mono plugs of the same size.

The results of this physical compatibility are:

- If a two-conductor plug of the same size is connected to a three-conductor socket, the result is that the ring (right channel) of the socket is grounded. This property is deliberately used in several applications, see "tip ring sleeve", below. However, grounding one channel may also be dangerous to the equipment if the result is to short circuit the output of the right channel amplifier. In any case, any signal from the right channel is naturally lost.
- If a three-conductor plug is connected to a two-conductor socket, normally the result is to leave the ring of the plug unconnected (open circuit). In the days of vacuum tubes this was also potentially dangerous to equipment but most solid-state devices tolerate this condition well. A three-conductor socket could be wired as an unbalanced mono socket to ground the ring in this situation, but the more conventional wiring is to leave the ring unconnected, exactly simulating a mono socket.

Due to a lack of standardization in the past regarding the dimensions (length) given to the ring conductor and the insulating portions on either side of it in 6.35 mm (1⁄4 in) phone connectors and the width of the conductors in different brands and generations of sockets there are occasional issues with compatibility between differing brands of plug and socket. This can result in a contact in the socket bridging (shorting) the ring and sleeve contacts on a phone connector, or where a phone plug is inserted into a two-conductor TS socket in some cases the intended 'sleeve' contact in the socket making contact with only the 'ring' portion of the plug.

1.4 Uses

Some common uses of phone plugs and their matching sockets are:

- Headphone and earphone jacks on a wide range of equipment. 6.35 mm (1⁄4 in) plugs are common on home and professional component equipment, while 3.5 mm plugs are nearly universal for portable audio equipment. 2.5 mm plugs are not as common, but are used on communication equipment such as

A 3.5 mm phone connector

A 3.5 mm 4-conductor TRRS phone connector

cordless phones, mobile phones, and two-way radios.

- Consumer electronics devices such as digital cameras, camcorders, and portable DVD players use 3.5 mm connectors for composite video and audio output. Typically, a TRS connection is used for mono unbalanced audio plus video, and a TRRS connection for stereo unbalanced audio plus video. Cables designed for this use are often terminated with RCA connectors on the other end.

- Hands-free sets and headsets often use 3.5 mm or 2.5 mm connectors. Phone connectors are used for mono audio out and an unbalanced microphone (with a shared ground). Four-conductor TRRS phone connectors are used to add an additional audio channel such as microphone input added to stereo output.

- Microphone inputs on tape and cassette recorders, sometimes with remote control switching on the ring, on early, monaural cassette recorders mostly a dual-pin version consisting of a 3.5 mm TS for the microphone and a 2.5 mm TS for remote control which switches the recorder's power supply.

- Patching points (insert points) on a wide range of equipment.

- Personal computers, sometimes using a sound card plugged into the computer. Stereo 3.5 mm jacks are used for:
  - Line in (stereo)
  - Line out (stereo)
  - Headphones/loudspeaker out (stereo)
  - Microphone input (mono, usually with 5 V power available on the ring. Note that traditional, incompatible, use of a stereo plug for a mono microphone is for balanced output)
  - Older laptop computers generally have one jack for headphones and one mono jack for a microphone at microphone level. An attenuating cable can be used to convert line level or use a signal from an XLR connector, but is not designed to record from a stereo device such as a radio or music player. Newer computers may feature a single TRRS female jack (see below).
  - LCD monitors with built-in speakers will need a cable with 3.5 mm male TRS plugs on each end to connect to the sound card.

  Note: Some higher-end sound cards provide a breakout panel which supports $^1\!/_4$ in plug devices as well.

- Devices designed for surround output may use multiple jacks for paired channels (e.g. TRS for front left and right; TRRS for front center, rear center, and subwoofer; and TRS for surround left and right). Circuitry on the sound device may be used to switch between traditional Line In/Line Out/Mic functions and surround output.

- Electric guitars. Almost all electric guitars use a $^1\!/_4$ in mono jack (socket) as their output connector. Some makes (such as Shergold) use a stereo jack instead for stereo output, or a second stereo jack, in addition to a mono jack (as with Rickenbacker).

- Instrument amplifiers for guitars, basses and similar amplified musical instruments. $^1\!/_4$ in jacks are overwhelmingly the most common connectors for:
  - Inputs. A shielded cable with a mono $^1\!/_4$ in phone plug on each end is commonly termed a *guitar cable* or a *patch cable*, the first name reflecting this usage, the second the history of the phone plug's development for use in manual telephone exchanges.
  - Loudspeaker outputs, especially on low-end equipment. On professional loudspeakers, Speakon connectors carry higher current, mate

with greater contact area, lock in place and do not short out the amplifier upon insertion or disconnection. However, some professional loudspeakers carry both Speakon and TRS connectors for compatibility. Heavy-duty $^1/_4$ in loudspeaker jacks are rated at 15 A maximum which limits them to applications involving less than 1,800 watts. $^1/_4$ in loudspeaker jacks commonly are not rigged to lock the plug in place and will short out the amplifier's output circuitry if connected or disconnected when the amplifier is live.

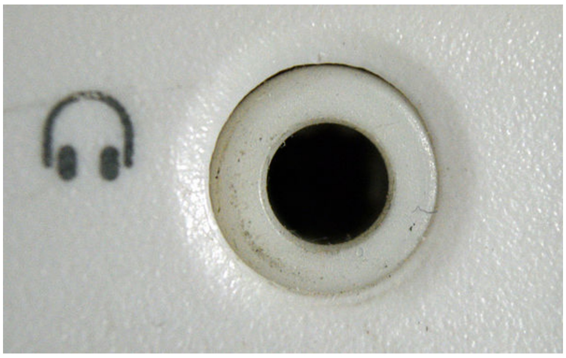
  - Line outputs.
  - Foot switches and effects pedals. Stereo plugs are used for double switches (for example by Fender). There is little compatibility between makers.
  - Effects loops, which are normally wired as patch points.

- Electronic keyboards use jacks for a similar range of uses to guitars and amplifiers, and in addition
  - Sustain pedals.
  - Expression pedals.
- Electronic drums use jacks to connect sensor pads to the synthesizer module or MIDI encoder. In this usage, a change in voltage on the wire indicates a drum stroke.
- Some compact and/or economy model audio mixing desks use stereo jacks for balanced microphone inputs.
- The majority of professional audio equipment uses TS jacks as the standard unbalanced input or output line-level connector. TRS jacks are sometimes used for balanced connections, the latter often alongside (or sometimes in the middle of) and as an alternative to an XLR balanced line connector.
- Modular synthesizers commonly use monophonic cables for creating patches.
- Quarter-inch phone connectors are widely used to connect external processing devices to mixing consoles' insert points (see Insert (effects processing)). Two- or three-conductor phone connectors might be used in pairs as separate *send* and *return* jacks, or a single three-conductor phone jack might be employed for both *send* and *return*, in which case the signals are unbalanced. The one unbalanced combination send/return TRS insert jack saves both panel space and component complexity, but may introduce a slight buzz. Insert points on mixing consoles may also be XLR, RCA or bantam TT (tiny telephone) jacks, depending on the make and model.
- Some small electronic devices such as audio cassette players, especially in the cheaper price brackets, use a two-conductor 3.5 mm or 2.5 mm phone jack as a DC power connector.
- Some photographic studio strobe lights have $^1/_4$ in or 3.5 mm jacks for the flash synchronization input. A camera's electrical flash output (PC socket or hot shoe adapter) is cabled to the strobe light's sync input jacks. Some examples: Calumet Travelite, and Speedotron use a $^1/_4$ in mono jack as the sync input; White Lightning uses $^1/_4$ in stereo jacks; PocketWizard (radio trigger) and AlienBees use 3.5 mm mono jacks.
- Some cameras (for example, Canon, Sigma, and Pentax DSLRs) use the 2.5 mm stereo jack for the connector for the remote shutter release (and focus activation); examples are Canon's RS-60E3 remote switch and Sigma's CR-21 wired remote control.
- Some miniaturized electronic devices use 2.5 mm or 3.5 mm jacks as serial port connectors for data transfer and unit programming. This technique is particularly common on graphing calculators, such as the TI-83 series, and some types of amateur and two-way radio, though in some more modern equipment USB mini-B connectors are provided in addition to or instead of jack connectors. The second-generation iPod Shuffle from Apple has one TRRS jack which serves as headphone, USB, or power supply, depending on the connected plug.
- Samsung YP-S MP3 player "pebble" uses USB-to-3.5 mm TRRS jack adapter for charging as well as for data transfer.
- On CCTV cameras and video encoders, mono audio in (originating from a microphone in or near the camera) and mono audio out (destined to a speaker in or near the camera) are provided on one three-conductor connector, where one signal is on the tip conductor and the other is on the ring conductor.[10]
- The Atari 2600 (Video Computer System), the first widely popular home video game console with interchangeable software programs, used a 3.5 mm TS (two conductor) jack for 9V 500ma DC power. Later games machines included the ZX Spectrum (for loading software from cassette) and the Sega Mega Drive (for stereo audio output).
- The Apple Lisa personal computer used a three-conductor TRS phone connector for its keyboard.

1.4.1 Computer sound

Personal computer sound cards, such as Creative Labs' Sound Blaster line use a 3.5 mm phone connector as a mono microphone input, and deliver a 5 V polarizing

A 3.5 mm plug for computer audio



A 3.5 mm headphone socket (TRS) on a computer

voltage on the ring to power electret microphones. Sometimes termed *phantom power*, this is not a suitable power source for microphones designed for true phantom power and is better termed *bias voltage*. (Note that this is not a polarizing voltage for the condenser, as electrets by definition have an intrinsic voltage; it is power for an FET preamplifier built into the microphone.) Compatibility between different manufacturers is unreliable.

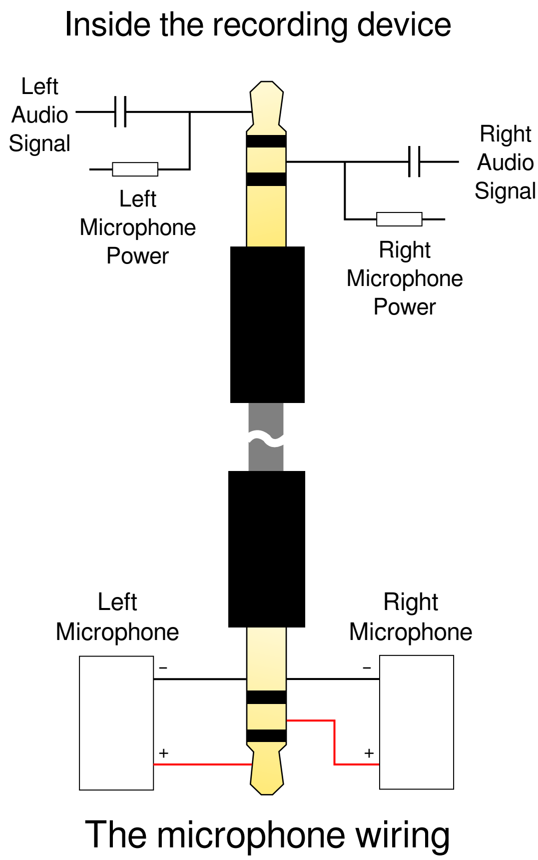
The Apple PlainTalk microphone jack used on some older Macintosh systems is designed to accept an extended 3.5 mm three-conductor phone connector; in this case, the tip carries power for a preamplifier inside the microphone. If a PlainTalk-compatible microphone is not available, the jack can accept a line-level sound input, though it cannot accept a standard microphone without a preamp.

Normally, 3.5 mm three-conductor sockets are used in computer sound cards for stereo output. Thus, for a sound card with 5.1 output, there will be three sockets to accommodate six channels: "front left and right," "surround left and right," and "center + subwoofer." 6.1 and 7.1 channel sound cards from Creative Labs, however, use a single three-conductor socket (for the *front* speakers) and two 4-conductor sockets. This is to accommodate rear-center (6.1) or rear left and right (7.1) channels without the need for additional sockets on the sound card. (Note that Creative's documentation uses the word "pole" instead of "conductor".)

Some portable computers have a combined 3.5 mm TRS-TOSLINK jack, supporting stereo audio output using a TRS connector, or TOSLINK (stereo or 5.1 Dolby Digital/DTS) digital output using a suitable optical adaptor. Most iMac computers have this digital/analog combo output feature as standard, with early MacBooks having two ports, one for analog/digital audio input and other for output. Support for input was dropped on various later models[11][12]

Some newer computers, such as Lenovo laptops, have 3.5 mm TRRS headset sockets, which are compatible with phone headsets, and may be distinguished by a headset icon, instead of the usual headphones or microphone icons. These are particularly used for Voice over IP.

1.4.2 Recording equipment



Stereo devices which use "plug-in power": the electret capsules are wired in this way

Many small video cameras, laptops, recorders and other consumer devices use a 3.5 mm microphone connector for attaching a (mono/stereo) microphone to the system. These fall into three categories:

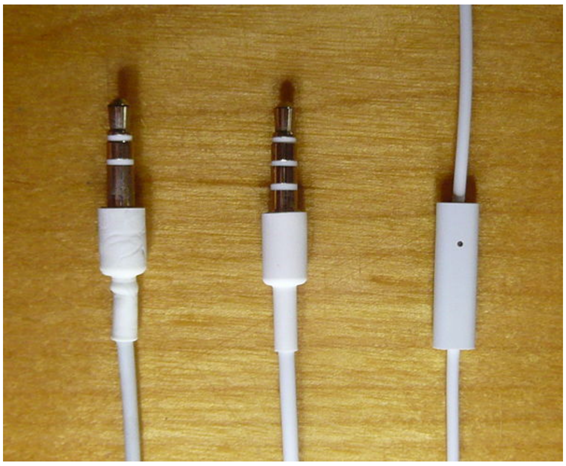
- Devices that use an un-powered microphone: usually a cheap dynamic or piezoelectric microphone. The microphone generates its own voltage, and needs no power.

- Devices that use a self-powered microphone: usually a condenser microphone with internal battery-powered amplifier.
- Devices that use a “plug-in powered” microphone: an electret microphone containing an internal FET amplifier. These provide a good quality signal, in a very small microphone. However, the internal FET needs a DC power supply, which is provided as a bias voltage for an internal preamp transistor.

Plug-in power is supplied on the same line as the audio signal, using an RC filter. The DC bias voltage supplies the FET amplifier (at a low current), while the capacitor decouples the DC supply from the AC input to the recorder. Typically, V=1.5 V, R=1 kΩ, C=47 μF.

If a recorder provides plug-in power, and the microphone does not need it, everything will usually work ok, although the sound quality may be lower than expected. In the converse case (recorder provides no power; microphone needs power), no sound will be recorded. Neither misconfiguration will damage consumer hardware, but providing power when none is needed could destroy a broadcast-type microphone.

1.4.3 Mobile phones



The iPhone uses a 4-conductor (TRRS) phone connector (center) for its headset (microphone and control button right).

Three- or four-conductor (TRS or TRRS) 2.5 mm and 3.5 mm sockets are common on cell phones, providing mono (three conductor) or stereo (four conductor) sound and a microphone input, together with signaling (e.g., push a button to answer a call). Three-conductor 2.5 mm connectors are particularly common on older phones, while four-conductor 3.5 mm connectors are more common on newer smartphones. These are used both for handsfree headsets (esp. mono audio plus mic, also stereo audio plus mic, plus signaling for call handling) and for (stereo) headphones (stereo audio, no mic). Wireless (connectorless) headsets or headphones usually use the Bluetooth protocol.

There is no recognised standard for TRRS connectors or compatibility with three-ring TRS. The four rings of a TRRS connector are assigned to different purposes by different manufacturers. Any 3.5 mm plug can be plugged mechanically into any socket, but many combinations are electrically incompatible. For example, plugging TRRS headphones into a TRS headset socket (or the reverse), plugging TRS headphones or headsets into a TRRS socket, or plugging TRRS headphones or headsets from one manufacturer into a TRRS socket from another may not function correctly, or at all. Mono audio will usually work, but stereo audio or microphone may not work, depending on wiring. Signaling compatibility depends both on wiring compatibility and the signals sent by the hands-free/headphones controller being correctly interpreted by the phone. Adapters that are wired for headsets will not work for stereo headphones and conversely. Further, as TTY/TDDs are wired as headsets, TTY adapters can also be used to connect a 2.5 mm headset to a phone.

3.5 mm TRRS (stereo-plus-mic) sockets became particularly common on smartphones, and have been used e.g. by Nokia since 2006; they are often compatible with standard 3.5 mm stereo headphones. Two different forms are frequently found, both of which place left audio on the tip and right audio on the first ring (mirroring the configuration found on stereo connectors). Where they differ is in the placement of the microphone and return contacts. The first, which places the ground return on the second ring and the microphone on the sleeve, is used by Apple's iPhone line, HTC devices, latest Samsung, Nokia and Sony phones, among others. The second, which reverses these contacts, is used by older Nokia mobiles, Samsung smartphones and some Sony Ericsson phones.[13] There are adapters that swap the poles over to allow a device made to one standard to be used with a headset made to the other.[14]

Some computers now include a TRRS headset socket, compatible with headsets intended for smartphones. One such pin assignment, with ground on the sleeve, is standardized in OMTP[15] and has been accepted as a national Chinese standard YDT 1885-2009.

TRRS standards

Notes:

Nokia started to implement a universal audio connector, which enables the use of both American Headset Jack (AHJ) headsets and standard Nokia OMTP headsets.[18][19]

The 4-pole 3.5mm connector is defined by the Japanese standard JEITA/EIAJ RC-5325A, “4-Pole minature concentric plugs and jacks”, originally published in 1993.[20] 3-pole 3.5mm TRS connectors are defined in JIS C 6560. See also JIS C 5401 and IEC 60130-8.

A posting on All About Windows Phone provides more detail about the differences between the AHJ, OMTP, and Apple implementations, in covering the one earbud manufacturer's introduction of three separate models for each “standard”.[21]

The Android Wired audio headset specification requires the CTIA pinout order (LRGM), “Except in regions with legal requirements for OMTP pinout”. This document also describes the headset button actions, and these may be taken from the CTIA spec.[22]

The article “Headset jacks on newer laptops” details how Linux can be configured to take these differences into account.[23]

The USB Type-C Cable and Connector Specification Revision 1.1 specifies a mapping from a Type-C jack to a 4-pole TRRS jack, for the use of headsets, and supports both CTIA and OMTP (YD/T 1885-2009) modes. See Audio Adapter Accessory Mode (Appendix A).

This is a comprehensive description of many of the phone/laptop/etc. compatability issues.[24]

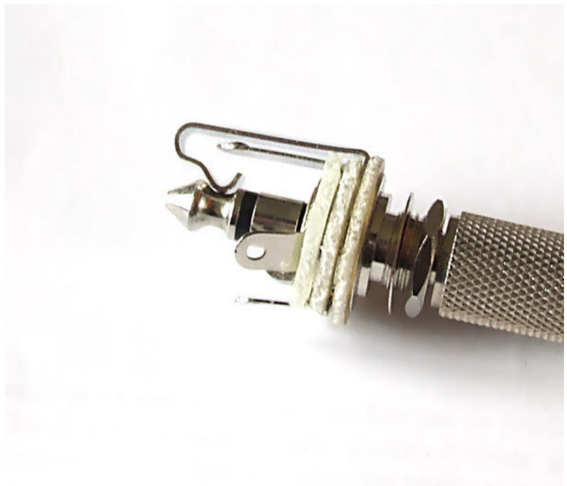
1.4.4 Aircraft headsets

Aviation plug type U-174/U or Nexus TP120, commonly used on military aircraft and civil helicopters.

Commercial and general aviation (GA) civil airplane headset plugs are similar, but not identical. A standard $\frac{1}{4}$ in monaural plug, type PJ-055, is used for headphones, paired with special tip-ring-sleeve, 0.206 inch diameter plug, type PJ-068, for the microphone. On the microphone plug the Ring is used for the microphone 'hot' and the sleeve is common or microphone 'Lo'. The extra (tip) connection in the microphone plug is often left unconnected but is also sometimes used for various functions, most commonly an optional push-to-talk switch, but on some aircraft it carries headphone audio and on others a DC supply. On many newer GA aircraft the headphone jack is a standard $\frac{1}{4}$ in phone connector wired in the standard unbalanced stereo configuration instead of the PJ-055 to allow stereo music sources to be reproduced.

Military aircraft and civil helicopters have another type termed a U-174/U. These are also termed 'NATO plugs' or Nexus TP120[25] telephone plugs. They are similar to $\frac{1}{4}$ in (6.3 mm) plug, but with a 7.10 mm (0.280 in) diameter short shaft with an extra ring, i.e. four conductors in total, allowing two for the headphones (mono), and two for the microphone. There is a confusingly similar four pole (or four conductor) British connector with a slightly smaller diameter and a different wiring configuration used for headsets in many UK Military aircraft and often also referred to as a NATO or 'UK NATO' connector.

1.5 Switch contacts



A phone plug breaks the contact of a normally closed switch.

Miniature phone plugs and jacks. All are 3.5 mm except the gold-plated plug, which is 2.5 mm. One of the 3.5 mm jacks is two-conductor and the others are three conductor. The tan-colored jacks have a normally-closed switch.

Panel-mounting jacks are often provided with switch contacts. Most commonly, a mono jack is provided with one normally closed (NC) contact, which is connected to the tip (live) connection when no plug is in the socket, and disconnected when a plug is inserted. Stereo sockets commonly provide two such NC contacts, one for the tip (left channel live) and one for the ring or collar (right channel live). Some designs of jack also have such a connection on the sleeve. As this contact is usually ground, it is not much use for signal switching, but could be used to indicate to electronic circuitry that the socket was in use.

Less commonly, some jacks are provided with normally open (NO) or change-over contacts, and/or the switch contacts may be isolated from the connector.

The original purpose of these contacts was for switching in telephone exchanges, for which there were many patterns. Two sets of change-over contacts, isolated from the connector contacts, were common. The more recent pattern of one NC contact for each signal path, internally attached to the connector contact, stems from their use as headphone jacks. In many amplifiers and equipment containing them, such as electronic organs, a headphone jack is provided that disconnects the loudspeakers when in use. This is done by means of these switch contacts. In other equipment, a dummy load is provided when the headphones are not connected. This is also easily provided by means of these NC contacts.

Other uses for these contacts have been found. One is to interrupt a signal path to enable other circuitry to be inserted. This is done by using one NC contact of a stereo jack to connect the tip and ring together when no plug is inserted. The tip is then made the output, and the ring the input (or vice versa), thus forming a patch point.

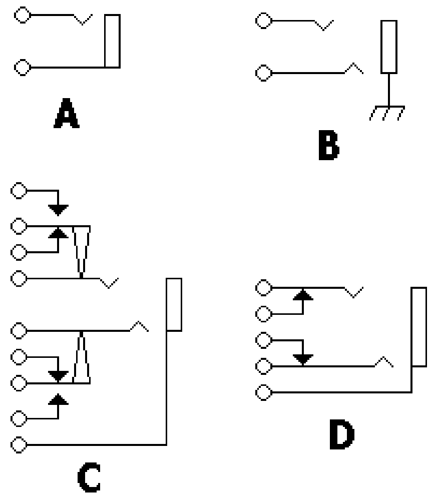
Another use is to provide alternative mono or stereo output facilities on some guitars and electronic organs. This is achieved by using two mono jacks, one for left channel and one for right, and wiring the NC contact on the right channel jack to the tip of the other, to connect the two connector tips together when the right channel output is not in use. This then mixes the signals so that the left channel jack doubles as a mono output.

Where a 3.5 mm or 2.5 mm jack is used as a DC power inlet connector, a switch contact may be used to disconnect an internal battery whenever an external power supply is connected, to prevent incorrect recharging of the battery.

A standard stereo jack is used on most battery-powered guitar effects pedals to eliminate the need for a separate power switch. In this configuration, the internal battery has its negative terminal wired to the sleeve contact of the jack. When the user plugs in a two-conductor (mono) guitar or microphone lead, the resulting short-circuit between sleeve and ring connects an internal battery to the unit's circuitry, ensuring that it powers up or down automatically whenever a signal lead is inserted or removed. A drawback of this design is the risk of inadvertently discharging the battery if the lead is not removed after use, such as if the equipment is left plugged in overnight.

1.6 Design

Notes:

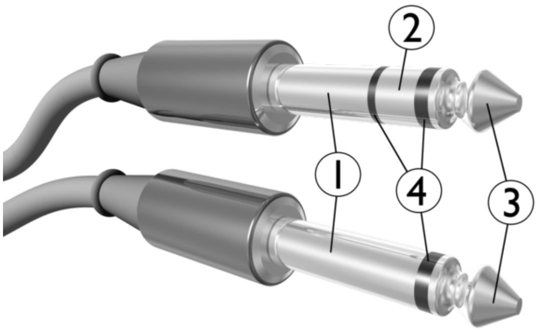


Examples of jack configurations, oriented so the plug 'enters' from the right. The most common circuit configurations are the simple mono and stereo jacks (A and B); however there are a great number of variants manufactured.[26]

1. *A two-conductor TS phone connector. The connection to the sleeve is the rectangle towards the right, and the connection to the tip is the line with the notch. Wiring connections are illustrated as white circles.*
2. *A three-conductor TRS phone connector. The upper connector is the tip, as it is farther away from the sleeve. The sleeve is shown connected directly to the chassis, a very common configuration. This is the typical configuration for a balanced connection. Some jacks have metal mounting connections (which would make this connection) and some have plastic, to isolate the sleeve from the chassis, and provide a separate sleeve connection point, as in* A.
3. *This three-conductor jack has two isolated* SPDT switches. *They are activated by a plug going into the jack, which disconnects one throw and connects the other. The white arrowheads indicate a mechanical connection, while the black arrowheads indicate an electrical connection. This would be useful for a device that turns on when a plug is inserted, and off otherwise, with the power routed through the switches.*
4. *This three-conductor jack has two normally closed switches connected to the contacts themselves. This would be useful for a patch point, for instance, or for allowing another signal to feed the line until a plug is inserted. The switches open when a plug is inserted. A common use for this style of connector is a stereo headphone jack that shuts off the default output (speakers) when the connector is plugged in.*

The first version of the popular Mackie 1604 mixer, the CR1604, used a tip negative, ring positive jack wiring scheme on the main left and right outputs.[29][30]

Early QSC amplifiers used a tip negative, ring positive input wiring scheme.[31]



1. ***Sleeve:*** *usually ground*
2. ***Ring:*** *Right-hand channel for stereo signals, negative polarity for balanced mono signals, power supply for power-using mono signal sources*
3. ***Tip****: Left-hand channel for stereo signals, positive polarity for balanced mono signals, signal line for unbalanced mono signals*
4. ***Insulating rings***

Whirlwind Line Balancer/Splitters do not use the sleeve as a conductor on their unbalanced 6.5 mm/$^1\!/_4$ in TRS phone input. Tip and ring are wired to the transformer's two terminals; the sleeve is not connected.[32]

1.6.1 Balanced audio

When a phone connector is used to make a balanced connection, the two active conductors are both used for a monaural signal. The ring, used for the right channel in stereo systems, is used instead for the inverting input. This is a common use in small audio mixing desks, where space is a premium and they offer a more compact alternative to XLR connectors. Another advantage offered by TRS phone connectors used for balanced microphone inputs is that a standard unbalanced signal lead using a TS phone jack can simply be plugged into such an input. The ring (right channel) contact then makes contact with the plug body, correctly grounding the inverting input.

A disadvantage of using phone connectors for balanced audio connections is that the ground mates last and the socket grounds the plug tip and ring when inserting or disconnecting the plug. This causes bursts of hum, cracks and pops and may stress some outputs as they will be short circuited briefly, or longer if the plug is left half in.

This problem does not occur when using the 'gauge B' (BPO) phone connector (PO 316)[33] which although it is of 0.25 in (6.3 mm) diameter has a smaller tip and a recessed ring so that the ground contact of the socket never touches the tip or ring of the plug. This type was designed for balanced audio use, being the original telephone 'switchboard' connector and is still common in broadcast, telecommunications and many professional audio applications where it is vital that permanent circuits being monitored (bridged) are not interrupted by the insertion or removal of connectors. This same tapered shape used in the 'gauge B' (BPO) plug can be seen also in aviation and military applications on various diameters of jack connector including the PJ-068 and 'bantam' plugs. The more common straight-sided profile used in domestic and commercial applications and discussed in most of this article is known as 'gauge A'.

XLR connectors used in much professional audio equipment mate the ground signal on pin 1 first.

1.6.2 Unbalanced audio

Phone connectors with three conductors are also commonly used as unbalanced audio *patch points* (or *insert points*, or simply *inserts*), with the output on many mixers found on the tip (left channel) and the input on the ring (right channel). This is often expressed as “tip send, ring return”. Other mixers have unbalanced insert points with “ring send, tip return”. One advantage of this system is that the switch contact within the panel socket, originally designed for other purposes, can be used to close the circuit when the patch point is not in use. An advantage of the *tip send* patch point is that if it is used as an output only, a 2-conductor mono phone plug correctly grounds the input. In the same fashion, use of a “tip return” insert style allows a mono phone plug to bring an unbalanced signal directly into the circuit, though in this case the output must be robust enough to withstand being grounded. Combining *send* and *return* functions via single $^1\!/_4$ in TRS connectors in this way is seen in very many professional and semi-professional audio mixing desks, due to the halving of space needed for insert jack fields which would otherwise need two jacks, one for *send* and one for *return*. The tradeoff is that unbalanced signals are more prone to buzz, hum and outside interference.

In some three-conductor TRS phone inserts, the concept is extended by using specially designed phone jacks that will accept a mono phone plug partly inserted *to the first click* and will then connect the tip to the signal path without breaking it. Most standard phone connectors can also be used in this way with varying success, but neither the switch contact nor the tip contact can be relied upon unless the internal contacts have been designed with extra strength for holding the plug tip in place. Even with stronger contacts, an accidental mechanical movement of the inserted plug can interrupt signal within the circuit. For maximum reliability, any usage involving *first click* or *half-click* positions will instead rewire the plug to short tip and ring together and then insert this modified plug all the way into the jack.

The TRS *tip return, ring send* unbalanced insert configuration is mostly found on older mixers. This allowed for the insert jack to serve as a standard-wired mono line input that would bypass the mic preamp. However tip send has become the generally accepted standard for mixer inserts since the early-to-mid 1990s. The TRS *ring send* configuration is still found on some compressor sidechain input jacks such as the dbx 166XL.[34]

In some very compact equipment, 3.5 mm TRS phone connectors are used as patch points.

Some sound recording devices use a three-conductor phone connector as a mono microphone input, using the tip as the signal path and the ring to connect a standby switch on the microphone.

1.7 See also

- Line level

1.8 References

[1] *International Library of Technology: ... Principles of Telephony ...* International Textbook Company, Scranton, PA. 1907.

[2] Robert McLeish (2005). *Radio Production*. Newnes. ISBN 0-240-51972-8.

[3] *Standard Reference Designations for Electrical and Electronics Parts and Equipments: IEEE 200-1975 (Reaffirmed 1988): Section 4.1.5.3*. IEEE and ANSI, New York, NY. 1975.

[4] *Reference Designations for Electrical and Electronics Parts and Equipment: ASME Y14.44-2008 (Replaced IEEE 200-1975): Section 2.1.5.3*. ASME, Fairfield, NJ. 2008.

[5] Gary D. Davis and Ralph Jones (1989). *The Sound Reinforcement Handbook*. Hal Leonard. ISBN 0-88188-900-8.

[6] "*Build a Data Cable for the Yaesu VX-6*".

[7] "Switchcraft Z15J 1/4" High Power Speaker Jack". Full Compass. Retrieved October 24, 2011. High power 2-conductor speaker jack carries 15A (continuous) audio speaker current levels.

[8] Gibson, Bill. (2007) *The Ultimate Live Sound Operator's Handbook*, p. 202. Hal Leonard Corporation. ISBN 1-4234-1971-5

[9] "Switchcraft *Telephone Jack and Telephone Plug Mating Chart*".

[10] page 137

[11] "*Questions Answered 4: Optical Output on the Mac*".

[12] "*Audio input/output on Macbook computers.*".

[13] "MEElectronics - P version headset earphone compatibility". Meelec.com. Retrieved 2013-07-14.

[14] Digital Silence (earphone manufacturer): explanation of TRRS connectors and availability of adapter.

[15] "Wired Analogue Audio". Retrieved 2012-06-01.

[16] http://allaboutwindowsphone.com/flow/item/17561_Jays_AB_headset_for_Windows_Ph.php

[17] https://together.jolla.com/question/6716/headphone-nokia-n9-and-jolla/#post-id-6721

[18] FAQ - What type of wired headsets can I use with my Nokia Lumia phone? - "Nokia Lumia 820 and 920 support both American Headset Jack (AHJ) headsets and standard Nokia OMTP headsets."

[19] Jays AB headset for Windows Phone and a note on headset standards - "Nokia's Windows Phone 8 devices (Nokia Lumia 520, 521, 620, 720, 810, 820, 822, 920, 925, and 928) use a new universal connector, enabling the use of both AHJ and OMTP headsets."

[20] "EIAJ RC-5325A".

[21] "Jays AB headset for Windows Phone and a note on headset standards".

[22] "Android Wired audio headset specification".

[23] "Headset jacks on newer laptops".

[24] "Wired Headsets: A Tutorial on Connectors, Cables & Pinouts".

[25] "Item # TP-120, Telephone Plug". Amphenol Nexus Technologies, Inc. Retrieved 2012-01-12.

[26] "Jack Schematics table".

[27] "Diagrams". Retrieved 2012-05-28.

[28] "Frequently Asked Questions". Retrieved 2012-05-28.

[29] Sweetwater (2000-01-13). "Sweetwater inSync". Sweetwater.com. Retrieved 2013-07-14.

[30] "Silent Way's recording tricks- Mackie CR-1604 mixer". Silentway.com. Retrieved 2013-07-14.

[31] "QSC Audio Products. *Frequently Asked Questions*".

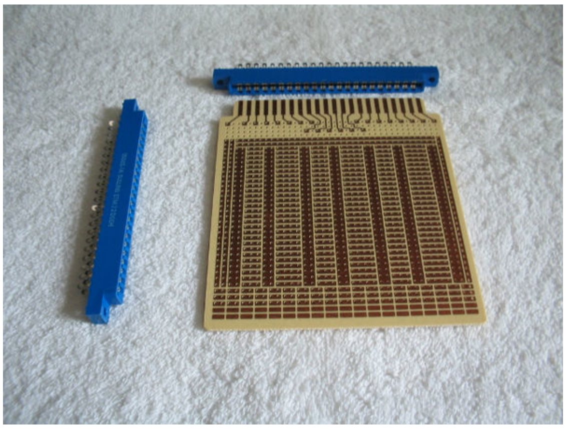
[32]

[33] "*Neutrik mil-b-gauge-type plugs*".

[34] "dbx 166XL compressor with balanced TRS *tip send* input and output jacks and one TRS *ring send* sidechain jack".

Chapter 2

Edge connector



Two 44-pin edge connector sockets (blue objects) and matching circuit board. The Edge connector is 3.5 in (89 mm) long, with 22 contacts on each side

An **edge connector** is the portion of a printed circuit board (PCB) consisting of traces leading to the edge of the board that are intended to plug into a matching socket. The edge connector is a money-saving device because it only requires a single discrete female connector (the male connector is formed out of the edge of the PCB), and they also tend to be fairly robust and durable. They are commonly used in computers for expansion slots for peripheral cards, such as PCI, PCI Express, and AGP cards.

2.1 Socket design

Edge connector sockets consist of a plastic "box" open on one side, with pins on one or both side(s) of the longer edges, sprung to push into the middle of the open center. Connectors are often keyed to ensure the correct polarity, and may contain bumps or notches both for polarity and to ensure that the wrong type of device is not inserted. The socket's width is chosen to fit to the thickness of the connecting PCB.

The opposite side of the socket is often an insulation-piercing connector which is clamped onto a ribbon cable. Alternatively, the other side may be soldered to a motherboard or daughtercard.

2.2 Uses

Edge connectors are commonly used in personal computers for connecting expansion cards and computer memory to the system bus. Example expansion peripheral technologies which use edge connectors include PCI, PCI Express, and AGP. Slot 1 and Slot A also used edge connectors; the processor being mounted on a card with an edge connector, instead of directly to the motherboard as before and since.

IBM PCs used edge connector sockets attached to ribbon cables to connect 5.25" floppy disk drives. 3.5" drives use a pin connector instead.

Video game cartridges typically take the form of a PCB with an edge connector: the socket is located within the console itself. The Nintendo Entertainment System was unusual in that it was designed to use a zero insertion force edge connector:[1] instead of the user forcing the cartridge into the socket directly, the cartridge was first placed in a bay and then mechanically lowered into position.

2.3 See also

- Pin header connector
- Insulation-displacement connector

2.4 References

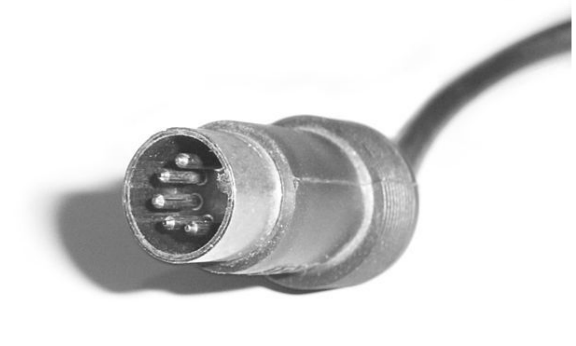
[1] "Nintendo News, Previews, Reviews, Editorials and Interaction". Nintendojo.com. Retrieved 2011-10-20.

Chapter 3

DIN connector

This article is about the standard connector. For other uses, see DIN (disambiguation).

A **DIN connector** is an electrical connector that was



Five-pin male 180° DIN connector from the keyboard of an original IBM PC. Note the unusually thick shielding skirt.

originally standardized by the *Deutsches Institut für Normung* (DIN), the German national standards organization. There are DIN standards for a large number of different connectors, therefore the term "DIN connector" alone does not unambiguously identify any particular type of connector unless the document number of the relevant DIN standard is added (e.g., "DIN 41524 connector"). Some DIN connector standards are:

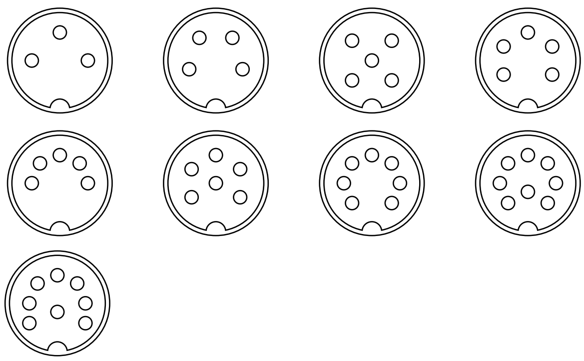
- DIN 41524, for circular connectors often used for audio signals
- DIN 41612, rectangular connectors used to connect plug-in cards to a back plane or motherboard
- DIN 41652 D-subminiature connectors used for computer data and video

In the context of consumer electronics, the term "DIN connector" commonly refers to a member of a family of circular connectors that were initially standardized by DIN for analog audio signals. Some of these connectors have also been used in analog video applications, for power connections and for digital interfaces such as MIDI or the IBM AT computer keyboard (later PS/2 connectors for keyboard and mouse are Mini-DIN connectors). The original DIN standards for these connectors are no longer in print and have been replaced with the equivalent international standard IEC 60130-9.

While DIN connectors appear superficially similar to the newer professional XLR connectors, they are not compatible.

3.1 Circular connectors

All male connectors (plugs) of this family of connectors feature a 13.2 mm diameter metal shield with a notch that limits the orientation in which plug and socket can mate. A range of connectors of the same form that differ only in their pin configuration exist and have been standardized originally in DIN 41524 / IEC/DIN EN 60130-9 (3-pin at 90° and 5-pin at 45°), DIN 45322 (5-pin and 6-pin at 60°), DIN 45323 (6-pin), DIN 45329/IEC 10 (7-pin at 45°), DIN 45326 / IEC/DIN EN 60130-9 (8-pin at 45°), and other standards for a range of different applications, including the following examples:



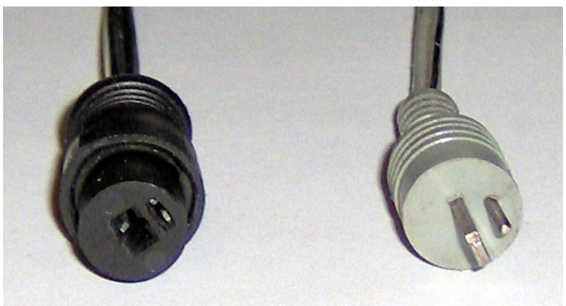
The plugs consist of a circular shielding metal skirt protecting a number of straight round pins. The pins are 1.45 mm in diameter and equally spaced (at 90°, 72°, 60° or 45° angles) in a 7.0 mm diameter circle. The skirt is keyed to ensure that the plug is inserted with the correct orientation, and to prevent damage to the pins. The basic design also ensures that the shielding is connected between socket and plug prior to any signal path connection being made. However, as the keying is consistent across all connectors, it does not prevent incompatible connectors from mating, which can lead to damage; this is changed in Mini-DIN, which keys different connectors.

There are seven common patterns, with any number of pins from three to eight. Three different five-pin connectors exist, known as 180°, 240°, and 270° after the angle of the arc swept between the first and last pin (see figures above). There are also two variations of the six-pin, seven-pin and eight-pin connectors, one where the outer pins form 360° and one where they form 270°.[1] There is some limited compatibility, for example a three-pin connector will fit any 180° five-pin socket, engaging three of the pins and leaving the other two unconnected, a 180° five-pin plug will fit into a seven- or eight-pin socket. 3-pin and 180° 5-pin connectors will also fit the 270° 7-pin and both 8-pin sockets. In addition to these connectors, there are also connectors with 10, 12 and 14 pins. Some high-range equipment used seven-pin connectors where the outer two carried digital system data:[2] if the connected equipment was incompatible, the outer two pins could be unscrewed from plugs so that they fitted into standard five-pin 180° sockets without data connections.

Screw-locking versions of this connector have also been used in instrumentation, process control and professional audio.[3] In North America this variant is often called a "small Tuchel" connector after one of the major manufacturers. Tuchel is now a division of Amphenol. The pin and socket inserts are nearly identical to those used in non-locking connectors, and in some cases locking and non-locking connectors can be mated. Additional configurations up to 24 pins are also offered in the same shell size. A bayonet-locking version was also used on portable tape recorders and dictation machines through the 1980s, an example of this where found from sixties to eighties in the "Report" family of UHER tape recorders, which microphone input connector was fitted with bayonet locking instead of the standard screw. In addition to this, the input pin of such a connector are inverted with respect to DIN standards.

Some manufacturers offered panel-mounted jacks with potential-free auxiliary contacts that would open if a plug were inserted.

3.2 Loudspeaker connector



Speaker DIN line socket (left) and plug (right)

A polarised two-pin unshielded connector, designed for connecting a loudspeaker to a power amplifier (or other device; many of the earlier shoebox style tape recorders used them), is known as the DIN 41529 loudspeaker connector. It exists as a panel-mounting female version, and line-mounted male and female versions. The male version has a central flat pin, and circular pin mounted off-centre. The circular pin is connected to the positive line (red) while the spade is connected to the negative line (black).[4] The panel-mounting female version is available with or without an auxiliary contact that disconnects the internal speaker of the device if an external speaker connector is inserted. Most common is a three-hole female connector with one circular hole on either side of the spade hole, one of them with an aux contact and one without, which provides the option to leave the internal speaker connected by inserting the plug twisted by 180°.

It is now mainly found on older equipment, such as 16 mm movie projectors. The Becker radio found in many Mercedes-Benz automobiles uses this connector. The same connector is used on some LED lamps and halogen lamps to connect the bulb to the power supply. While all other versions of the DIN plug are generally very reliable, the two-pin DIN plug is considered inferior in some ways - the lack of the outer sheath means far less force is required to disconnect the plug accidentally, makes it more prone to bending or shifting of the pins during use, and also not as solidly seated in its socket - worn two-pin speaker plugs on audio equipment are notorious for being very unreliable, often requiring only the slightest nudge to break contact. There are also a three- and four-pin version of this loudspeaker connector used for example by Bang & Olufsen.

3.3 Applications

3.3.1 Analog audio

The 3/180° and 5/180° connectors were originally standardized and widely used in Germany, Czechoslovakia, and, later, in some other western European countries (for example the Netherlands, UK, Sweden), USSR, Comecon countries for interconnecting analog audio equipment, for example a stereo tape recorder to a stereo amplifier or preamplifier, using the five pins for the four signal connections plus ground. The cord used for this has a connector on each end, and the pins are connected pin for pin, that is, pin 1 to pin 1, 2 to 2, etc. Pins on male connectors are numbered (from right to left, viewed from outside of the connector, with the 5 pins upwards, and facing them): 1–4–2–5–3. Holes on female connectors are also numbered 1-4-2-5-3, but from left to right (facing the holes). A four-channel cord wired in this way is sometimes simply called a *DIN cord*, a *DIN lead* or a *DIN cable*. For mono interconnections, the 3/180° plugs are sufficient. When a mono plug is inserted into a stereo socket, it mates with the left channel. This interface was rare in the U.S. market, and has progressively disappeared on new equipment, both in Germany and worldwide, since the 1980s, in favour of RCA connectors.

3.3.2 Other uses

The 5/180° connectors are commonly used for the

- SYNC interface for electronic musical instruments,
- MIDI interfaces for electronic musical instruments,
- Serial ports in the original Apple IIc personal computer,
- In the original IBM PC, PC/XT and PC/AT, as well as the Amiga, for the computer keyboard cable (this connector fell out of use in the mid nineties as the ATX form factor used the PS/2 connector instead).
- The original IBM PC also used this connector type for its cassette port—right next to the keyboard port using the same connector type.
- Audio in the original HME wireless communicators, it is the headset connector for (Tx & Rx) Inbound and Outbound audio for Drive Through Restaurants
- Controlling tilt of UMTS Antennas (Antenna Interface Standards Group)[5]
- Connecting two controllers for radio controlled model aircraft together for training purposes.

The DIN connector saw several other uses outside of audio. It was particularly popular as a data connector for various home microcomputers in the 8-bit era and as an audiovisual connector for several video game consoles. The AT keyboard uses a 5-pin DIN connector; the TurboDuo game console used a 5-pin DIN for its A/V output. Oddly, later versions of the Atari 8-bit computers as well as Commodore C64 and Elektronika BK used a DIN connector for their AC adapter. Also, early C64s that only supported composite video out used a 5-pin DIN for A/V - however, the newer C64s that supported chroma/luma output used an 8-pin DIN to carry extra signals. The Sega Genesis/Mega Drive (Model 1 only), Neo Geo and Neo Geo CD used an 8-pin DIN for their composite, RGB video and mono audio outputs, also providing +5V for using an RF modulator.[6] The Dragon 32 also used four 5-pin DIN connectors for joysticks, tape connection and monitor outputs. The TRS-80 Model I used three identical 5-pin DIN connectors for its AC adapter, video output, and tape recorder, making it easy to destroy the unit if the plugs were confused. Almost the same could be seen on Soviet Elektronika BK home computers, where four 5-pin DIN connectors were used for tape recorder, B/W video output, RGB video output and AC adapter. The Geneve 9640 uses an 8 pin DIN for its composite video, analog RGB, audio, and +12V for an RF modulator. On the Colour Genie, three 5-pin DIN connectors were used for the cassette recorder interface, the lightpen interface and the RS232 interface. The BBC Micro and Acorn Electron used a 270° 7-pin variety, utilising 2 pins for control of the Audio Cassette tape player motor; this family of computers also used a 6-pin DIN for RGB monitor connection, and a 5-pin DIN for the RS423 serial port.

In the Soviet Union, 3-pin and 5-pin DIN connectors named ОНЦ-ВГ (Latin: *ONC-VG*), could be seen on many pieces of equipment, as well as factory-made audio equipment. Radio amateurs and small cooperatives quickly discovered these reliable connectors and began to put them into almost every low frequency signal device, often with non-standard pin usage. Versions other than 3 or 5-pin were very rare in the USSR and very hard to buy. 4-pin DIN connectors, for example, were never seen on any device or in stores.

3.4 See also

- Mini-DIN connector
- PS/2 connector
- XLR connector

3.5 References

[1] "Amabilidade 8-pin DIN Connectors". Amabilidade2002.com. Retrieved 2012-07-28.

[2] "Sounds Heavenly - Help and Advice". Retrieved 2009-03-19.

[3] IEC 60268-11

[4] Carter, Simon (2010). "DIN Connectors". *Electronics 2000*. Retrieved 27 March 2010.

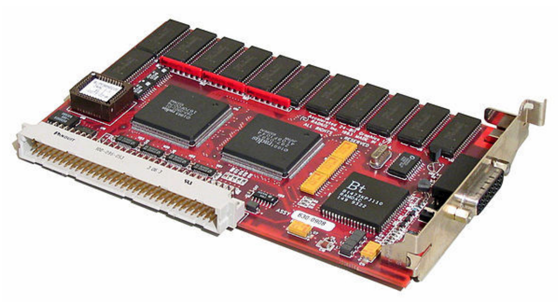
[5] "AISG Website". 5 March 2009. Retrieved 8 May 2009. AISG (13 June 2006). "Control interface for antenna line devices". Retrieved 8 May 2009.

[6] "NEOGEO/CD A/V Pinout". Gamesx.com. Retrieved 2012-07-28.

- DIN Connectors
- IEC 60130-9: Connectors for frequencies below 3 MHz — Part 9: Circular connectors for radio and associated sound equipment. International Electrotechnical Commission, Geneva.
- IEC 60574-3: Audiovisual, video and television equipment and systems — Part 3: Specification for connectors for the interconnection of equipment in audiovisual systems.

Chapter 4

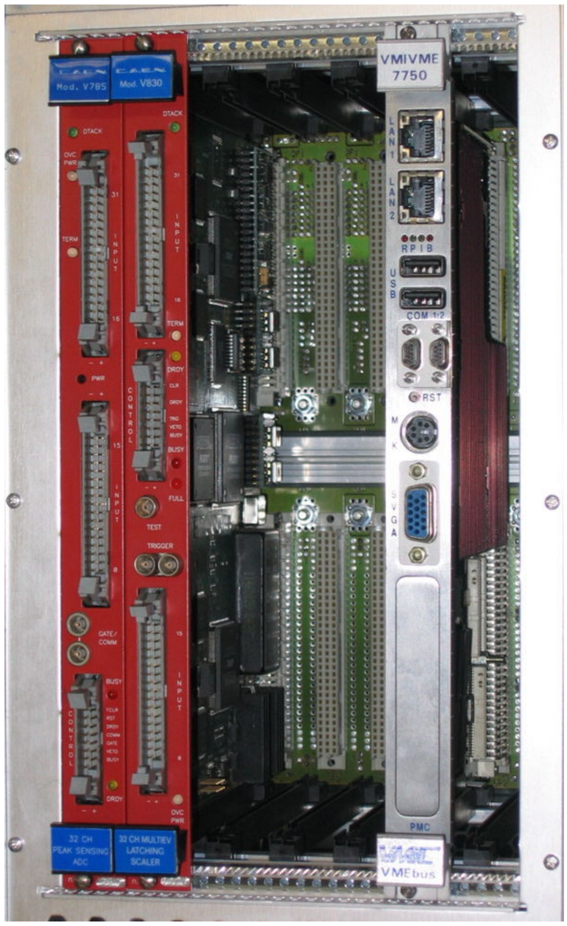
DIN 41612



A NuBus graphics card with a male 3×32 DIN 41612 connector (white, foreground left).

DIN 41612 is a DIN standard for electrical connectors that are widely used in rack based electrical systems. Standardisation of the connectors is a pre-requisite for open systems, where users expect components from different suppliers to operate together. The most widely known use of DIN 41612 connectors is in the VMEbus system. They were also used by NuBus. The standard has subsequently been upgraded to international standards **IEC 60603-2** and **EN 60603-2**.

DIN 41612 connectors are used in STEbus,[1] Futurebus, VMEbus, Multibus II, NuBus, VXI Bus,[2] eurocard TRAM motherboards,[3] and Europe Card Bus, all of which typically use male DIN 41612 connectors on Eurocards plugged into female DIN 41612 on the backplane in a 19-inch rack chassis.



VMEbus crate. 3×32 DIN 41612 female connectors can be seen on the green motherboard in back.

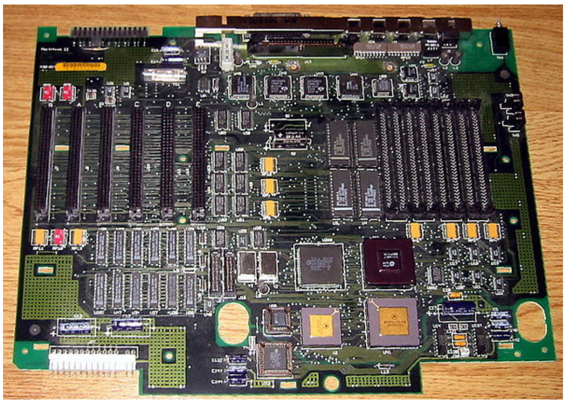
4.1 Mechanical details

The standard describes connectors which may have one, two or three rows of contacts, which are labelled as rows a, b and c. Two row connectors may use rows a+b or rows a+c. The connectors may have 16 or 32 columns, which means that the possible permutations allow 16, 32, 48, 64 or 96 contacts. The rows and columns are on a 0.1 inch (2.54 mm) grid pitch. Insertion and removal force are controlled, and three durability grades are available.

Often the female DIN 41612 connectors have press fit contacts rather than solder pin contacts, to avoid thermal shock to the backplane.[4]

4.2 Electrical details

The headline performance of the connectors is a 2 amp per pin current carrying capacity, and 500 volt working voltage. Both these figures may need to be de-rated according to safety requirements or environmental conditions.



A NuBus motherboard, with six female 3×32 DIN 41612 connectors (black, centre left).

4.3 References

[1] Michael J. Spinks. "Microprocessor System Design: A Practical Introduction". 2013. p. 158.

[2] "Eurocard Connectors per DIN 41612 and IEC 60603-2"

[3] "IMS B012 User Guide and Reference Manual". "Appendix A". 1988.

[4] Andrew Fletcher. "Connector Industry: A Profile of the European Connector Industry". p. 67.

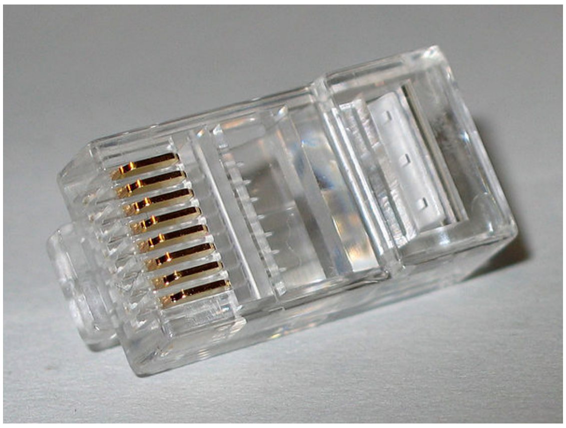
4.4 External links

- VME Bus Connector Mechanical Dimensions

Chapter 5

Modular connector

Left to right, modular connectors: 8P8C plug, 6P6C plug, 6P4C plug, 4P4C plug, 6P6C jack.



An 8P8C modular plug. This is the common crimp type plug, of the same kind pictured above crimped onto a cable (with moulded sleeve)

A **modular connector** is an electrical connector that was originally designed for use in telephone wiring, but has since been used for many other purposes. Many applications that originally used a bulkier, more expensive connector have converted to modular connectors. Probably the most well known applications of modular connectors are for telephone jacks and for Ethernet jacks, both of which are nearly always modular connectors.

Modular connectors were originally used in the Registration Interface system, mandated by the Federal Communications Commission (FCC) in 1976 in which they became known as registered jacks. The registered jack specifications define the wiring patterns of the jacks, not the physical dimensions or geometry of the connectors of either gender. Instead, these latter aspects are covered by ISO standard 8877, first used in ISDN systems. TIA/EIA-568 is a standard for data circuits wired on modular connectors.

Other systems exist for assigning signals to modular connectors; physical interchangeability of plugs and jacks does not ensure interoperation, nor protection from electrical damage to circuits. For example, modular cables and connectors have been used to supply low-voltage AC or DC power and no clear standard exists for this application.

5.1 Nomenclature

Main article: Registered jack § Unofficial plug names

Modular connectors also go by the names "modular phone jack/plug", "RJ connector," and "Western jack/plug." The term "modular connector" arose from its original use in a novel system of cabling designed to make telephone equipment more modular. This includes the 4P4C handset connector.

It is very common to use a registered jack number to refer to the physical connector itself; for instance, the 8P8C modular connector type is often called RJ45 because the Registered Jack standard of that name was an early user of 8P8C modular connectors. A very popular use of 8P8C today is Ethernet over twisted pair, and that may be the most well known context in which the name RJ45 is known, even though it has nothing to do with the RJ45 standard. Likewise, the 4P4C connector is sometimes called RJ9 or RJ22 and various 6P connectors are called RJ11.

5.2 History

Modular connectors were originally developed and patented by General Cable Corp in 1974.[lower-alpha 1] They replaced the hard-wired connections on most Western

Electric telephones around 1976. At the same time, they began to replace screw terminals and larger 3 and 4 pin telephone jacks in buildings.

5.3 Gender

Modular connectors have gender: male connectors are called **plugs,** while female connectors are called **jacks** or, sometimes, **sockets.**

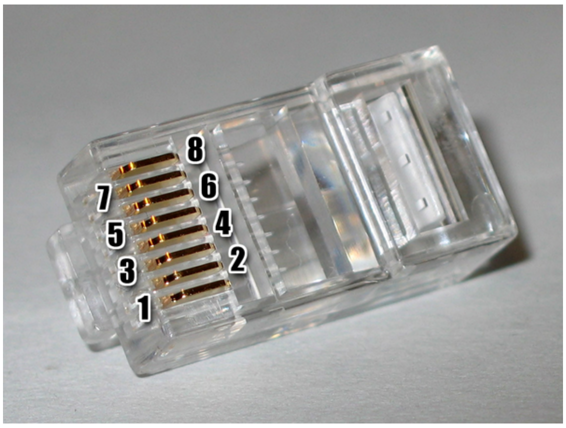
Plugs are used to terminate loose cables and cords, while jacks are used for fixed locations on surfaces such as walls and panels, and on equipment. Other than telephone extension cables, cables with a modular plug on one end and a jack on the other are rare. Instead, cables are connected using a male-to-male adapter, which consists of two female jacks wired back-to-back.

5.4 Latching tab and orientation

Modular connectors are designed to latch together. A spring-loaded tab on the plug snaps into a jack so that the plug cannot be pulled out. To remove the plug, the latching tab must be depressed. The standard and most common way to install a jack in a wall or panel is with the tab side down. This usually makes it easier to operate the tab when removing the plug, because the person grabs the plug with thumb on top and presses the tab up with the index finger. This orientation is recommended by manufacturers because any dust or fine abrasive or conductive particles that may enter an unused jack will tend to fall away from the electrical contacts, rather than settling onto the contact surfaces.

The modular connector suffers from a design flaw or weakness however, as the fragile latching tab easily snags on other cables and breaks off. When this happens, the connector is still functional, but the crucial latching feature is lost. Some higher quality cables have a flexible sleeve called a *boot* over the plug, or a special tab design, to prevent this. These cables are often marketed as **snagless**. Boots are seen mainly on 8P8C data cables, but are also used on other sizes of connectors.

Most protective boots must be installed onto a cable *before* the modular plug is crimped on. This means that field retrofits of these types of boots are not possible, except by cutting off the existing plug, and then replacing it with a new one. However, protective boots or rigid protective "ramp" adapters are available which can be snapped over an installed unprotected modular plug, to add a measure of protection to the latch tab.



8P8C modular plug pin numbering

8P8C plug with contacts for solid wire (left) and stranded wire (right)

contacts for solid wire (top left) and stranded wire (bottom right)

5.5 Sizes and contacts

Modular connectors come in four sizes: 4-, 6-, 8-, and 10-position, where a *position* is a location for a contact. Not all of the positions may have contacts installed. When contacts are omitted, they are typically done so from the outermost pair of contacts inward, such that the number of contacts is almost always an even number. The insulating plastic bodies of 4P and 6P connectors have different widths, whereas 8P or 10P connectors share an even larger body width. The connector body positions with omitted contacts or contacts unattached to wires are unused for the electrical connection, but ensure that the plug fits correctly. For instance, RJ11 cables often have connectors with six positions and four contacts, to which are attached just two wires.

The connectors are designated with two numbers that represent the quantity of positions and contacts, with each number followed by a "P" and "C", respectively: for example, "6P2C" for a connector having six positions and two contacts. Alternate designations omit the "P" and "C" while separating the position and contact quantities with either an "x" ("6x2") or a slash ("6/2").

Internally, the contacts have sharp prongs that when crimped, pierce the insulation and connect with the wire conductor, a mechanism known as insulation displacement. Ethernet cables, in particular, may have solid or stranded wire conductors and the sharp prongs are different in the 8P8C connectors made for each type of wire. A modular plug for solid (single strand) wire often has three slightly splayed prongs on each contact to securely surround and grip the conductor. Modular plugs for stranded or tinsel wire have prongs that are designed to connect to multiple wire strands. Connector plugs are designed for either solid or stranded wire; a plug for one wire type might not make reliable contact when crimped to a cable with wires of the other type.

The contact positions are numbered sequentially starting from 1. When viewed head-on with the retention mechanism on the bottom, jacks will have contact position number 1 on the left and plugs will have it on the right. Contacts are numbered by the contact position. For example, on a six-position, two-contact plug, where the outermost four positions do not have contacts, the innermost two contacts are numbered 3 and 4.

5.5.1 Interchangeability

Some modular connectors are *indexed*: their dimensions are intentionally non-standard, preventing connections with connectors of standard dimensions. The means of indexing may be non-standard cross-section dimensions or shapes, retention mechanism dimensions, or retention mechanism quantity. For example, a Modified Modular Jack (MMJ) using an offset latching tab was developed by Digital Equipment Corporation (DEC) to prevent accidental interchange of data and telephone cables.

The dimensions of modular connectors are such that a narrower plug can be inserted into a wider jack that has more positions than the plug, leaving the jack's outermost contacts unconnected. However, not all plugs from all manufacturers have this capability, and some jack manufacturers warn that their jacks are not designed to accept smaller plugs without damage. If an inserted plug lacks slots to accommodate the jack's contacts at the outermost extremes, it may permanently deform those outermost contacts of an incompatible jack. Excessive resistance may be encountered when inserting an incompatible plug, as the outermost contacts in the jack are forcibly deformed.

Special modular plugs have been manufactured (for example, the Siemon UP-2468[2]) which have extra slots beyond their standard contacts, to accommodate the wider jack's outermost contacts without damage. These special plug connectors can be visually identified by carefully looking for the extra slots molded into the plug. The molded plastic bodies of the special plugs may also be colored with a light blueish tinge, to aid in quick recognition.

The special plugs are preferred for test equipment and adapters, which may be rapidly connected to a large number of corresponding connectors in quick succession for testing purposes. Use of the special plugs avoids inadvertent damage to the equipment under test, even when a narrower plug is inserted into a nominally incompatible wider jack.

The contact spacing is always 1.02 mm (center to center).

5.6 Termination

A modular plug crimper

Termination of modular connector cables is very similar, regardless of the number of positions and contacts in the plug. To prevent damage to the plug (and the expensive crimp die-set), the crimp tool must be carefully matched to the plug being attached. For example, termination of a cable with an 8P8C plug involves using a hand crimper or crimp machine containing an 8P8C die-set or an A67T standard die-set. An 8P8C crimp die-set usually looks similar to an 8P8C jack, except for the eight teeth lining the top portion of the die. When the tool is operated, the die compresses around the 8P8C plug. As the die compresses, these teeth force the plug contacts down into the conductors of the cable being terminated, permanently attaching the plug to the cable.

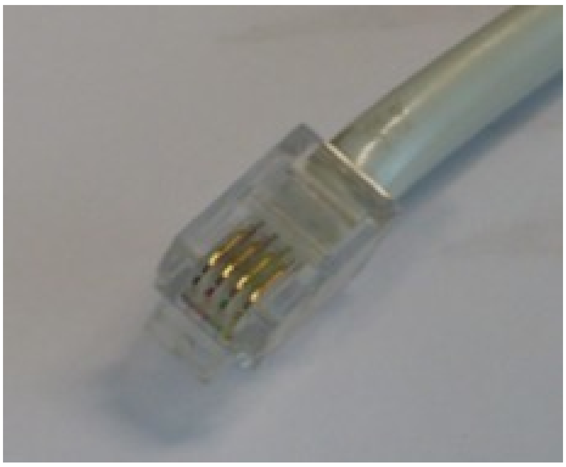
There are two sub-types of plug, that differ only in the type of contacts used. One contact is suitable for solid (single strand) copper conductors and the other is suitable for stranded or tinsel wire copper conductors. The crimper may also permanently deform part of the plastic plug body in such a way that it grips the outer sheath of the cable. This helps to keep the plug securely fastened to the end of the cable, by providing strain relief.

5.7 Pinouts

Contact assignments, or pinouts, vary by application. Telephone network connections are standardized by registered jack numbers, and Ethernet over twisted pair is specified by the TIA/EIA-568-B standard. Other applications have no standardization; for example, there are multiple conventions for use of 8P8C connectors for RS-232.

For this reason, D-sub-to-modular adapters are typically shipped with the D-sub contacts (pins or sockets) terminated but not inserted into the connector body, so that the D-sub-to-modular contact pairing can—and must—be performed by the end-user.

5.8 4P4C



4P4C modular connector on a handset cord

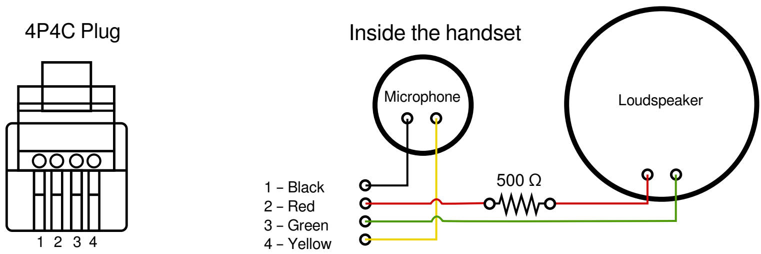
Wired telephone that uses 4P4C connectors for the coiled handset cord

The **4P4C** connector is the standard modular connector used on both ends of telephone handset cords, and is therefore often called a *handset connector*.[4]

This handset connector is not a registered jack, because it was not intended to connect directly to the telephone lines. However, it is incorrectly often referred to as *RJ9*, *RJ10*, or *RJ22*.

5.8.1 Handset wiring

Handsets and often headsets for use with telephones commonly use a 4P4C connector.



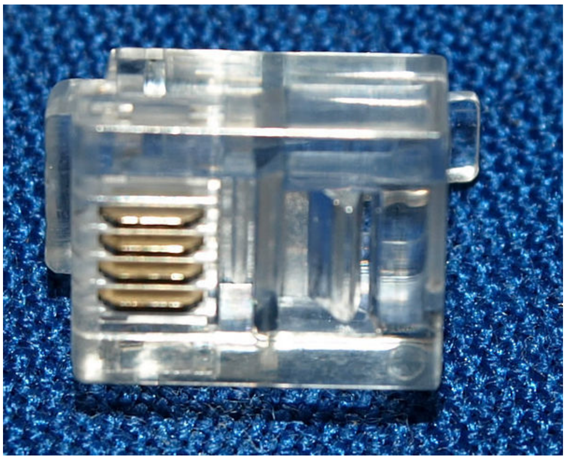
The two center pins are commonly used for the receiver, and the outer pins connect the transmitter, so that a reversal of pin connection is unaffected. Standard handset receivers functions normally when their polarity is reversed, but the electret microphone transmitter used in most modern handsets may not. Many telephones include polarity protection, so that the polarity may be reversed without affecting operation. Old handsets manufactured before 1985 using a carbon microphone transmitter are not sensitive to polarity. Some hands-free headsets also may have a 4P4C connector, but the wiring may differ from the above diagram.

5.8.2 Data port

The Macintosh 128K, Macintosh 512K and Macintosh Plus from Apple used 4P4C connectors to connect the keyboard to the main computer housing. The connector provided power to the keyboard on the outer two contacts and received data signals on the inner pair. The cable between the computer and the keyboard was a coiled cord with an appearance very similar to a telephone handset cable.[5] The connector wiring, however, required a polarized straight through pinout. Using a telephone handset cable instead of the supplied cable could short out the +5 volt DC supply and damage the computer or the keyboard.[6]

Some consumer equipment such as DirecTV set top boxes include a 4P4C low-speed data port connector.[7] Such connectors can be adapted for use with a computer's serial port so that control commands can be sent from the computer to the set top box.

5.9 6P6C



6P4C crimp-on style connector

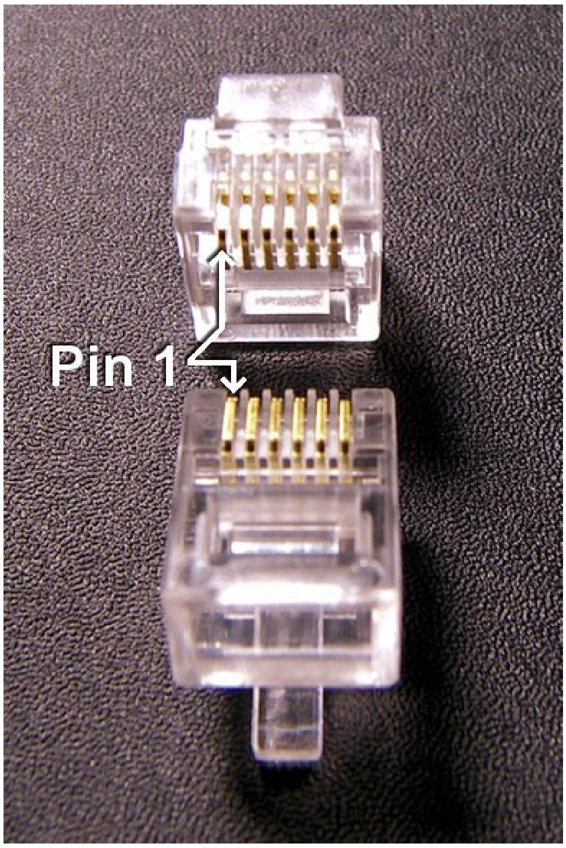
Modular plugs are described as containing a number of potential contact "positions" and the actual number of contacts installed within these positions. RJ11, RJ14, and RJ25 all use the same six-position modular connector, thus are physically identical except for the different number of contacts (two, four and six respectively).

The **6P2C**, **6P4C**, and **6P6C** modular connectors are probably most well known for their use as RJ11, RJ14, and RJ25 registered jacks respectively.

RJ11 is a physical interface often used for terminating telephone wires. It is probably the most familiar of the registered jacks, being used for single line POTS telephone jacks in most homes across the world.

RJ14 is similar, but for two lines, and **RJ25** is for three lines. RJ61 is a similar registered jack for four lines. The telephone line cord and its plug are more often a true RJ11 with only two contacts.

5.9.1 RJ11 wiring



6P6C connector showing the location of pin 1

Cables sold as RJ11 often actually use 6P4C RJ14 connectors (six position, four contacts), with four wires running to a central junction box. Two of its six possible contact positions connect tip and ring, and the other two contact positions are then unused. 6P2C and 6P6C can also be found in stores.

The contacts other than the two central tip and ring contacts are in practice used for various things such as a ground for selective ringers, low voltage power for a dial light, or for 'anti-tinkle' circuitry to prevent pulse dialing phones from ringing the bell on other extensions. With tone dialing, anti-tinkle measures are not required.

5.9.2 Pinouts

The pins of the 6P6C connector are numbered 1–6, counting left to right when holding the connector tab side down with the cable opening toward the viewer.

- **^[a]** While the old solid color code was well established for pair 1 and usually pair 2, there are several conflicting conventions for pair 3 (and sometimes even pair 2). The colors shown above were taken from a vendor of "silver satin" flat 8-conductor phone cable that claims to be standard. 6-pair solid (old) bellwire cables previously used by the Bell System use white for pair 3 tip but some vendors' cable may substitute orange for white. At least one other vendor of flat 8-conductor cable uses the sequence blue, orange, black, red, green, yellow, brown and white/slate.

- **^[b]** This color scheme originates in the (withdrawn) national standard DIN 47100. The scheme shown here is the correct color code for interfacing with the RJ connector standards.

However, with German domestic telephone equipment (and that in some neighbouring countries), 6P4C plugs and sockets are typically only used to connect the telephone cable to the phone base unit, whereas the mechanically different TAE plug is used at the other end of the cable. Older base units may accommodate the additional connectors of TAE (E, W, a2, b2) and may feature non-RJ standard sockets that can be connected "straight" to TAE plugs. Further, flat DIN 47100 cables typically place the wires in ascending order. When used directly with 6P4C plugs, the colors will be scrambled.

5.9.3 Powered version of RJ11

In the powered version, Pins 2 and 5 (black and yellow) may carry low voltage AC or DC power. While the phone line itself (tip and ring) supplies enough power for most telephone terminals, old telephone terminals with incandescent lights in them (such as the classic Western Electric Princess and Trimline telephones) need more power than the phone line can supply. Typically, the power on Pins 2 and 5 comes from a transformer plugged into a wall near one jack, supplying power to all of the jacks in the house. Trimline and Princess phone dial lights are rated at 6.3 volts and the transformer output is typically around 5 volts, providing a long service life for the incandescent lamps.

5.9.4 Compatibility with structured cabling

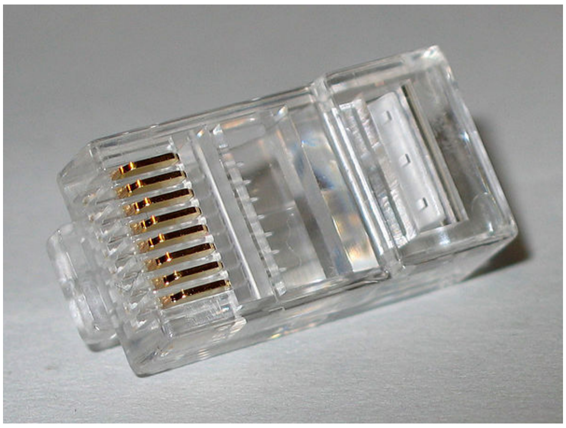
With the rise of Ethernet local area networks operating over Cat5e and Cat6 unshielded twisted pair cable, structured cabling networks adhering to TIA/EIA-568-B, ISO/IEC 11801 or ISO/IEC 15018 (home networks) are widely used for both computer networking and analog telephony, but these standards specify the T568-A or T568-B pin-outs compatible with Ethernet. The 8P8C ("RJ45") jack used by structured cabling physically accepts the 6-position connector used by RJ11, RJ14 and RJ25, but only RJ11 and RJ14 have full electrical compatibility. Ethernet compatible pin-outs "split" the third pair of RJ25 across two separate cable pairs, rendering that pair unusable by an analog phone. This was necessary to preserve the electrical properties of those pairs for Ethernet, which operates at much higher frequencies than analog telephony.

Both the third and fourth pairs of RJ61 are similarly split. Because of this incompatibility, and because they were never very common to begin with, the TIA/EIA-568-B conventions are displacing RJ25 and RJ61 for telephones with more than two lines.

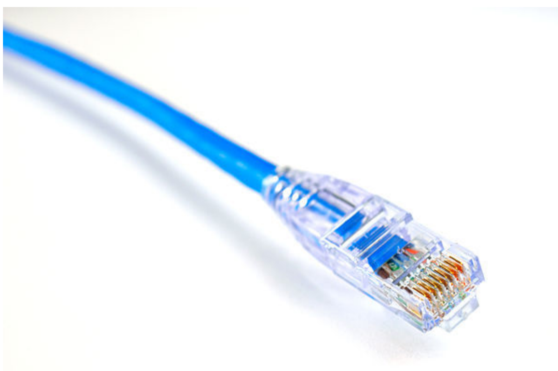
5.10 8P8C

This article is about the generic 8P8C modular connector. For the registered jack (RJ) wiring standard, see registered jack.

The **8 position 8 contact** (**8P8C**) connector is a modu-



An 8P8C modular plug before being crimped onto a cable



Connector and cable

lar connector commonly used to terminate twisted pair and multi-conductor flat cable. These connectors are commonly used for Ethernet over twisted pair, registered jacks and other telephone applications, RS-232 serial using the EIA/TIA-561 and Yost standards, and other applications involving unshielded twisted pair, shielded twisted pair, and multiconductor flat cable.

An 8P8C modular connector has two paired components: the male plug and the female jack, each with eight equally-spaced conducting channels. On the plug, these conductors are flat contacts positioned parallel with the connector body. Inside the jack, the contacts are suspended diagonally toward the insertion interface. When an 8P8C plug is mated with an 8P8C jack, the contacts meet and create an electrical connection. Spring tension in the jack's contacts ensures a good interface with the plug and allows for slight travel during insertion and removal.

Although commonly referred to as an *RJ45* in the context of Ethernet and category 5 cables, it is incorrect to refer to a generic 8P8C connector as an RJ45.[8][9][10] A telephone-system-standard RJ45 plug has a key which excludes insertion in an un-keyed 8P8C socket.[11] The registered jack (RJ) standard specifies a different mechanical interface and wiring scheme for an RJ45S from TIA/EIA-568-B which is often used for modular connectors used in Ethernet and telephone applications. 8P8C modular plugs and jacks look very similar to the plugs and jacks used for FCC's registered jack RJ45 variants, although the RJ45S is not compatible with 8P8C modular connectors.

For more details on the registered jack naming confusion, see Registered jack § Unofficial plug names.

The original RJ45S uses a[12][13] keyed 8P2C modular connector, with Pins 5 and 4 (the middle 2 positions) wired for tip and ring of a single telephone line and Pins 7 and 8 shorting a programming resistor. It was meant to be used with a high speed modem, and is obsolete today.

Telephone installers who wired RJ45S modem jacks or RJ61X telephone jacks were familiar with the pin assignments that were part of the standard. However, the standard un-keyed modular connectors became ubiquitous for computer networking, and informally inherited the name "RJ45". While RJ45S uses a "keyed" variety of the 8P body, meaning it may have an extra tab that a common modular connector is unable to mate with, the visual difference is subtle and likely caused the confusion.

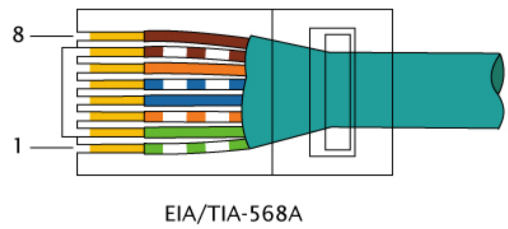
Understandably, because telephone RJ61 and data RJ45/RJ48 connectors never saw wide usage and computer 8P8C connectors are quite well known today, "RJ45" is used to refer to 8P8C, un-keyed modular connectors with Ethernet-type wiring pin-outs. Electronics catalogs commonly advertise 8P8C modular connectors as "RJ45", many electronic equipment manuals using an 8P8C connector will document it as an "RJ45" connector. In common usage, RJ45 may also refer to the pin assignments for the attached cable, which are actually defined as T568A and T568B in wiring standards such as TIA/EIA-568.

5.10.1 Standardization

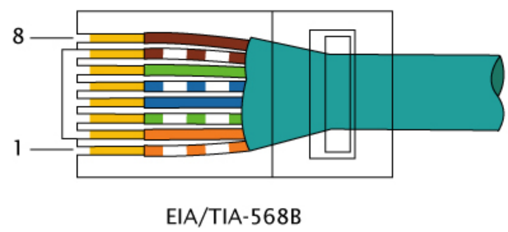
The shape and dimensions of an 8P8C modular connector are specified for US telephone applications by the Administrative Council for Terminal Attachment (ACTA) in national standard ANSI/TIA-1096-A. This standard does not use the short term 8P8C and covers more than just 8P8C modular connectors, but the 8P8C modular connector type is the eight position connector type described therein, with eight contacts installed. The international standard is ISO-8877.

For data communication applications (LAN, structured cabling), International Standard IEC 60603 specifies in parts 7-1, 7-2, 7-4, 7-5, and 7-7 not only the same physical dimensions, but also high-frequency performance requirements for shielded and unshielded versions of this connector for frequencies up to 100, 250 and 600 MHz, respectively.

5.10.2 Pinouts



T568A wiring



T568B wiring

Connectors are frequently terminated using the T568A or T568B pin/pair assignments that are defined in TIA/EIA-568. The drawings to the right show that the copper connections and pairing are the same, the only difference is that the orange and green pairs (colors) are swapped. A cable wired as T568A at one end and T568B at the other (Tx and Rx pairs reversed) is a "crossover" cable. Before the widespread acceptance of auto MDI-X capabilities a crossover cable was needed to interconnect similar network equipment (such as hubs to hubs). A cable wired the same at both ends is called a "patch" or "straight-through" cable, because no pin/pair assignments are swapped. Crossover cables are sometimes still used to connect two computers together without a switch or hub, however most Network Interface Cards (NIC) in use today implement auto MDI-X to automatically configure themselves based on the type of cable plugged into them. If a “patch” or “straight” cable is used to connect two computers with auto MDI-X capable NICs, one NIC will configure itself to swap the functions of its Tx and Rx wire pairs.

5.10.3 Types and incompatibility

Two types of 8P8C plugs and installation tools (used for crimping the plug onto a cable) are commonly available: Western Electric/Stewart Stamping (WE/SS) and Tyco/AMP. While both types look remarkably similar, the tooling used to install the two different plug types is mutually exclusive and cannot be interchanged between the two types. WE/SS compatible plugs are available from a large number of manufacturers, whereas Tyco/AMP plugs are produced exclusively by Tyco Electronics. Both types of modular plugs will plug into the same standard 8P8C modular jack.

WE/SS and Tyco/AMP 8P8C plugs have different spacing for the cable strain relief.[14][15] Thus, using a WE/SS 8P8C crimp die set on a Tyco/AMP 8P8C plug will crush the top of the connector and damage the crimp die set, and vice versa. While the WE/SS compatible plug is produced by a larger number of manufacturers than the Tyco/AMP plug, it is still important to know what style is being used to avoid damaging the plug or tool during crimping.

Both types of 8P8C plugs are available in shielded and unshielded varieties, depending on the attenuation tolerance needed. Shielded plugs are more expensive and require shielded cable, but have a lower attenuation and can reduce signal noise.

Although a narrower 4-pin and 6-pin connector will fit into the wider 8-pin jack, the smaller connector can potentially damage the contacts of the larger, because the outside edges of the smaller connector press onto the contacts of the larger. The outside edges of an RJ11/RJ45 plug typically project out by about 0.5 to 1.0 mm further than the contact surfaces, and these edges press the outermost contacts of the larger connector further than if a full-size connector were plugged in. The smaller connector may therefore permanently bend pins 1,8 or 2,7 of the larger connector.

5.10.4 Applications

8P8C are commonly used in computer networking and telephone applications, where the plug on each end is an 8P8C modular plug wired according to a TIA/EIA standard. Most wired Ethernet network communications today are carried over Category 5e or Category 6 cable with an 8P8C modular plug crimped on each end.

The 8P8C modular connector is also used for RS-232 serial interfaces according to the EIA/TIA-561 standard.[16] This application is common as a console interface on network equipment such as switches and routers. Other applications include other networking services such as ISDN and T1.

In floodwired[lower-alpha 2] environments the center (blue) pair is often used to carry telephony signals. Where so wired, the physical layout of the 8P8C modular jack allows for the insertion of an RJ11 plug in the center of the jack, provided the RJ11 plug is wired in true compliance with the US telephony standards (RJ11) using the center pair. The formal approach to connect telephony equipment is the insertion of a type-approved converter.

The remaining (brown) pair is increasingly used for Power over Ethernet (PoE). Legacy equipment may use just this pair; this conflicts with other equipment, because some manufacturers previously short circuited unused pairs to reduce signal crosstalk. Some routers, bridges and switches can be powered by the unused 4 lines—blues (+) and browns (−)—to carry current to the unit. There is now a standardized wiring scheme for Power over Ethernet.

Different manufacturers of 8P8C modular jacks arrange for the pins of the 8P8C modular connector jack to be linked to wire connectors (often IDC type terminals) that are in a different physical arrangement from that of other manufacturers: Thus, for example, if a technician is in the habit of connecting the white/orange wire to the “bottom right hand” IDC terminal, which links it to 8P8C modular connector pin 1, in jacks made by other manufacturers this terminal may instead connect to 8P8C modular connector pin 2 (or any other pin). Labels and manufacturer’s documentation should be consulted whenever an unfamiliar connector is first encountered.

8P8C modular connectors are also commonly used as a microphone connector for PMR, LMR, and amateur radio transceivers. Frequently the pinout is different, usually mirrored (i.e. what would be pins 1 to 8 in the TIA/EIA-568 standard might be pins 8 to 1 in the radio and its manual.

In landline telephony, an 8P8C jack is used at the point a line enters the building to allow the line to be broken to insert automatic dialling equipment, including intrusion alarm panels. In analogue mobile telephony, the 8P8C connector was used to connect an AMPS cellular handset to its (separate) base unit; this usage is now obsolete.

The “RJ45” physical connector is standardized as the IEC 60603-7 8P8C modular connector with different “categories” of performance, with all eight conductors present but 8P8C is commonly known as RJ45. The physical dimensions of the male and female connectors are specified in ANSI/TIA-1096-A and ISO-8877 standards and normally wired to the T568A and T568B pinouts specified in the TIA/EIA-568 standard to be compatible with both telephone and Ethernet.

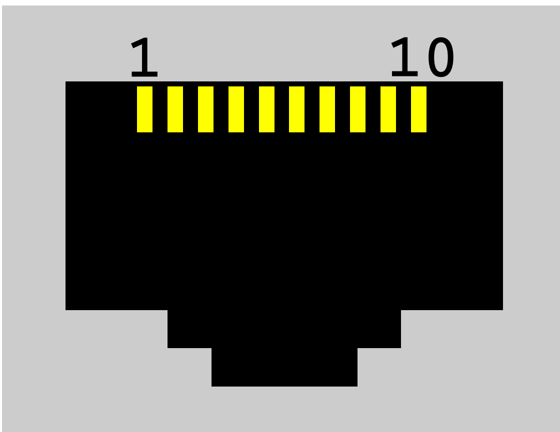
A similar standard jack once used for modem/data connections, the RJ45S, used a "keyed" variety of the 8P8C body with an extra tab that prevents it mating with other connectors; the visual difference compared to the more common 8P8C is subtle, but it is a different connector. The original RJ45S[17][18] keyed 8P2C modular connector had pins 5 and 4 wired for tip and ring of a single telephone line and pins 7 and 8 shorting a programming resistor, but is obsolete today.

Electronics catalogs commonly advertise 8P8C modular connectors as "RJ45". An installer can wire the jack to any pin-out or use it as part of a generic structured cabling system such as ISO/IEC 15018 or ISO/IEC 11801 using RJ45 patch panels for both phone and data. Virtually all electronic equipment which uses an 8P8C connector (or possibly any 8P connector at all) will document it as an "RJ45" connector.

5.10.5 Crossover cables

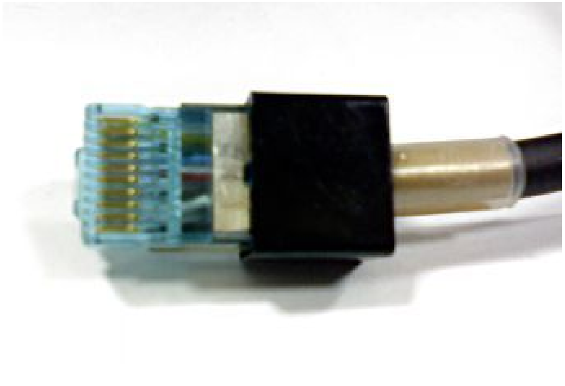
A router to router crossover cable uses two 8 position connectors and a UTP (Unshielded Twisted Pair) cable with differently wired connectors at each end. Although a registered jack specifies the wiring pattern and corresponding form factor rather than just the pin assignments or the physical connector, crossover cables are often incorrectly marketed as "RJ45 crossover cables".

5.11 10P10C



The pin arrangement for a 10P10C socket

The 10P10C connector is commonly referred to as an **RJ50** connector, although this was never a standard registered jack in the Universal Service Order Codes. The 10P10C has 10 contact positions and 10 contacts.



A 10P10C plug

The most common uses of the 10P10C connector are in proprietary data transfer systems,[19] such as the Digiboard[20] and Equinox Super-Serial multi-port TIA-232 adapters.[20] 10P10C connectors are also used to implement RS-485 interfaces, and for data link connections in APC and Eaton uninterruptible power supplies. In the latter case, a keyed 10P10C plug with a protrusion on the pin 1 side near the back is used.

This connector is also used by some vendors, such as BOCA, for expansion modules of their multi-port RS-232C serial boards. For example, Cyclades (later absorbed by Equinox) used pin 1 as an "RI" (ring indicator) signal, which is seldom used, allowing an 8P8C plug to be inserted to their 10P10C socket for most applications. The Cisco Systems STS-10X terminal server features this connector. FordNet, a five-pair communications networking medium, also used the 10P10C between terminals.

Motorola uses the 10-pin connector as a microphone connector in several of their mobile radio product lines.

The 10-pin connector is also used by Demag Cranes AG[21] in some pendant connections. National Instruments is also using the 10p10c connector for their NI 9237.[22]

MTS Systems Corporation is using the 10p10c connector for their MTS FlexTest® Controller Family.

5.12 See also

- ARJ45
- BS 6312: British equivalent to RJ25
- GG45
- Telephone plug
- TERA
- EtherCON ruggedized 8P8C Ethernet connector

5.13 Notes

[1] Patent filed 12 Nov 1971; U.S. Patent 3,789,344 issued 29 January 1974.[1]

[2] *Floodwire* is a chiefly British term for installing communications cables in a massive fashion in anticipation of their eventual use.

5.14 References

[1] https://www.google.com/patents/US3789344?dq=ininventor:%22Brorein+W%22&hl=en&sa=X&ei=4ELmVNKEL8H7sASDsYCYAw&ved=0CC0Q6AEwAg

[2] "Universal Modular Plug".

[3] "Modular Connectors" (PDF). Cambridge connectors. Retrieved 2012-09-28.

[4] BICSI (October 7, 2002). "Background Information". *Telecommunications Cabling Installation* (2nd ed.). McGraw-Hill Professional. p. 88. ISBN 0-07-140979-3. 4-position and 4-contact connectors are used primarily for telephone handset cords.

[5] "Apple Macintosh Plus", *My Old Computers*.

[6] "Mac Plus Keyboard Cable", *Syrinx*, UK: Megadon, ...the cable is the same as the telephone cable that connects handsets to the phone, unfortunately [...] this type of cable and pretty much any type of pre manufactured cable [...] is wired wrong for the Mac Plus. Under no circumstances should you use this cable as you will damage your keyboard and/or your Mac!

[7] *Direc TV Channel Control* (wiki), GBPVR, Each end of a handset cord is wired opposite the other...

[8] Trulove 2005, pp. 23, 132: '*Designing LAN Wiring Systems*: The 8-pin modular jack is sometimes referred to as an "RJ-45," because the connector/jack components are the same. However, RJ-45 actually applies to a special purpose jack configuration that is not used in LAN or standard telephone wiring. [...] *Work Area Outlets*: Modular jacks are often referred to as "RJ-45" jacks. This is not really the correct moniker, although it is in very common use.'

[9] Oliviero, Andrew; Woodward, Bill (July 20, 2009). "Connectors". *Cabling: The Complete Guide to Copper and Fiber-Optic Networking* (4th ed.). Sybex. p. 294. ISBN 0-470-47707-5. The RJ (registered jack) prefix is one of the most widely (and incorrectly) used prefixes in the computer industry; nearly everyone, including people working for cabling companies, is guilty of referring to an eight-position modular jack (sometimes called an 8P8C) as an RJ-45.

[10] Semenov, Andrey B.; Strizhakov, Stanislav K.; Suncheley, Igor R. (October 3, 2002). "Electrical Cable Connectors". *Structured cable systems*. Springer. p. 129. ISBN 3-540-43000-8. The traditional 8-contact connector, which is called Western Plug, 8PMJ (8-position modular jack), 8P8C (8 position 8 conductor), or somewhat incorrectly RJ-45, is used widely in SCS practice.

[11] Trulove 2005, p. 219: '*User Cords and Connectors*: This 8-pin modular plug is probably the most subject to name abuse, because it resembles the specialized RJ-45 connector. However, the RJ-45 wiring pattern (which includes an interface programming resistor) is so radically different from that of T568A and B that it really should not be called by that name at all.'

[12] *Modular jack wiring*, Ontario, CA: HVS

[13] *Modular wiring reference*, Siemon

[14] "Stewart Connector 937-SP-3088 – Eight conductor/eight position line cord module" (PDF). Glen Rock, PA: Bel Stewart Connector. 2006-02-01. Retrieved 2009-09-10.

[15] "Tyco/AMP 5-554739-2 – Modular plug assembly, 8 position, flat oval cable" (PDF). Harrisburg, PA: Tyco Electronics. 2008-03-31. Retrieved 2009-09-10.

[16] "RJ45", *Layer 1*, Zytrax.

[17] "Modular Jack Wiring". Ontario, CA: HVS. Retrieved 2010-10-14.

[18] "Modular Wiring Reference". Siemon. Retrieved 2010-10-14.

[19] *10 pin RJ50 (10P10C) male* (connector diagram and applications), Pinouts guide

[20] *Digi PortServer TS 10P10C (RJ50) Modular RS-232 pinout*, Pinouts guide.

[21] *Demag cranes AG*.

[22] *NI 9237 4-Channel, ±25 mV/V, 24-Bit Simultaneous Bridge Module specifications*.

5.15 Bibliography

- Trulove, James (December 19, 2005), *LAN wiring* (3rd ed.), McGraw-Hill Professional, ISBN 0-07-145975-8.

5.16 Standards

- ANSI/TIA-968-A: Telephone terminal equipment: Technical requirements for connection of terminal equipment to the telephone network
- ANSI/TIA-1096-A: Telecommunications telephone terminal equipment connector requirements for connection of terminal equipment to the telephone network
- IEC 60603-7-1: Connectors for electronic equipment: Part 7-1: Detail specification for 8-way, shielded free and fixed connectors with common mating features, with assessed quality

- IEC 60603-7-2: Connectors for electronic equipment: Part 7-2: Detail specification for 8-way, unshielded, free and fixed connectors, for data transmissions with frequencies up to 100 MHz
- IEC 60603-7-4: Connectors for electronic equipment: Part 7-4: Detail specification for 8-way, unshielded, free and fixed connectors, for data transmissions with frequencies up to 250 MHz
- IEC 60603-7-5: Connectors for electronic equipment: Part 7-5: Detail specification for 8-way, shielded, free and fixed connectors, for data transmissions with frequencies up to 250 MHz
- IEC 60603-7-7: Connectors for electronic equipment: Part 7-7: Detail specification for 8-way, shielded, free and fixed connectors, for data transmissions with frequencies up to 600 MHz
- ISO/IEC 8877, EN 28877: Information Technology—Telecommunications and Information Exchange between Systems—Interface Connector and Contact Assignments for ISDN Basic Access Interface Located at Reference Points S and T
- Registered Jack references are US government documents that define modular connectors for telecommunications. (Note: 4P4C and 10P10C connectors are NOT defined in these standards.)

5.17 External links

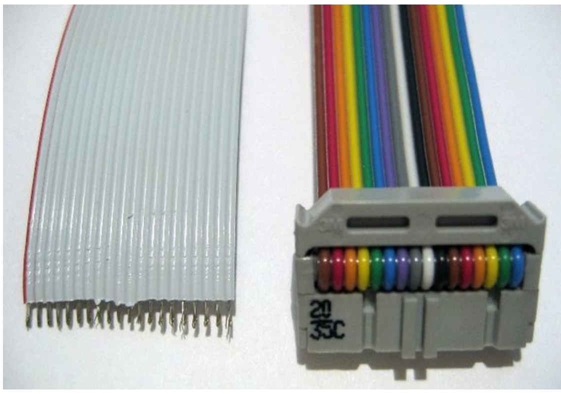
- How to Make a Network Cable, a how-to article from wikiHow
- John R. Carlsen: On wiring modular telephone connectors
- Modular wiring reference showing differences between 8P8C, true RJ45 8-position keyed connector, 6P6C, and 6-position modified offset tab
- Common outlet configurations graphical representation of twisted pair pinouts
- Catalog page showing the difference between solid and stranded contacts
- List of pinouts for many applications of 8P8C connectors

Chapter 6

Ribbon cable

For the 300-ohm antenna cable, see Twin-lead.

A **ribbon cable** (also known as multi-wire planar cable)



Left: 20-way grey ribbon cable with wire no. 1 marked red, insulation partly stripped. Right: 16-way rainbow ribbon with IDC connector.

is a cable with many conducting wires running parallel to each other on the same flat plane. As a result the cable is wide and flat. Its name comes from its resemblance to a piece of ribbon.[1]

Ribbon cables are usually seen for internal peripherals in computers, such as hard drives, CD drives and floppy drives. On some older computer systems (such as the BBC Micro and Apple II series) they were used for external connections as well. The ribbon-like shape interferes with computer cooling by disrupting airflow within the case and also makes the cables awkward to handle, especially when there are a lot of them; as a result, round cables have almost entirely replaced ribbon cables for external connections and are increasingly being used internally as well.

6.1 History

The ribbon cable was invented in 1956 by Cicoil Corporation, a company based in Chatsworth, California. The company's engineers figured out how to use a new material, silicone rubber, to 'mold' a flat cable containing multiple conductors of the same size. Since the cable looked like a flat ribbon or tape, it was named a ribbon cable. The ribbon cable allowed companies like IBM and Sperry/Univac to replace bulky, stiff round cables with sleek, flexible ribbon cables.

The early ribbon cables were used in the mainframe computer industry, on card readers, card punching machines, and tape machines. Subsequently ribbon cables were manufactured by a number of different companies, including 3M. Methods and materials were developed to simplify and reduce the cost of ribbon cables, by standardizing the design and spacing of the wires, and the thickness of the insulation, so that they could be easily terminated through the use of insulation displacement connectors (IDC). Due to the simplicity of ribbon cables, their low profile, and low cost due to standardization, ribbon cables are used today in most computers, printers, and many electronic devices.

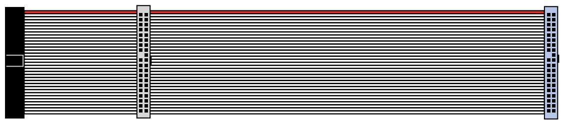
During the 1960s and 1970s the company provided flat cables for NASA and the US Government. In the 1990s Cicoil developed a unique extrusion process to make ribbon cables and flat flexible cables out of wires, hollow tubing, coaxial cable, and fiber optics. These cables are used in applications including missiles, satellites, semiconductor manufacturing equipment, and medical equipment.

6.2 Color-coding

To reduce the risk of reversed connections—which could potentially damage hardware—either when making a cable or when using a cable with unpolarized connectors, one edge of the cable is usually marked with a red stripe. By convention the edge with the stripe is connected to pin 1 on the connector. This method of identification is fine for cables that just consist of two or more IDC connectors with every connector connecting to every wire, but is somewhat less helpful when individual wires or small groups of wires must be terminated separately.

To make it easier to identify individual conductors in a cable; ribbon-cable manufacturers introduced rainbow ribbon cable, which uses a repeating pattern of colors borrowed from the standard resistor color code (Brown is pin 1 or pin 11 or pin 21, etc. Red is pin 2 or pin 12 or pin 22, etc.). It is often known affectionately to its users as "hippie cable" due to its distinct appearance. However, this has remained a specialized and relatively expensive product.

6.3 Sizes



Ribbon cable with three connectors

Ribbon cables are usually specified by two numbers: the spacing or *pitch* of the conductors, and the number of conductors or *ways*. A spacing of 0.05 inch (1.27 mm) is the most usual, allowing for a two-row connector with a pin spacing of 0.1 inch (2.54 mm). These types are used for many types of equipment, in particular for interconnections within an enclosure. For personal computers, this size is used today in floppy-disk-drive cables and older or custom Parallel ATA cables.

Based on availability of standard connectors, the number of conductors is usually restricted to a few values, These include 4, 6, 8, 9, 10, 14, 15, 16, 18, 20, 24, 25, 26, 34, 37, 40, 50, 60, 64 and 80. The wire is usually stranded copper wire, usually either 0.32, 0.20, or 0.13 mm^2 (22, 24, or 26 AWG).

Finer and coarser pitch cables are also available. For instance, the high-speed ATA interface cable used for computer hard disk interfaces ULTRA-ATA has 0.025-inch (0.64-mm) pitch. Finer pitches, as small as 0.3 mm, are found in portable electronic equipment, such as laptops; however, portable electronic equipment usually uses flexible flat cables (FFC).

6.4 Connectors

The main point of ribbon cables is to allow mass termination to specially designed IDC connectors in which the ribbon cable is forced onto a row of sharp forked contacts. (The phrase "IDC connector" is widely used, even though it is redundant—an example of RAS syndrome.) Most commonly termination is done at both ends of the cable, although sometimes (for example, when making a lead that needs to change wiring between the two connectors) only one end will be IDC terminated, with the other end being terminated in a regular crimp or solder-bucket connection. Although it is sometimes possible to dismantle and re-use IDC connectors, they are not designed to allow this to be done easily.

Popular types of connectors available with IDC termination suitable for ribbon cable include

- BT224 connector – also defined by BS9525-F0023, DIN41651, MIL-C-83503 standards; these are the type used on ATA cables and are often simply called "IDC connectors". They mate with either a purpose-made plug or a two-row grid of header pins with 0.1 inch (2.54 mm) spacing.
- D-subminiature connector – used for serial ports and printer ports (however IDC D connectors are far less common than crimp and solder bucket types).
- Micro ribbon connector - used for 36-pin printer ports (IEEE 1284 - "Centronics") and 50-pin SCSI ports.
- DIN 41612 connector – used for Eurocard buses.
- PCB transition headers – has two rows of pins with the same spacings as BT244 connectors. Intended to be soldered directly into a PCB.
- DIL headers – Has pins with the same spacings as standard DIL ICs. Generally used where for some reason it is desired to replace an IC with a connection to an external device (*e.g.,* in-circuit emulators). Can also be used like a PCB transition header, especially on stripboard. (Fitting a standard-spacing header to stripboard is tricky, because you have to cut the tracks between two holes rather than on a hole.)

When electronics hobbyists are working on their computers or digital musical keyboards to "mod" (modify) or "hack" them, they sometimes have to solder ribbon cables. Soldering ribbon cables can present a challenge to a hobbyist who has not been trained as an electronics technician. In some cases, hobbyists strip off the wire with a fine razor, and then separate the wires before soldering them. Some hobbyists use fine sandpaper to wear away the plastic insulation from the wires. The sanding also primes the copper tracks. Then when the "tinned" soldering iron is touched onto the bare wire, the solder is guided into the track.

6.4.1 Interference

From a digital point of view, ribbon cable is an ideal way to connect two devices. However, from an analog point of view, these cables are problematic. Around 1980, the U.S. Federal Communications Commission (FCC) discovered that ribbon cables were highly efficient antennas, broadcasting essentially random signals across a wide band of the electromagnetic spectrum. These unintended signals could interfere with domestic TV reception, putting "snow" on the screen. The FCC issued edicts and injunctions to the personal-computer industry, restricting the use of ribbon cables to connect devices together. "Naked" ribbon cable could be used inside the case of a computer or peripheral device, but any ribbon cable connecting two boxes together had to be grounded. This rule led to solutions such as ribbon cables covered by a copper-braid shield, which made it impossible to see or separate the individual connectors. On the Apple II, these cables passed through the holes on the back of the computer that were grounded to the power supply. Eventually, ribbon connectors were replaced, for inter-connect purposes, by a wide profusion of custom-designed round cables with molded connectors.

6.4.2 Impedance

One of the most popular sizes of ribbon cable employs 26AWG wire. Using the common 0.050” spacing and common PVC insulation the resultant impedance for any two adjacent wires within the cable is; Z = 110 - 130 (ohms).[2] The precise number will vary a few percent due to materials. Knowledge of the impedance is one step toward understanding and control of interference that may be caused by ribbon cables.

6.4.3 Proper Usage

According to NASA standards, the minimum bend radius for short term uses should be no less than 6 diameters, and no less than 10 diameters for long term use.[3]

6.5 See also

- Flexible flat cable (FFC)

6.6 References

[1] Hunter Cable Assembly Ltd. “Ribbon-and-Flat-Cable-Assemblies-whitepaper.pdf”. *white paper*. Hunter Cable Assembly.

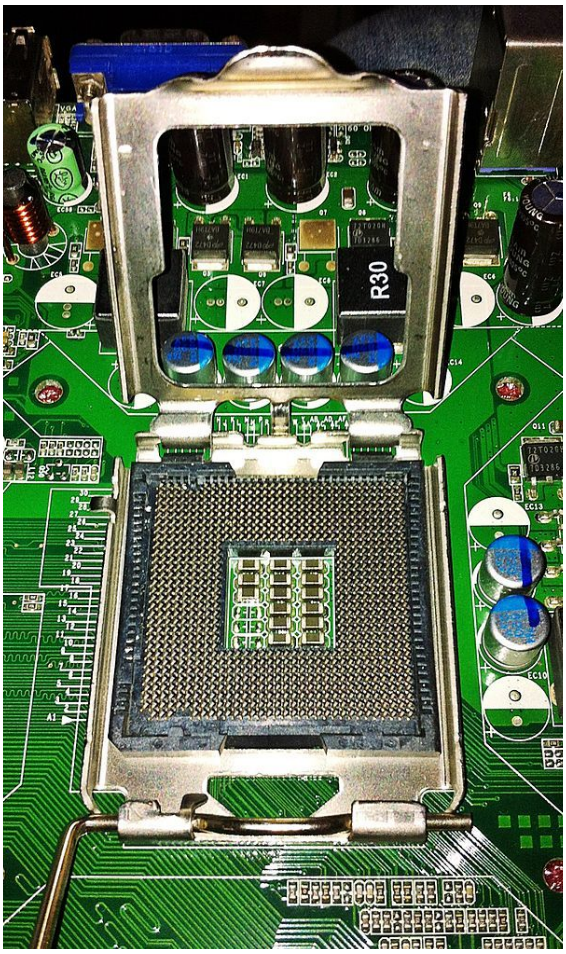
[2] Digital Systems Engineering, William J. Dally, John W. Poulton, page 52 “2.7.2.2 Ribbon cable”

[3] Gregory, Frederick D. “NASA-STD 8739.4: Crimping, Interconnecting Cables, Harnesses, and Wiring”. *hq.nasa.gov*. National Aeronautics and Space Administration. p. 36. Retrieved 5 December 2014.

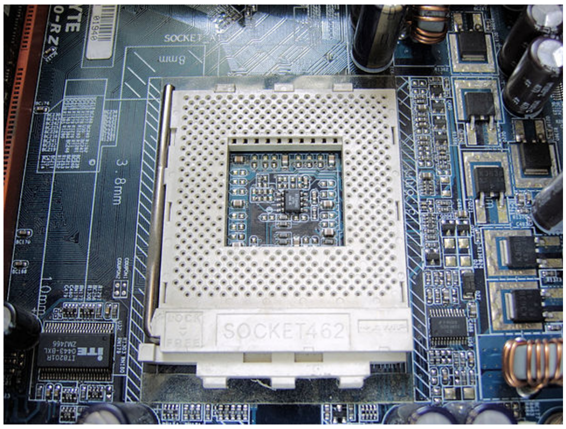
- Product Design for Manufacture and Assembly, Third Edition page 143-144 “4.4 Types of wires and cables”
- Digital Systems Engineering, William J. Dally, John W. Poulton, page 52 “2.7.2.2 Ribbon cable”

Chapter 7

CPU socket



LGA 775, an LGA Socket



Socket A (also known as Socket 462)

A **CPU socket** or CPU slot is a mechanical component(s) that provides mechanical and electrical connections between a microprocessor and a printed circuit board (PCB). This allows the CPU to be placed and replaced without soldering.

Common sockets have retention clips that apply a constant force, which must be overcome when a device is inserted. For chips with a large number of pins, either zero insertion force (ZIF) sockets or land grid array (LGA) sockets are used instead. These designs apply a compression force once either a handle (for ZIF type) or a surface plate (LGA type) is put into place. This provides superior mechanical retention while avoiding the risk of bending pins when inserting the chip into the socket.

CPU sockets are used in desktop and server computers. As they allow easy swapping of components, they are also used for prototyping new circuits. Laptops typically use surface mount CPUs, which need less space than a socketed part.

7.1 Function

A CPU socket is made of plastic, a lever or latch, and metal contacts for each of the pins or lands on the CPU. Many packages are keyed to ensure the proper insertion of the CPU. CPUs with a PGA (pin grid array) package are inserted into the socket and the latch is closed. CPUs with an LGA package are inserted into the socket, the latch plate is flipped into position atop the CPU, and the lever is lowered and locked into place, pressing the CPU's contacts firmly against the socket's lands and ensuring a good connection, as well as increased mechanical stability.

7.2 List of 80x86 sockets and slots

7.3 Slotkets

Slotkets are special adapters for using socket processors in bus-compatible slot motherboards.

7.4 See also

- List of AMD microprocessors
- List of Intel microprocessors

7.5 References

[1] "Intel 815 Chipset Family". intel.com. Retrieved 2009-05-04.

[2] "423 Pin Socket (PGA423) Design Guidelines". intel.com. Retrieved 2009-05-03.

[3] "Intel Pentium 4 Processor 478-Pin Socket (mPGA478) Design Guidelines". intel.com. Retrieved 2009-05-03.

[4] "495-Pin and 615-pin micro-PGA ZIF Socket Design Specification Application Note". intel.com. Retrieved 2009-05-03.

[5] "mPGA 604 Socket Mechanical Design Guide". intel.com. Retrieved 2009-05-03.

[6] "AMD Sempron Processor Product Data Sheet". amd.com. Retrieved 2009-05-03.

[7] "AMD Opteron Processor Product Data Sheet". amd.com. Retrieved 2009-05-03.

[8] CPU only has 478 pins, but the socket has 479.

[9] "LGA775 Socket Mechanical Design Guide". amd.com. Retrieved 2009-05-04.

[10] "LGA771 Socket Mechanical Design Guide". intel.com. Retrieved 2009-05-03.

[11] "Low-Profile Socket S1 Design Specification". amd.com. Retrieved 2009-05-03.

[12] "Thermal Design Guide for Socket F (1207) Processors". amd.com. Retrieved 2009-05-06.

[13] CPU only has 938 pins, but the socket has 941.

[14] AMD Documentation "Socket AM3 design Specification". amd.com. Retrieved 2012-01-05.

7.6 External links

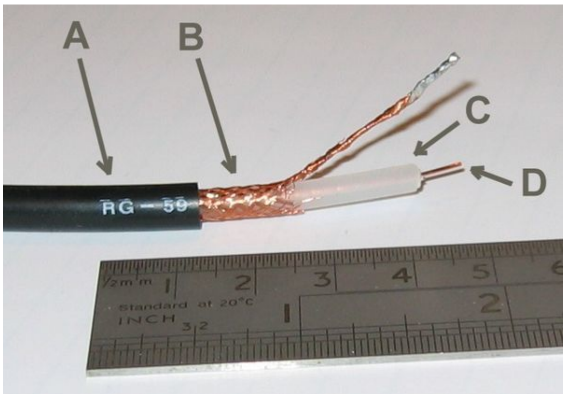
- Socket ID Guide
- CPU Sockets Chart - A fairly detailed table listing x86 Sockets and associated attributes.
- techPowerUp! CPU Database
- Processor sockets

Chapter 8

Coaxial cable

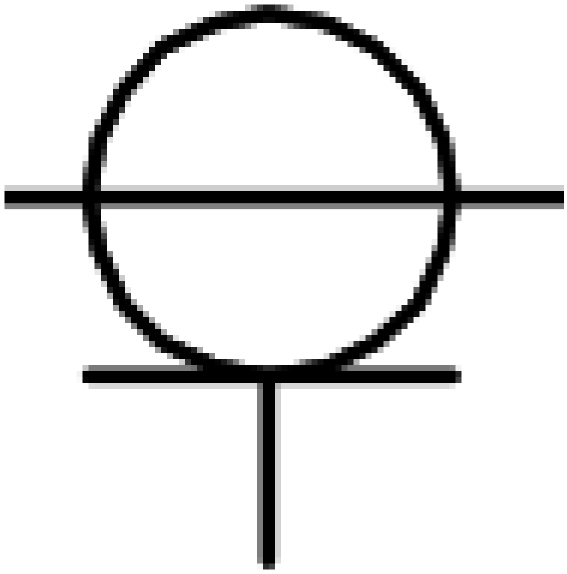
"Coax" redirects here. For the act of coaxing, see Persuasion.

Coaxial cable, or **coax** (pronounced /ˈkoʊ.æks/), is a type of cable that has an inner conductor surrounded by a tubular insulating layer, surrounded by a tubular conducting shield. Many coaxial cables also have an insulating outer sheath or jacket. The term coaxial comes from the inner conductor and the outer shield sharing a geometric axis. Coaxial cable was invented by English engineer and mathematician Oliver Heaviside, who patented the design in 1880.[1] Coaxial cable differs from other shielded cable used for carrying lower-frequency signals, such as audio signals, in that the dimensions of the cable are controlled to give a precise, constant conductor spacing, which is needed for it to function efficiently as a radio frequency transmission line.



RG-59 ***flexible coaxial cable*** *composed of:*

1. *Outer plastic sheath*
2. *Woven copper shield*
3. *Inner dielectric insulator*
4. *Copper core*



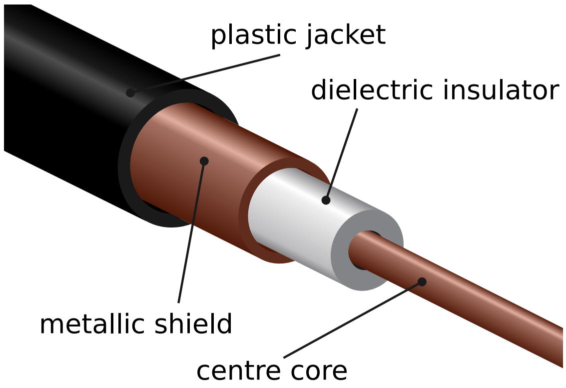
Electronic symbol for a coaxial cable

8.1 Applications

Coaxial cable is used as a transmission line for radio frequency signals. Its applications include feedlines connecting radio transmitters and receivers with their antennas, computer network (Internet) connections, and distributing cable television signals. One advantage of coaxial over other types of radio transmission line is that in an ideal coaxial cable the electromagnetic field carrying the signal exists only in the space between the inner and outer conductors. This allows coaxial cable runs to be installed next to metal objects such as gutters without the power losses that occur in other types of transmission lines. Coaxial cable also provides protection of the signal from external electromagnetic interference.

8.2 Description

Coaxial cable conducts electrical signal using an inner conductor (usually a solid copper, stranded copper or copper plated steel wire) surrounded by an insulating



Coaxial cable cutaway (not to scale)

layer and all enclosed by a shield, typically one to four layers of woven metallic braid and metallic tape. The cable is protected by an outer insulating jacket. Normally, the shield is kept at ground potential and a voltage is applied to the center conductor to carry electrical signals. The advantage of coaxial design is that electric and magnetic fields are confined to the dielectric with little leakage outside the shield. Conversely, electric and magnetic fields outside the cable are largely kept from causing interference to signals inside the cable. Larger diameter cables and cables with multiple shields have less leakage. This property makes coaxial cable a good choice for carrying weak signals that cannot tolerate interference from the environment or for higher electrical signals that must not be allowed to radiate or couple into adjacent structures or circuits.[2]

Common applications of coaxial cable include video and CATV distribution, RF and microwave transmission, and computer and instrumentation data connections.[3]

The characteristic impedance of the cable (Z_0) is determined by the dielectric constant of the inner insulator and the radii of the inner and outer conductors. A controlled cable characteristic impedance is important because the source and load impedance should be matched to ensure maximum power transfer and minimum standing wave ratio. Other important properties of coaxial cable include attenuation as a function of frequency, voltage handling capability, and shield quality.[2]

8.3 Construction

Coaxial cable design choices affect physical size, frequency performance, attenuation, power handling capabilities, flexibility, strength, and cost. The inner conductor might be solid or stranded; stranded is more flexible. To get better high-frequency performance, the inner conductor may be silver-plated. Copper-plated steel wire is often used as an inner conductor for cable used in the cable TV industry.[4]

The insulator surrounding the inner conductor may be solid plastic, a foam plastic, or air with spacers supporting the inner wire. The properties of dielectric control some electrical properties of the cable. A common choice is a solid polyethylene (PE) insulator, used in lower-loss cables. Solid Teflon (PTFE) is also used as an insulator. Some coaxial lines use air (or some other gas) and have spacers to keep the inner conductor from touching the shield.

Many conventional coaxial cables use braided copper wire forming the shield. This allows the cable to be flexible, but it also means there are gaps in the shield layer, and the inner dimension of the shield varies slightly because the braid cannot be flat. Sometimes the braid is silver-plated. For better shield performance, some cables have a double-layer shield.[4] The shield might be just two braids, but it is more common now to have a thin foil shield covered by a wire braid. Some cables may invest in more than two shield layers, such as “quad-shield”, which uses four alternating layers of foil and braid. Other shield designs sacrifice flexibility for better performance; some shields are a solid metal tube. Those cables cannot be bent sharply, as the shield will kink, causing losses in the cable.

For high-power radio-frequency transmission up to about 1 GHz, coaxial cable with a solid copper outer conductor is available in sizes of 0.25 inch upward. The outer conductor is rippled like a bellows to permit flexibility and the inner conductor is held in position by a plastic spiral to approximate an air dielectric.[4]

Coaxial cables require an internal structure of an insulating (dielectric) material to maintain the spacing between the center conductor and shield. The dielectric losses increase in this order: Ideal dielectric (no loss), vacuum, air, polytetrafluoroethylene (PTFE), polyethylene foam, and solid polyethylene. A low relative permittivity allows for higher-frequency usage. An inhomogeneous dielectric needs to be compensated by a non-circular conductor to avoid current hot-spots.

While many cables have a solid dielectric, many others have a foam dielectric that contains as much air or other gas as possible to reduce the losses by allowing the use of a larger diameter center conductor. Foam coax will have about 15% less attenuation but some types of foam dielectric can absorb moisture—especially at its many surfaces — in humid environments, significantly increasing the loss. Supports shaped like stars or spokes are even better but more expensive and very susceptible to moisture infiltration. Still more expensive were the air-spaced coaxials used for some inter-city communications in the mid-20th century. The center conductor was suspended by polyethylene discs every few centimeters. In some low-loss coaxial cables such as the RG-62 type, the inner conductor is supported by a spiral strand of polyethylene, so that an air space exists between most of the conductor and the inside of the jacket. The lower dielectric constant of air allows for a greater inner diameter at the same impedance and a greater outer diameter at the same cutoff frequency, lowering ohmic losses. Inner conductors are sometimes silver-plated to smooth the surface and reduce losses due to skin effect.[4] A rough surface prolongs the path for the current and concentrates the current at peaks and, thus, increases ohmic losses.

The insulating jacket can be made from many materials. A common choice is PVC, but some applications may require fire-resistant materials. Outdoor applications may require the jacket resist ultraviolet light, oxidation and rodent damage. Flooded coaxial cables use a water blocking gel to protect the cable from water infiltration through minor cuts in the jacket. For internal chassis connections the insulating jacket may be omitted.

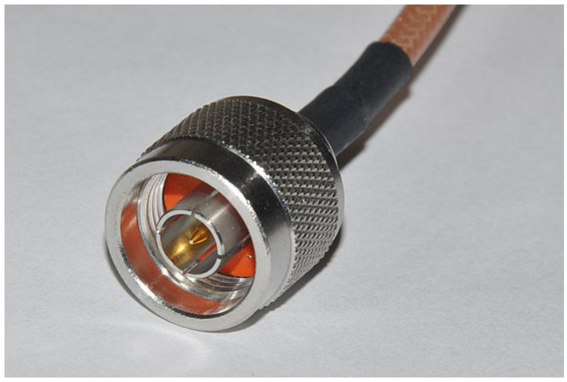
8.4 Signal propagation

Twin-lead transmission lines have the property that the electromagnetic wave propagating down the line extends into the space surrounding the parallel wires. These lines have low loss, but also have undesirable characteristics. They cannot be bent, tightly twisted, or otherwise shaped without changing their characteristic impedance, causing reflection of the signal back toward the source. They also cannot be buried or run along or attached to anything conductive, as the extended fields will induce currents in the nearby conductors causing unwanted radiation and detuning of the line. Coaxial lines largely solve this problem by confining virtually all of the electromagnetic wave to the area inside the cable. Coaxial lines can therefore be bent and moderately twisted without negative effects, and they can be strapped to conductive supports without inducing unwanted currents in them.

In radio-frequency applications up to a few gigahertz, the wave propagates primarily in the transverse electric magnetic (TEM) mode, which means that the electric and magnetic fields are both perpendicular to the direction of propagation. However, above a certain cutoff frequency, transverse electric (TE) or transverse magnetic (TM) modes can also propagate, as they do in a waveguide. It is usually undesirable to transmit signals above the cutoff frequency, since it may cause multiple modes with different phase velocities to propagate, interfering with each other. The outer diameter is roughly inversely proportional to the cutoff frequency. A propagating surface-wave mode that does not involve or require the outer shield but only a single central conductor also exists in coax but this mode is effectively suppressed in coax of conventional geometry and common impedance. Electric field lines for this [TM] mode have a longitudinal component and require line lengths of a half-wavelength or longer.

Coaxial cable may be viewed as a type of waveguide. Power is transmitted through the radial electric field and the circumferential magnetic field in the TEM00 transverse mode. This is the dominant mode from zero frequency (DC) to an upper limit determined by the electrical dimensions of the cable.[5]

8.5 Connectors



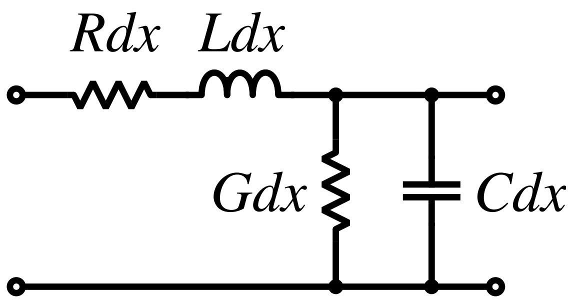
A coaxial connector (male N-type).

Main article: RF connector

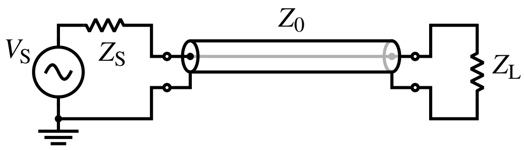
The ends of coaxial cables usually terminate with connectors. Coaxial connectors are designed to maintain a coaxial form across the connection and have the same impedance as the attached cable.[4] Connectors are usually plated with high-conductivity metals such as silver or tarnish-resistant gold. Due to the skin effect, the RF signal is only carried by the plating at higher frequencies and does not penetrate to the connector body. Silver however tarnishes quickly and the silver sulfide that is produced is poorly conductive, degrading connector performance, making silver a poor choice for this application.

8.6 Important parameters

Coaxial cable is a particular kind of transmission line, so the circuit models developed for general transmission lines are appropriate. See Telegrapher's equation.



Schematic representation of the elementary components of a transmission line.



Schematic representation of a coaxial transmission line, showing the characteristic impedance Z_0 .

8.6.1 Physical parameters

In the following section, these symbols are used:

- Length of the cable, h .
- Outside diameter of *inner* conductor, d .
- Inside diameter of the shield, D .
- Dielectric constant of the insulator, ϵ . The dielectric constant is often quoted as the relative dielectric constant ϵ_r referred to the dielectric constant of free space ϵ_0 : $\epsilon = \epsilon_r \epsilon_0$. When the insulator is a mixture of different dielectric materials (e.g., polyethylene foam is a mixture of polyethylene and air), then the term effective dielectric constant ϵ_{eff} is often used.
- Magnetic permeability of the insulator, μ . Permeability is often quoted as the relative permeability μ_r referred to the permeability of free space μ_0 : $\mu = \mu_r \mu_0$. The relative permeability will almost always be 1.

8.6.2 Fundamental electrical parameters

- Shunt capacitance per unit length, in farads per metre.[6]

$$\left(\frac{C}{h}\right) = \frac{2\pi\epsilon}{\ln(D/d)} = \frac{2\pi\epsilon_0\epsilon_r}{\ln(D/d)}$$

- Series inductance per unit length, in henrys per metre.

$$\left(\frac{L}{h}\right) = \frac{\mu}{2\pi}\ln(D/d) = \frac{\mu_0\mu_r}{2\pi}\ln(D/d)$$

- Series resistance per unit length, in ohms per metre. The resistance per unit length is just the resistance of inner conductor and the shield at low frequencies. At higher frequencies, skin effect increases the effective resistance by confining the conduction to a thin layer of each conductor.
- Shunt conductance per unit length, in siemens per metre. The shunt conductance is usually very small because insulators with good dielectric properties are used (a very low loss tangent). At high frequencies, a dielectric can have a significant resistive loss.

8.6.3 Derived electrical parameters

- Characteristic impedance in ohms (Ω). Neglecting resistance per unit length for most coaxial cables, the characteristic impedance is determined from the capacitance per unit length (C) and the inductance per unit length (L). The simplified expression is ($Z_0 = \sqrt{L/C}$). Those parameters are determined from the ratio of the inner (d) and outer (D) diameters and the dielectric constant (ϵ). The characteristic impedance is given by[7]

$$Z_0 = \frac{1}{2\pi}\sqrt{\frac{\mu}{\epsilon}}\ln\frac{D}{d} \approx \frac{60\Omega}{\sqrt{\epsilon_r}}\ln\frac{D}{d} \approx \frac{138\Omega}{\sqrt{\epsilon_r}}\log_{10}\frac{D}{d}$$

Assuming the dielectric properties of the material inside the cable do not vary appreciably over the operating range of the cable, this impedance is frequency independent above about five times the shield cutoff frequency. For typical coaxial cables, the shield cutoff frequency is 600 (RG-6A) to 2,000 Hz (RG-58C).[8]

- Attenuation (loss) per unit length, in decibels per meter. This is dependent on the loss in the dielectric material filling the cable, and resistive losses in the center conductor and outer shield. These losses are frequency dependent, the losses becoming higher as the frequency increases. Skin effect losses in the conductors can be reduced by increasing the diameter of the cable. A cable with twice the diameter will have half the skin effect resistance. Ignoring dielectric and other losses, the larger cable would halve the dB/meter loss. In designing a system, engineers consider not only the loss in the cable but also the loss in the connectors.
- Velocity of propagation, in meters per second. The velocity of propagation depends on the dielectric constant and permeability (which is usually 1).

$$v = \frac{1}{\sqrt{\epsilon\mu}} = \frac{c}{\sqrt{\epsilon_r\mu_r}}$$

- Single-mode band. In coaxial cable, the dominant mode (the mode with the lowest cutoff frequency) is the TEM mode, which has a cutoff frequency of zero; it propagates all the way down to d.c. The mode with the next lowest cutoff is the TE_{11} mode. This mode has one 'wave' (two reversals of polarity) in going around the circumference of the cable. To a good approximation, the condition for the TE_{11} mode to propagate is that the wavelength in the dielectric is no longer than the average circumference of the insulator; that is that the frequency is at least

$$f_c \approx \frac{1}{\pi(\frac{D+d}{2})\sqrt{\mu\epsilon}} = \frac{c}{\pi(\frac{D+d}{2})\sqrt{\mu_r\epsilon_r}}$$

Hence, the cable is single-mode from to d.c. up to this frequency, and might in practice be used up to 90%[9] of this frequency.

- Peak Voltage. The peak voltage is set by the breakdown voltage of the insulator. One website[10] gives:

$$V_p = 1150\, S_{\text{mils}}\, d_{\text{in}}\, \log_{10}\left(\frac{D}{d}\right)$$

where
S_{mils} is the insulator's breakdown voltage in volts per mil
d_{in} is the inner diameter in inches
The 1150 factor converts inches (diameter) to mils (radius) and $\log_{10}$ to ln.

The above expression may be rewritten[11] as

$$V_p = 0.5\, S\, d\, \ln\left(\frac{D}{d}\right)$$

where
S is the insulator's breakdown voltage in volts per meter
d is the inner diameter in meters

The calculated peak voltage is often reduced by a safety factor.

8.6.4 Choice of impedance

The best coaxial cable impedances in high-power, high-voltage, and low-attenuation applications were experimentally determined at Bell Laboratories in 1929 to be 30, 60, and 77 Ω, respectively. For a coaxial cable with air dielectric and a shield of a given inner diameter, the attenuation is minimized by choosing the diameter of the inner conductor to give a characteristic impedance of 76.7 Ω.[12] When more common dielectrics are considered, the best-loss impedance drops down to a value between 52–64 Ω. Maximum power handling is achieved at 30 Ω.[13]

The approximate impedance required to match a centre-fed dipole antenna in free space (i.e., a dipole without ground reflections) is 73 Ω, so 75 Ω coax was commonly used for connecting shortwave antennas to receivers. These typically involve such low levels of RF power that power-handling and high-voltage breakdown characteristics are unimportant when compared to attenuation. Likewise with CATV, although many broadcast TV installations and CATV headends use 300 Ω folded dipole antennas to receive off-the-air signals, 75 Ω coax makes a convenient 4:1 balun transformer for these as well as possessing low attenuation.

The arithmetic mean between 30 Ω and 77 Ω is 53.5 Ω; the geometric mean is 48 Ω. The selection of 50 Ω as a compromise between power-handling capability and attenuation is in general cited as the reason for the number.[14] 50 Ω also works out tolerably well because it corresponds approximately to the drive impedance (ideally 36 ohms) of a quarter-wave monopole, mounted on a less than optimum ground plane such as a vehicle roof. The match is better at low frequencies, such as for CB Radio around 27MHz, where the roof dimensions are much less than a quarter wavelength, and relatively poor at higher frequencies, VHF and UHF, where the roof dimensions may be several wavelengths. The match is at best poor, because the antenna drive impedance, due to the imperfect ground plane, is reactive rather than purely resistive, and so a 36 ohm coaxial cable would not match properly either. Installations which need exact matching will use some kind of matching circuit at the base of the antenna, or elsewhere, in conjunction with a carefully chosen (in terms of wavelength) length of coaxial, such that a proper match is achieved, which will be only over a fairly narrow frequency range.

RG-62 is a 93 Ω coaxial cable originally used in mainframe computer networks in the 1970s and early 1980s (it was the cable used to connect IBM 3270 terminals to IBM 3274/3174 terminal cluster controllers). Later, some manufacturers of LAN equipment, such as Datapoint for ARCNET, adopted RG-62 as their coaxial cable standard. The cable has the lowest capacitance per unit-length when compared to other coaxial cables of similar size. Capacitance is the enemy of square-wave data transmission (in particular, it slows down edge transitions), and this is a much more important factor for baseband digital data transmission than power handling or attenuation.

All of the components of a coaxial system should have the same impedance to avoid internal reflections at connections between components. Such reflections may cause signal attenuation and ghosting TV picture display; multiple reflections may cause the original signal to be followed by more than one echo. In analog video or TV systems, this causes ghosting in the image. Reflections also introduce standing waves, which cause increased losses and can even result in cable dielectric breakdown with high-power transmission (see Impedance matching). Briefly, if a coaxial cable is open, the termination has nearly infinite resistance, this causes reflections; if the coaxial cable is short-circuited, the termination resistance is nearly zero, there will be reflections with the opposite polarity. Reflection will be nearly eliminated if the coaxial cable is terminated in a pure resistance equal its impedance.

8.7 Issues

8.7.1 Signal leakage

Signal leakage is the passage of electromagnetic fields through the shield of a cable and occurs in both directions. Ingress is the passage of an outside signal into the cable and can result in noise and disruption of the desired signal. Egress is the passage of signal intended to remain within the cable into the outside world and can result in a weaker signal at the end of the cable and radio frequency interference to nearby devices. Severe leakage usually results from improperly installed connectors or faults in the cable shield.

For example, in the United States, signal leakage from cable television systems is regulated by the FCC, since cable signals use the same frequencies as aeronautical and radionavigation bands. CATV operators may also choose to monitor their networks for leakage to prevent ingress. Outside signals entering the cable can cause unwanted noise and picture ghosting. Excessive noise can overwhelm the signal, making it useless.

An ideal shield would be a perfect conductor with no holes, gaps, or bumps connected to a perfect ground. However, a smooth solid highly conductive shield would be heavy, inflexible, and expensive. Such coax is used for straight line feeds to commercial radio broadcast towers. More economical cables must make compromises between shield efficacy, flexibility, and cost, such as the corrugated surface of flexible hardline, flexible braid, or foil shields. Since shields cannot be perfect conductors, current flowing on the inside of the shield produces an electromagnetic field on the outer surface of the shield.

Consider the skin effect. The magnitude of an alternating current in a conductor decays exponentially with distance beneath the surface, with the depth of penetration being proportional to the square root of the resistivity. This means that, in a shield of finite thickness, some small amount of current will still be flowing on the opposite surface of the conductor. With a perfect conductor (i.e., zero resistivity), all of the current would flow at the surface, with no penetration into and through the conductor. Real cables have a shield made of an imperfect, although usually very good, conductor, so there must always be some leakage.

The gaps or holes, allow some of the electromagnetic field to penetrate to the other side. For example, braided shields have many small gaps. The gaps are smaller when using a foil (solid metal) shield, but there is still a seam running the length of the cable. Foil becomes increasingly rigid with increasing thickness, so a thin foil layer is often surrounded by a layer of braided metal, which offers greater flexibility for a given cross-section.

Signal leakage can be severe if there is poor contact at the interface to connectors at either end of the cable or if there is a break in the shield.

To greatly reduce signal leakage into or out of the cable, by a factor of 1000, or even 10,000, superscreened cables [15] are often used in critical applications, such as for neutron flux counters in nuclear reactors.

8.7.2 Ground loops

A continuous current, even if small, along the imperfect shield of a coaxial cable can cause visible or audible interference. In CATV systems distributing analog signals the potential difference between the coaxial network and the electrical grounding system of a house can cause a visible “hum bar” in the picture. This appears as a wide horizontal distortion bar in the picture that scrolls slowly upward. Such differences in potential can be reduced by proper bonding to a common ground at the house. See ground loop.

8.7.3 Noise

External fields create a voltage across the inductance of the outside of the outer conductor between sender and receiver. The effect is less when there are several parallel cables, as this reduces the inductance and, therefore, the voltage. Because the outer conductor carries the reference potential for the signal on the inner conductor, the receiving circuit measures the wrong voltage.

Transformer effect

The transformer effect is sometimes used to mitigate the effect of currents induced in the shield. The inner and outer conductors form the primary and secondary winding of the transformer, and the effect is enhanced in some high-quality cables that have an outer layer of mu-metal. Because of this 1:1 transformer, the aforementioned voltage across the outer conductor is transformed onto the inner conductor so that the two voltages can be cancelled by the receiver. Many sender and receivers have means to reduce the leakage even further. They increase the transformer effect by passing the whole cable through a ferrite core one or more times.

8.7.4 Common mode current and radiation

Common mode current occurs when stray currents in the shield flow in the same direction as the current in the center conductor, causing the coax to radiate.

Most of the shield effect in coax results from opposing currents in the center conductor and shield creating opposite magnetic fields that cancel, and thus do not radiate. The same effect helps ladder line. However, ladder line is extremely sensitive to surrounding metal objects, which can enter the fields before they completely cancel. Coax does not have this problem, since the field is enclosed in the shield. However, it is still possible for a field to form between the shield and other connected objects, such as the antenna the coax feeds. The current formed by the field between the antenna and the coax shield would flow in the same direction as the current in the center conductor, and thus not be canceled. Energy would radiate from the coax itself, affecting the radiation pattern of the antenna. With sufficient power this could be a hazard to people near the cable. A properly placed and properly sized balun can prevent common mode radiation in coax. An isolating transformer or blocking capacitor can be used to couple a coaxial cable to equipment, where it is desirable to pass radio-frequency signals but to block direct current or low-frequency power.

8.8 Standards

Most coaxial cables have a characteristic impedance of either 50, 52, 75, or 93 Ω. The RF industry uses standard type-names for coaxial cables. Thanks to television, RG-6 is the most commonly used coaxial cable for home use, and the majority of connections outside Europe are by F connectors.

A series of standard types of coaxial cable were specified for military uses, in the form "RG-#" or "RG-#/U". They date from World War II and were listed in *MIL-HDBK-216* published in 1962. These designations are now obsolete. The RG designation stands for Radio Guide; the U designation stands for Universal. The current military standard is MIL-SPEC MIL-C-17. MIL-C-17 numbers, such as "M17/75-RG214", are given for military cables and manufacturer's catalog numbers for civilian applications. However, the RG-series designations were so common for generations that they are still used, although critical users should be aware that since the handbook is withdrawn there is no standard to guarantee the electrical and physical characteristics of a cable described as "RG-# type". The RG designators are mostly used to identify compatible connectors that fit the inner conductor, dielectric, and jacket dimensions of the old RG-series cables.

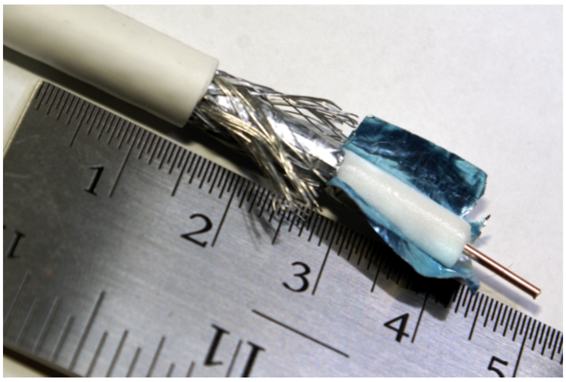
Dielectric Material Codes

- FPE is foamed polyethylene
- PE is solid polyethylene
- PF is polyethylene foam
- PTFE is polytetrafluoroethylene;
- ASP is air space polyethylene[34]

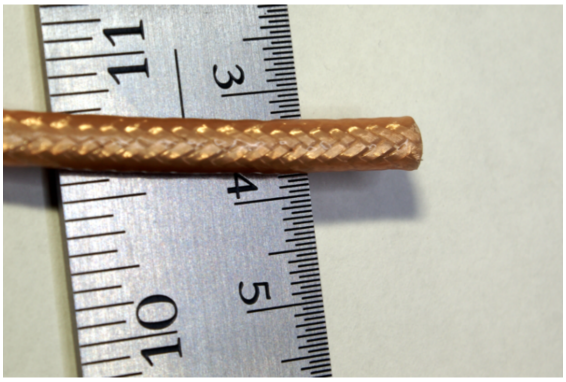
VF is the Velocity Factor; it is determined by the effective ϵ_r and μ_r [35]

- VF for solid PE is about 0.66
- VF for foam PE is about 0.78 to 0.88
- VF for air is about 1.00
- VF for solid PTFE is about 0.70
- VF for foam PTFE is about 0.84

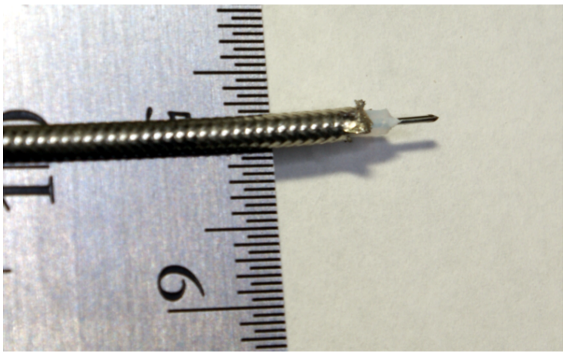
There are also other designation schemes for coaxial cables such as the URM, CT, BT, RA, PSF and WF series.



RG-6 Coaxial cable



RG-142 Coaxial cable



RG-405 semi-rigid coaxial cable

8.9 Uses

Short coaxial cables are commonly used to connect home video equipment, in ham radio setups, and in measurement electronics. They used to be common for implementing computer networks, in particular Ethernet, but twisted pair cables have replaced them in most applications except in the growing consumer cable modem market for broadband Internet access.

Long distance coaxial cable was used in the 20th century to connect radio networks, television networks, and Long Distance telephone networks though this has largely been superseded by later methods (fibre optics, T1/E1, satellite).

Shorter coaxials still carry cable television signals to the majority of television receivers, and this purpose consumes the majority of coaxial cable production. In 1980s and early 1990s coaxial cable was also used in computer networking, most prominently in Ethernet networks, where it was later in late 1990s to early 2000s replaced by UTP cables in North America and STP cables in Western Europe, both with 8P8C modular connectors.

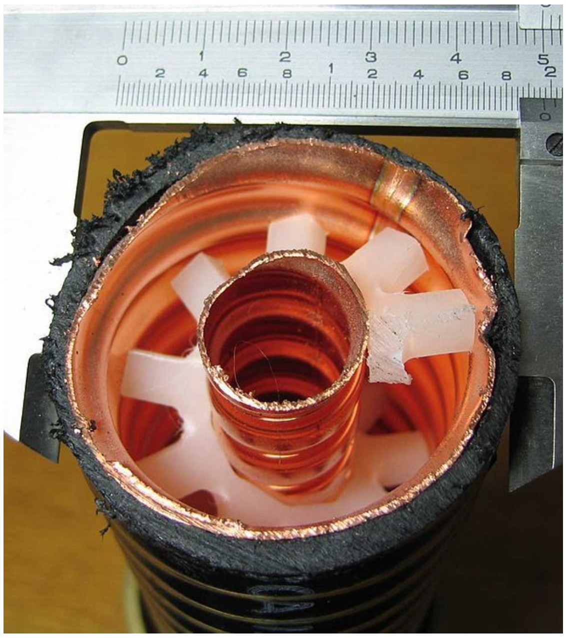
Micro coaxial cables are used in a range of consumer devices, military equipment, and also in ultra-sound scanning equipment.

The most common impedances that are widely used are 50 or 52 ohms, and 75 ohms, although other impedances are available for specific applications. The 50 / 52 ohm cables are widely used for industrial and commercial two-way radio frequency applications (including radio, and telecommunications), although 75 ohms is commonly used for broadcast television and radio.

Coax cable is often used to carry data/signals from an antenna to a receiver—from a satellite dish to a satellite receiver, from a television antenna to a television receiver, from a radio mast to a radio receiver, etc. In many cases, the same single coax cable carries power in the opposite direction, to the antenna, to power the low-noise amplifier. In some cases a single coax cable carries (unidirectional) power and bidirectional data/signals, as in DiSEqC.

8.10 Types

8.10.1 Hard line



1-5/8" flexible line

Hard line is used in broadcasting as well as many other forms of radio communication. It is a coaxial cable constructed using round copper, silver or gold tubing or a combination of such metals as a shield. Some lower-quality hard line may use aluminum shielding, aluminum however is easily oxidized and unlike silver or gold oxide, aluminum oxide drastically loses effective conductivity. Therefore all connections must be air and water tight. The center conductor may consist of solid copper, or copper-plated aluminum. Since skin effect is an issue with RF, copper plating provides sufficient surface for an effective conductor. Most varieties of hardline used for external chassis or when exposed to the elements have a PVC jacket; however, some internal applications may omit the insulation jacket. Hard line can be very thick, typically at least a half inch or 13 mm and up to several times that, and has low loss even at high power. These large-scale hard lines are almost always used in the connection between a transmitter on the ground and the antenna or aerial on a tower. Hard line may also be known by trademarked names such as Heliax (Andrew),[36] or Cablewave (RFS/Cablewave).[37] Larger varieties of hardline may have a center conductor that is constructed from either rigid or corrugated copper tubing. The dielectric in hard line may consist of polyethylene foam, air, or a pressurized gas such as nitrogen or desiccated air (dried air). In gas-charged lines, hard plastics such as nylon are used as spacers to separate the inner and outer conductors. The addition of these gases into the dielectric space reduces moisture contamination, provides a stable dielectric constant, and provides a reduced risk of internal arcing. Gasfilled hardlines are usually used on high-power RF transmitters such as television or radio broadcasting, military transmitters, and high-power amateur radio applications but may also be used on some critical lower-power applications such as those in the microwave bands. However, in the microwave region, *waveguide* is more often used than hard line for transmitter-to-antenna, or antenna-to-receiver applications. The various shields used in hardline also differ; some forms use rigid tubing, or pipe, others may use a corrugated tubing, which makes bending easier, as well as reduces kinking when the cable is bent to conform. Smaller varieties of hard line may be used internally in some high-frequency applications, in particular in equipment within the microwave range, to reduce interference between stages of the device.

8.10.2 Radiating

Main article: Leaky feeder

Radiating or **leaky cable** is another form of coaxial cable which is constructed in a similar fashion to hard line, however it is constructed with tuned slots cut into the shield. These slots are tuned to the specific RF wavelength of operation or tuned to a specific radio frequency band. This type of cable is to provide a tuned bi-directional "desired" leakage effect between transmitter and receiver. It is often used in elevator shafts, US Navy Ships, underground transportation tunnels and in other areas where an antenna is not feasible. One example of this type of cable is Radiax (Andrew).[38]

8.10.3 RG-6

Main article: RG-6

RG-6 is available in four different types designed for various applications. In addition, the core may be copper clad steel (CCS) or bare solid copper (BC). "Plain" or "house" RG-6 is designed for indoor or external house wiring. "Flooded" cable is infused with waterblocking gel for use in underground conduit or direct burial. "Messenger" may contain some waterproofing but is distinguished by the addition of a steel messenger wire along its length to carry the tension involved in an aerial drop from a utility pole. "Plenum" cabling is expensive and comes with a special Teflon-based outer jacket designed for use in ventilation ducts to meet fire codes. It was developed since the plastics used as the outer jacket and inner insulation in many "Plain" or "house" cabling gives off poison gas when burned.

8.10.4 Triaxial cable

Main article: Triaxial cable

Triaxial cable or **triax** is coaxial cable with a third layer of shielding, insulation and sheathing. The outer shield, which is earthed (grounded), protects the inner shield from electromagnetic interference from outside sources.

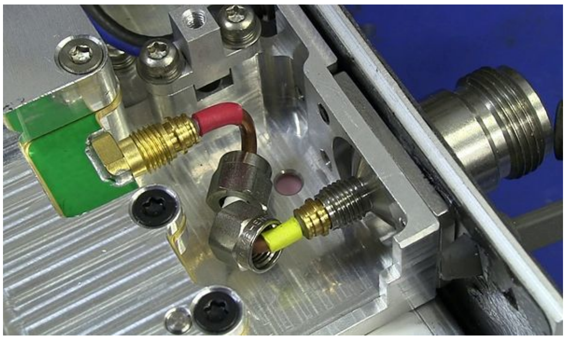
8.10.5 Twin-axial cable

Main article: Twinaxial cabling

Twin-axial cable or **twinax** is a balanced, twisted pair within a cylindrical shield. It allows a nearly perfect differential signal which is *both* shielded *and* balanced to pass through. Multi-conductor coaxial cable is also sometimes used.

8.10.6 Semi-rigid

Semi-Rigid coax assembly



Semi-Rigid coax installed in an Agilent N9344C 20GHz spectrum analyser

Semi-rigid cable is a coaxial form using a solid copper outer sheath. This type of coax offers superior screening compared to cables with a braided outer conductor, especially at higher frequencies. The major disadvantage is that the cable, as its name implies, is not very flexible, and is not intended to be flexed after initial forming. (See "hard line")

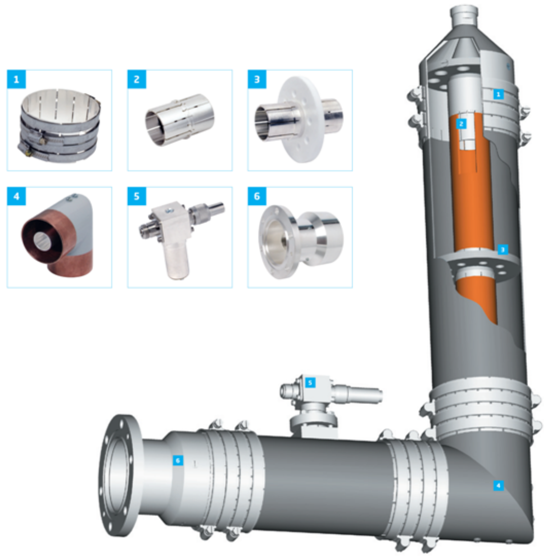
Conformable cable is a flexible reformable alternative to semi-rigid coaxial cable used where flexibility is required. Conformable cable can be stripped and formed by hand without the need for specialized tools, similar to standard coaxial cable.

8.10.7 Rigid line

Rigid line

Rigid line is a coaxial line formed by two copper tubes maintained concentric every other meter using PTFE-supports. Rigid lines can not be bent, so they often need elbows. Interconnection with rigid line is done with an inner bullet/inner support and a flange or connection kit. Typically rigid lines are connected using standardised EIA RF Connectors whose bullet and flange sizes match the standard line diameters, for each outer diameter either 75 or 50ohm inner tubes can be obtained. Rigid line is commonly used indoors for interconnection between high power transmitters and other RF-components, but more rugged rigid line with weatherproof flanges is used outdoors on antenna masts, etc. In the interests of saving weight and costs, on masts and similar structures the outer line is often aluminium, and special care must be taken to prevent corrosion. With a flange connector it is also possible to go from rigid line to hard line. Many broadcasting antennas and antenna splitters use the flanged rigid line interface even when connecting to flexible coaxial cables and hard line.

Rigid line is produced in a number of different sizes:



Rigid line parts

8.10.8 Cables used in the UK

At the start of analogue satellite TV broadcasts in the UK by BskyB, a 75 ohm cable referred to as *RG6* was used. This cable had a 1 mm copper core, air-spaced polyethylene dielectric and copper braid on an aluminium foil shield. When installed outdoors without protection, the cable was affected by UV radiation, which cracked the PVC outer sheath and allowed moisture ingress. The combination of copper, aluminium, moisture and air caused rapid corrosion, sometimes resulting in a 'snake swallowed an egg' appearance. Consequently, despite the higher cost, the RG6 cable was dropped in favour of CT100 when BSKYB launched its digital broadcasts.

From around 1999 to 2005 (when CT100 manufacturer Raydex went out of business), CT100 remained the 75 ohm cable of choice for satellite TV and especially BskyB. It had an air-spaced polyethylene dielectric, a 1 mm solid copper core and copper braid on copper foil shield. CT63 was a thinner cable in 'shotgun' style, meaning that it was two cables moulded together and was used mainly by BskyB for the twin connection required by the *Sky+* satellite TV receiver, which incorporated a hard drive recording system and a second, independent tuner.

In 2005, these cables were replaced by WF100 and WF65, respectively, manufactured by Webro and having a similar construction but a foam dielectric that provided the same electrical performance as air-spaced but was more robust and less likely to be crushed.

At the same time, with the price of copper steadily rising, the original RG6 was dropped in favour of a construction that used a copper-clad steel core and aluminium braid on aluminium foil. Its lower price made it attractive to aerial installers looking for a replacement for the so-called *low-loss* cable traditionally used for UK terrestrial aerial installations. This cable had been manufactured with a decreasing number of strands of braid, as the price of copper increased, such that the shielding performance of cheaper brands had fallen to as low as 40 percent. With the advent of digital terrestrial transmissions in the UK, this low-loss cable was no longer suitable.

The new RG6 still performed well at high frequencies because of the skin effect in the copper cladding. However, the aluminium shield had a high DC resistance and the steel core an even higher one. The result is that this type of cable could not reliably be used in satellite TV installations, where it was required to carry a significant amount of current, because the voltage drop affected the operation of the low noise block downconverter (LNB) on the dish.

A problem with all the aforementioned cables, when passing current, is that electrolytic corrosion can occur in the connections unless moisture and air are excluded. Consequently, various solutions to exclude moisture have been proposed. The first was to seal the connection by wrapping it with self-amalgamating rubberised tape, which bonds to itself when activated by stretching. The second proposal, by the American Channel Master company (now owned by Andrews corp.) at least as early as 1999, was to apply silicone grease to the wires making connection. The third proposal was to fit a self-sealing plug to the cable. All of these methods are reasonably successful if implemented correctly.

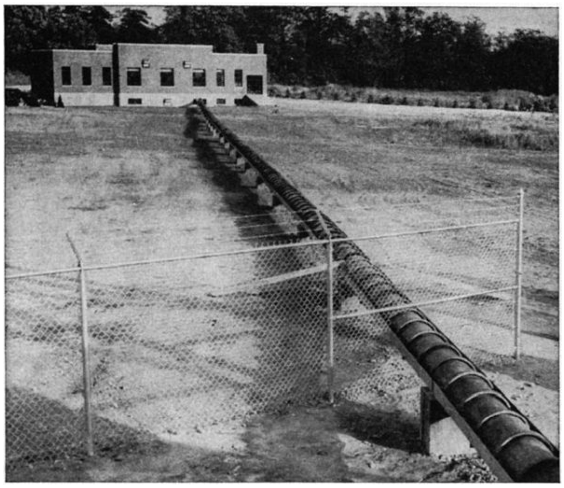
8.11 Interference and troubleshooting

Coaxial cable insulation may degrade, requiring replacement of the cable, especially if it has been exposed to the elements on a continuous basis. The shield is normally grounded, and if even a single thread of the braid or filament of foil touches the center conductor, the signal will be shorted causing significant or total signal loss. This most often occurs at improperly installed end connectors and splices. Also, the connector or splice must be properly attached to the shield, as this provides the path to ground for the interfering signal.

Despite being shielded, interference can occur on coaxial cable lines. Susceptibility to interference has little relationship to broad cable type designations (e.g. RG-59, RG-6) but is strongly related to the composition and configuration of the cable's shielding. For cable television, with frequencies extending well into the UHF range, a foil shield is normally provided, and will provide total coverage as well as high effectiveness against high-frequency interference. Foil shielding is ordinarily accompanied by a tinned copper or aluminum braid shield, with anywhere from 60 to 95% coverage. The braid is important to shield effectiveness because (1) it is more effective than foil at preventing low-frequency interference, (2) it provides higher conductivity to ground than foil, and (3) it makes attaching a connector easier and more reliable. "Quad-shield" cable, using two low-coverage aluminum braid shields and two layers of foil, is often used in situations involving troublesome interference, but is less effective than a single layer of foil and single high-coverage copper braid shield such as is found on broadcast-quality precision video cable.

In the United States and some other countries, cable television distribution systems use extensive networks of outdoor coaxial cable, often with in-line distribution amplifiers. Leakage of signals into and out of cable TV systems can cause interference to cable subscribers and to over-the-air radio services using the same frequencies as those of the cable system.

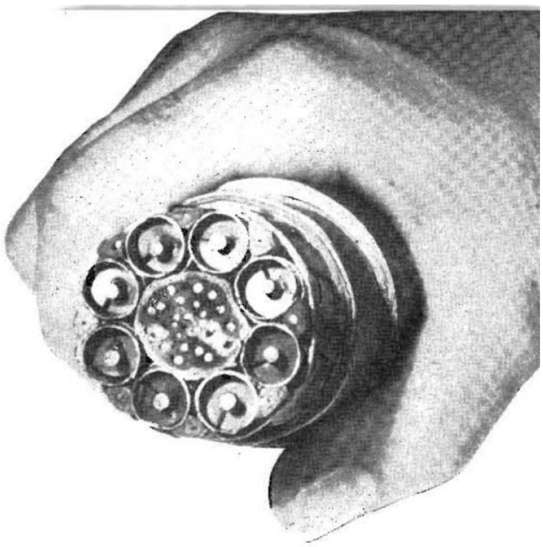
8.12 History



Early coaxial antenna feedline of 50 kW radio station WNBC, New York, in 1930s

- 1880 — Coaxial cable patented in England by Oliver Heaviside, patent no. 1,407.[39]
- 1884 — Siemens & Halske patent coaxial cable in Germany (Patent No. 28,978, 27 March 1884).[40]
- 1929 — First modern coaxial cable patented by Lloyd Espenschied and Herman Affel of AT&T's Bell Telephone Laboratories.[41]
- 1936 — First closed circuit transmission of TV pictures on coaxial cable, from the 1936 Summer Olympics in Berlin to Leipzig.[42]
- 1936 — World's first underwater coaxial cable installed between Apollo Bay, near Melbourne, Australia, and Stanley, Tasmania. The 300 km cable can carry one 8.5-kHz broadcast channel and seven telephone channels.[43]

- 1936 — AT&T installs experimental coaxial telephone and television cable between New York and Philadelphia, with automatic booster stations every ten miles. Completed in December, it can transmit 240 telephone calls simultaneously.[44][45]
- 1936 — Coaxial cable laid by the General Post Office (now BT) between London and Birmingham, providing 40 telephone channels.[46][47]
- 1941 — First commercial use in USA by AT&T, between Minneapolis, Minnesota and Stevens Point, Wisconsin. L1 system with capacity of one TV channel or 480 telephone circuits.



AT&T coaxial cable trunkline installed between East Coast and Midwest in 1949. Each of the 8 coaxial subcables could carry 480 telephone calls or one television channel.

- 1949 — On January 11, eight stations on the US East Coast and seven Midwestern stations are linked via a long-distance coaxial cable.[48]
- 1956 — First transatlantic coaxial cable laid, TAT-1.[49][50]

8.13 See also

- Transmission line
- Radio frequency power transmission
- L-carrier
- Balanced pair
- Shielded cable
- Triaxial cable
- Twinaxial cabling

8.14 References

[1] Nahin, Paul J. (2002). *Oliver Heaviside: The Life, Work, and Times of an Electrical Genius of the Victorian Age*. ISBN 0-8018-6909-9.

[2] H. Ward Silver, N0AX, and Mark J. Wilson, K1RO, ed. (2010). "Chapter 20: Transmission Lines". *The ARRL Handbook for Radio Communications* (87th ed.). The American Radio Relay League. ISBN 0-87259-144-1.

[3] Martin J. Van Der Burgt. "Coaxial Cables and Applications". Belden. p. 4. Retrieved 11 July 2011.

[4] *The ARRL UHF/Microwave Experimenter's Manual*, American Radio Relay League, Newington CT USA,1990 ISBN 0-87259-312-6, Chapter 5 *Transmission Media* pages 5.19 through 5.21

[5] Jackson, John David (1962). *Classical Electrodynamics*. New York: John Wiley & Sons, Inc. p. 244.

[6] Pozar, David M. (1993). *Microwave Engineering* Addison-Wesley Publishing Company. ISBN 0-201-50418-9.

[7] Elmore, William C.; Heald, Mark A. (1969). *Physics of Waves*. ISBN 0-486-64926-1.

[8] Ott, Henry W. (1976). *Noise Reduction Techniques in Electronic Systems*. ISBN 0-471-65726-3.

[9] Kizer, George Maurice (1990). *Microwave communication*. Iowa State University Press. p. 312. ISBN 978-0-8138-0026-4.

[10] "Coaxial Cable Equations Formulas". RF Cafe. Retrieved 2012-01-25.

[11] See "field enhancement" discussion at http://www.microwaves101.com/encyclopedia/why50ohms.cfm

[12] "Why 50 Ohms?". Microwaves 101. 2009-01-13. Retrieved 2012-01-25.

[13] "Coax power handling". Microwaves 101. 2008-09-14. Retrieved 2012-01-25.

[14] "Why 50 Ohms?". Microwaves 101. 2009-01-13. Retrieved 2012-01-25.

[15] "Superscreened Cables".

[16] "Coaxial Cable Specifications for RG-6". madaboutcable.com.

[17] "Times Microwave Coax Loss Calculator". Retrieved 2011-10-26.

[18] http://www.dxengineering.com/pdf/Belden%20RG8X%20Date%209258.pdf

[19] "Coaxial Cable Specifications for RG-11". madaboutcable.com.

[20] "Coaxial Cable Specifications for RG-58". madaboutcable.com.

[21] "Coaxial Cable Specifications for RG-59". madaboutcable.com.

[22] "Cable Velocity Factor and Loss Data". febo.com.

[23] "Coaxial Cable Specifications for RG-62". madaboutcable.com.

[24] "Coaxial Cable Specifications for RG-178". madaboutcable.com.

[25] Caledonian.com - RG178 Mini-Coax

[26] "Coaxial Cable Specifications for 5 Core RG-179 (RGBHV)". madaboutcable.com.

[27]

[28] "Coaxial Cable Specifications for RG-213". madaboutcable.com.

[29] "Coaxial Cable Specifications for RG-214". madaboutcable.com.

[30] "Coaxial Cable Specifications for RG-316". madaboutcable.com.

[31] "Coaxial Cable Specifications for RG-400". madaboutcable.com.

[32] "Times Microwave LMR-240 Data Sheet". Retrieved 2011-10-26.

[33] "Radio City Inc".

[34] "Coaxial Cable Specifications Cables Chart". RF Cafe. Retrieved 2012-01-25.

[35] "Phase Velocity". Microwaves 101. 2010-03-30. Retrieved 2012-01-25.

[36] "Andrew Heliax".

[37] "Cablewave Radio Frequency Systems <http://www.rfsworld.com>".

[38] "Andrew Radiax".

[39] Google Book Search - Oliver Heaviside By Paul J. Nahin

[40] Feldenkirchen, Wilfried (1994). *Werner von Siemens - Inventor and International Entrepreneur*. ISBN 0-8142-0658-1.

[41] U.S. Patent 1,835,031

[42] earlytelevision.org - Early Electronic Television - The 1936 Berlin Olympics

[43] The worldwide history of telecommunications By Anton A. Huurdeman - Copper-Line Transmission

[44] "Coaxial Debut," *Time*, Dec. 14, 1936.

[45] Boing Boing - Gallery: An illustrated history of the transoceanic cable

[46] Google books - Broadcast engineer's reference book By Edwin Paul J. Tozer

[47] Radio-electronics.com - Coaxial feeder or RF coax cable

[48] Teachout, Terry. "The New-Media Crisis of 1949". Wall Street Journal. Retrieved 19 January 2015.

[49] Atlantic-cable.com - 1956 TAT-1 Silver Commemorative Dish

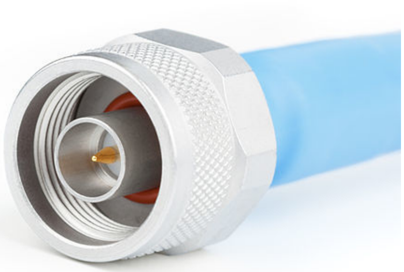
[50] Google books - The worldwide history of telecommunications By Anton A. Huurdeman

8.15 External links

- *RF transmission lines and fittings.* Military Standardization Handbook MIL-HDBK-216, U.S. Department of Defense, 4 January 1962.
- *Withdrawal Notice for MIL-HDBK-216 2001*
- *Cables, radio frequency, flexible and rigid.* Details Specification MIL-DTL-17H, 19 August 2005 (superseding MIL-C-17G, 9 March 1990).
- *Radio-frequency cables*, International Standard IEC 60096.
- *Coaxial communication cables*, International Standard IEC 61196.
- *Coaxial cables*, British Standard BS EN 50117
- H. P. Westman et al., (ed), *Reference Data for Radio Engineers, Fifth Edition*, 1968, Howard W. Sams and Co., no ISBN, Library of Congress Card No. 43-14665
- What's the Best Cable to Use (UK)

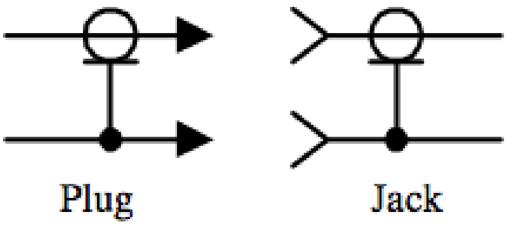
Chapter 9

RF connector



A ***Type N*** *coaxial RF connector (male)*

A double ***DIN 1.6/5.6*** *bulkhead jack connector, crimp type, for 75Ω coaxial cable*



Electronic symbols for the plug and jack coaxial connectors

A coaxial **RF connector** (radio frequency connector) is an electrical connector designed to work at radio frequencies in the multi-megahertz range. RF connectors are typically used with coaxial cables and are designed to maintain the shielding that the coaxial design offers. Better models also minimize the change in transmission line impedance at the connection. Mechanically, they provide a fastening mechanism (thread, bayonet, braces, blind mate) and springs for a low ohmic electric contact while sparing the gold surface, thus allowing very high mating cycles and reducing the insertion force. Research activity in the area of radio-frequency (RF) circuit design has surged in the 2000s in direct response to the enormous market demand for inexpensive, high-data-rate wireless transceivers.[1]

A ***Type N*** *connector (male), right-angled solder-type for semi-rigid coaxial cable with a diameter of 0.141 inch*

9.1 Standard types

- 7/16 DIN connector, a high-power 50 Ω connector originally developed by Spinner[2]
- 4.3-10 connector, a new connector interface, 1 jack - 3 plug designs.
- Belling Lee connector, also called *IEC 169-2 con-*

nector or *antenna plug*, used throughout Europe and some other countries for domestic television installations and as *FM connector* for radio

- BMA connector, also known as OSP (Omni Spectra push-on)
- BNC connector (Bayonet Neill-Concelman)
- C connector (Concelman)
- Dezifix connector, hermaphrodite connector used mainly by Rohde & Schwarz
- DIN 1.0/2.3 (DIN 47297), used for miniaturized 50 and 75 Ω coaxial modules in data- and telecommunications equipment. It can have a threaded, or a push-pull lock coupling mechanism.
- DIN 1.6/5.6 (DIN 47295), a 75 Ω connector, used for similar purposes as DIN 1.0/2.3.
- F connector, used for domestic television installations and domestic satellite LNBs (75 Ω) world wide
- GR connector (General Radio)
- Motorola connector, standard AM/FM antenna connector used for automotive radios
- Musa connector, a 50 Ω connector used in telecommunications and broadcast video
- N connector (Neill)
- NMO mount connector (new Motorola mount), removable mobile antenna connector uses a $^3/_4$ inch (19 mm) mounting hole and has a large base with a 1 1/8” - 18 tpi thread for attaching the antenna.
- SC connector (RF), screw version of C connector [not to be confused with the fiber optic connector of the same name]
- TNC connector (threaded Neill-Concelman)
- Twin-lead
- UHF connector (e.g., PL-259/SO-239). Also referred to as an *M-type* connector by Japanese manufacturers such as Kenwood

9.1.1 Miniature types

- DIN 47223 connector
- FME connector
- MCX connector
- Miniature BNC connector
- Miniature UHF connector
- SMZ connector - System 43 (BT43 and High Density HD43) for use in DDF

9.1.2 Sub-miniature types

- SMA connector, including variants:
    - 3.5 and 2.92 mm connectors, which cross-mate with SMA, and
    - 2.4, 1.85 and 1.0 mm connectors, which do not cross-mate with SMA
- SMB connector
    - FAKRA - Modified SMB connector with plastic housing and latch used in the automotive industry.[3]
- SMC connector

9.1.3 Micro-miniature types

- IMP connector
- MMCX connector
- MMS connector
- MMT connector
- UMP connector
- Hirose U.FL connector
- W.FL connector - (even smaller version of U.FL)

9.1.4 Precision types

- APC-7 connector

9.1.5 Flange connectors

- EIA RF Connectors series of flanged connectors, normally used in high power broadcast transmission sites with rigid lines

9.1.6 Quick-lock connectors

- HPQN connector[4]
- Mini Quick connector
- QLS connector
- QMA and QN connector
    - Mini-QMA connector
    - WQMA connector (Waterproof QMA)
- SnapN connector

*A **Mini Quick** connector, a Quick-lock type connector for coaxial cable*

9.1.7 High voltage types

- HN connector, a high voltage version of the N connector
- MHV connector, a coaxial connector designed for high voltages
- SHV connector, a safer coaxial connector designed for high voltages

9.1.8 Blindmate types

Main article: Blind mate connector § RF

- BMA (OSP) connector
- BMMA (OSSP) connector
- BZ connector
- BMZ connector
- SMP (GPO) connector
- SMPM (GPPO) connector

9.2 See also

- Antenna socket
- Coaxial cable
- Optical fiber connector
- List of coaxial connectors

The following audio and video connectors are sometimes used for RF, but are not generally considered to be RF connectors:

- DIN connector (not to be confused with “7/16 DIN” or “DIN 1.0/2.3” connectors)
- RCA connector (Radio Corporation of America) originally introduced for audio, but now widely used for video as well
- SCART
- Concentric twinax connector

9.3 References

[1] http://www.pasternack.com/pdf/catalog/ConnectorIdentifier.pdf, Pasternack, Inc.

[2] IEC 60169-4 (1975-01)

[3] http://www.everythingrf.com/search/connectors/filters?page=1&country=global&sconnector_type=;FAKRA;

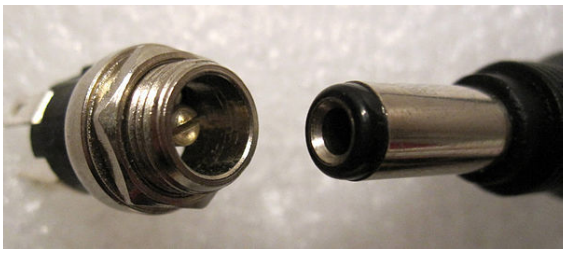
[4] “Analysis of Quick Lock N Type Connectors”. *Microwave Journal*, July 14, 2009

9.4 External links

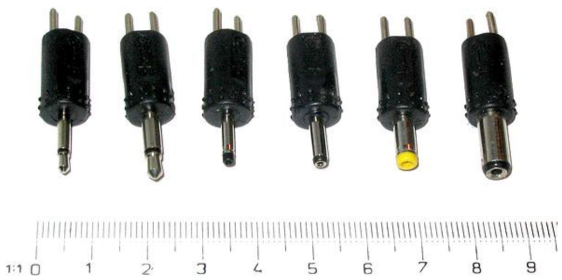
- RF connectors for upper frequencies
- Common Coaxial Connectors

Chapter 10

Coaxial power connector



Most common coaxial power connector, male and female, 5.5 x 2.5 mm



Common DC power connectors

A **coaxial power connector** is an electrical power connector used for attaching extra-low voltage devices such as consumer electronics to external electricity. Also known as **barrel connectors**, **concentric barrel connectors** or **tip connectors**, these small cylindrical connectors come in an enormous variety of sizes.

Barrel plug connectors are commonly used to interface the secondary side of a power supply with the device. Some of these jacks contain a normally closed switch; the switch can disconnect internal batteries whenever the external power supply is connected.

10.1 Connector construction and terminology

10.1.1 Female (plug)

On the female plug, the outer body is a one metal contact. Female coaxial power connectors generally have a cylindrical outer jacket and a hollow insulated tip constructed to accept insertion of the pin in the corresponding male connector in the device, which is an internal metallic surface lining the inside of the tip of the plug. The outer barrel contact is generally called **barrel** or **sleeve**, and the inner contact is called the **tip** . The inner and outer barrels are separated by an insulating layer.

10.1.2 Male (receptacle)

There is typically a single spring-loaded contact at the side of the male connector and a pin in the center corresponding to the intended female plug.

10.2 Connector sizes

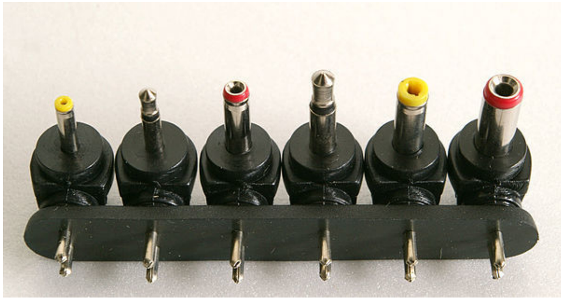
There are many different sizes of coaxial power connectors (see table at end of this article.)

Contact ratings commonly vary from unspecified up to 5 amp (11 amps for special hi-power versions). Voltage is again often unspecified, up to 48 V with 12 V typical. The smaller types usually have lower ratings, both for current and voltage.

It is quite possible that new sizes will continue to appear and disappear. One possible reason that a particular manufacturer may use a new size is to discourage use of third-party power supplies, either for technical reasons or to promote use of their own products, or both.

The sizes and shapes of connectors do not consistently correspond to the same power specifications across manufacturers and models. Two connectors from different manufacturers with different sizes could potentially be attached to power supplies with the same voltage and current. Alternatively, connectors of the same size can be part of power supplies with different voltages and currents. Use of the wrong power supply may cause severe equipment damage, or even fire.

10.3 Common sizes and interchangeability



Some common DC power connectors

Generic plugs are often named after the inside diameter, so these types will be seen described as *2.1 mm DC plugs* and *2.5 mm DC plugs* respectively.

After the two common 5.5 mm OD plugs, the next most common size is 3.5 mm OD with a 1.3 mm ID, usually about 9.5 mm in length but both longer and shorter versions also exist. These 3.5 mm OD plugs are normally used for lower voltages and currents.

10.4 Locking and retention features

A ring-shaped 'locking detent' or 'high-retention feature', present on the barrel of some DC coaxial connectors, is a feature intended to prevent accidental disconnection. Typically, this feature is a conical cut-back section of the tip, just behind the insulator that separates the inner from outer contact surfaces.

'lock-ring DC coaxial connector' uses a captive threaded ring or collar to secure the connection between the plug and jack. This design offers strong resistance to unplugging when used properly.

'lock-tab DC coaxial connector' (also called 'bayonet lock') offers a compromise that resists unplugging, but which will disengage when pulled hard enough. This connector uses small metal tab protrusions on the connector barrel to lock the plug in place, requiring a special push-and-rotate motion to engage the locks.

10.5 Standards

There are several standards in existence, such as IEC, EIAJ in Japan and DIN in Germany. More recently, some manufacturers appear to have implemented their own system correlating voltage and plug size. In addition, there appears to be a trend to standardize DC connector to negative **barrel** (or sleeve) of a coaxial power connector.

Close-up of a yellow-tipped EIAJ connector. Note 2 round adapter pins on the opposite end.

10.5.1 IEC 60130-10

IEC 60130-10:1971 defines five DC power connectors.[1]

- Type A: 5.5 mm OD, 2.1 mm ID (with optional screw lock)
- Type A: 5.5 mm OD, 2.5 mm ID (with optional screw lock)
- Type B: 6.0 mm OD, 2.1 mm ID
- Type B: 6.0 mm OD, 2.5 mm ID
- Type C: 3.8 mm OD, 1.4 mm ID
- Type D: 6.3 mm OD, 3.1 mm ID
- Type E: 3.4 mm OD, 1.3 mm ID

10.5.2 EIAJ power connectors

For more details on this topic, see EIAJ connector.

Five plug and matching socket or jack designs are defined by the EIAJ standard RC-5320A (also called JEITA RC-5320A). Each of these plugs is used with a specified voltage range. Most manufacturers use a yellow insulating material to distinguish these plugs from other similar-looking DC plugs.

- EIAJ-01 for 0–3.15 V
- EIAJ-02 for 3.15–6.3 V
- EIAJ-03 for 6.3–10.5 V
- EIAJ-04 for 10.5–13.5 V (also called JSBP 4)
- EIAJ-05 for 13.5–18 V (also called JSBP 5)

EIAJ-04 and 05 have an internal male pin in the plug. The 01 through 03 sizes do not and are similar to the generic plugs in structure. These five EIAJ plugs are 9.5 mm in length and have a current rating of 2A.

There are two other, less common, connectors defined by EIAJ; RC-5321 and RC-5322. The latter is designed for both 12 V and 24 V automotive applications.

10.5.3 DIN 45323

The German national standards organization DIN (Deutsches Institut für Normung — German Institute for Standardization) issued DIN 45323, which defines two DC power plug and jack (respectively) sizes. At least one of these sizes has a maximum rating of 34 V and 3 A. The information here is inferred from catalog references,[2] as the German standard has not been translated into English yet.

- 5.00 mm OD, 2.00 mm ID, 14 mm long?
- 6.00 mm OD, 1.98 mm ID

10.6 Listing of DC coaxial connectors

This list attempts to show all known sizes, and is annotated with some manufacturers producing selected types, since each manufacturer makes its own unique subset of the known types. Note that the example part numbers given may have different connector barrel (sleeve) lengths, and are not necessarily exact equivalents. There are many more design variants than can be listed in this table, so only a small sampling of part numbers is given.

Connector size is often listed in the format OD (outer diameter) x ID (inner diameter) x L (length of barrel and expressed in millimeters). Designations may vary between manufacturers.

Coaxial plugs that have a male center pin will have another measurement, Center Pin Diameter (CPD). These plugs are often used for higher power applications such as portable computers.

There are a number of sizes listed below that appear to be quite similar, and while the tolerances of these connectors are typically indicated as ±0.05 or ±0.03 mm by the manufacturers, there is still ambiguity as to whether two sizes differing by only 0.05 mm (or where the specification is only given to the nearest 0.10 mm) warrants listing them separately here.

10.7 RadioShack Adaptaplug conversion matrix

RadioShack sells a line of adapter plugs for universal AC adapters. Each “Adaptaplug” has a single-letter code, but does not provide any other official designation, nor publish the complete specifications and tolerances on barrel and pin dimensions. RadioShack’s web site lists the diameters to the nearest 0.1 mm, and sometimes differs slightly from the official EIAJ RC-5320A standard dimensions. This list may include some parts RadioShack has discontinued but are retained here for completeness.

10.8 See also

- AC adapter
- EIAJ connector
- Cigarette lighter receptacle
- DC connector
- Anderson Powerpole

10.9 References

[1] “Connectors for frequencies below 3 MHz. Part 10: Connectors for coupling an external low-voltage power supply to portable entertainment equipment”. IEC. 1 January 1971. IEC 60130-10 ed1.0. Retrieved 18 April 2012.

[2] Lumberg Connect GmbH. “Power supply connectors”. Retrieved 2011-03-23.

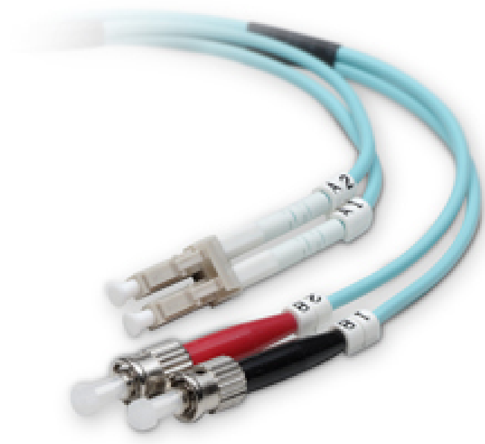
[3] http://podolsk.pro/for-mobile/Nokia/10-nsb-8-acc.pdf

10.10 External links

- Understanding the Radioshack Adaptaplug System
- NSSN Search engine for standards

Chapter 11

Optical fiber connector



LC and ST optical fiber connectors

An **optical fiber connector** terminates the end of an optical fiber, and enables quicker connection and disconnection than splicing. The connectors mechanically couple and align the cores of fibers so light can pass. Better connectors lose very little light due to reflection or misalignment of the fibers. In all, about 100 fiber optic connectors have been introduced to the market.[1]

11.1 Application

Optical fiber connectors are used to join optical fibers where a connect/disconnect capability is required. Due to the polishing and tuning procedures that may be incorporated into optical connector manufacturing, connectors are generally assembled onto optical fiber in a supplier's manufacturing facility. However, the assembly and polishing operations involved can be performed in the field, for example, to make cross-connect jumpers to size.

Optical fiber connectors are used in telephone company central offices, at installations on customer premises, and in outside plant applications to connect equipment and cables, or to cross-connect cables.

Most optical fiber connectors are spring-loaded, so the fiber faces are pressed together when the connectors are mated. The resulting glass-to-glass or plastic-to-plastic contact eliminates signal losses that would be caused by an air gap between the joined fibers.

Every fiber connection has two values:

- Attenuation or insertion loss
- Reflection or return loss.

Measurements of these parameters are now defined in IEC standard 61753-1. The standard gives five grades for insertion loss from A (best) to D (worst), and M for multimode. The other parameter is return loss, with grades from 1 (best) to 5 (worst).

A variety of optical fiber connectors are available, but SC and LC connectors are the most common types of connectors on the market. Typical connectors are rated for 500–1,000 mating cycles.[2] The main differences among types of connectors are dimensions and methods of mechanical coupling. Generally, organizations will standardize on one kind of connector, depending on what equipment they commonly use. Different connectors are required for multimode, and for single-mode fibers.

In many data center applications, small (e.g., LC) and multi-fiber (e.g., MTP) connectors are replacing larger, older styles (e.g., SC), allowing more fiber ports per unit of rack space.

Features of good connector design:

- Low insertion loss
- High return loss (*low* amounts of reflection at the interface)
- Ease of installation
- Low cost
- Reliability
- Low environmental sensitivity
- Ease of use

Outside plant applications may require connectors be located underground, or on outdoor walls or utility poles. In such settings, protective enclosures are often used, and fall into two broad categories: hermetic (sealed) and free-breathing. Hermetic cases prevent entry of moisture and air but, lacking ventilation, can become hot if exposed to sunlight or other sources of heat. Free-breathing enclosures, on the other hand, allow ventilation, but can also admit moisture, insects and airborne contaminants. Selection of the correct housing depends on the cable and connector type, the location, and environmental factors. Careful assembly is required to ensure good protection against the elements.

Depending on user requirements, housings for outside plant applications may be tested by the manufacturer under various environmental simulations, which could include physical shock and vibration, water spray, water immersion, dust, etc. to ensure the integrity of optical fiber connections and housing seals.

11.2 Types

Many types of optical connector have been developed at different times, and for different purposes. Many of them are summarized in the tables below.

11.2.1 Obsolete connectors

11.2.2 Notes

1. Modern connectors typically use a “physical contact” polish on the fiber and ferrule end. This is a slightly convex surface with the apex of the curve accurately centered on the fiber, so that when the connectors are mated the fiber cores come into direct contact with one another.[10][11] Some manufacturers have several grades of polish quality, for example a regular FC connector may be designated “FC/PC” (for physical contact), while “FC/SPC” and “FC/UPC” may denote “super” and “ultra” polish qualities, respectively. Higher grades of polish give less insertion loss and lower back reflection.

2. Many connectors are available with the fiber end face polished at an angle to prevent light that reflects from the interface from traveling back up the fiber. Because of the angle, the reflected light does not stay in the fiber core but instead leaks out into the cladding. Angle-polished connectors should only be mated to other angle-polished connectors. Mating to a non-angle polished connector causes very high insertion loss. Generally angle-polished connectors have higher insertion loss than good quality straight physical contact ones. “Ultra” quality connectors may achieve comparable back reflection to an angled connector when connected, but an angled connection maintains low back reflection even when the output end of the fiber is disconnected.

3. Angle-polished connections are distinguished visibly by the use of a green strain relief boot, or a green connector body. The parts are typically identified by adding "/APC” (angled physical contact) to the name. For example, an angled FC connector may be designated FC/APC, or merely FCA. Non-angled versions may be denoted FC/PC or with specialized designations such as FC/UPC or FCU to denote an “ultra” quality polish on the fiber end face.

4. SMA 906 features a “step” in the ferrule, while SMA 905 uses a straight ferrule. SMA 905 is also available as a keyed connector, used e.g., for special spectrometer applications.

11.2.3 Mnemonics

- LC connectors are sometimes called “Little Connectors”.
- MT-RJ connectors look like a miniature RJ-45 connector.
- ST connectors refer to having a “straight tip”, as the sides of the ceramic (which has a lower temperature coefficient of expansion than metal) tip are parallel—as opposed to the predecessor bi-conic connector which aligned as two nesting ice cream cones would. Other mnemonics include “Set and Twist”, “Stab and Twist”, and “Single Twist”, referring to how it is inserted (the cable is pushed into the receiver, and the outer barrel is twisted to lock it into place). Also they are known as “Square Top” due to the flat end face.
- SC connectors, being square, have a mnemonic of “Square Connector”, which some people believe to be the correct name, rather than the more official “Subscriber Connector”.[4] Other terms often used for SC connectors are “Set and Click” or “Stab and Click”.

11.2.4 Field-mountable connectors

Field-mountable optical fiber connectors are used to join optical fiber jumper cables that contain one singlemode fiber. These assemblies can be separated into two major categories: single-jointed connector assemblies and multiple-jointed connector assemblies. According to Telcordia GR-1081,[12] a single-jointed connector assembly is a connector assembly where there is only one spot where two different fibers are joined together. This is the situation generally found when connector assemblies are made from factory-assembled optical fiber connector plugs. A multiple-jointed connector assembly is a connector assembly where there is more than one closely spaced connection joining different fibers together. An example of a multiple-jointed connector assembly is a connector assembly that uses the stub-fiber type of connector plug.

Field-mountable optical fiber connectors are used for field restoration work and to eliminate the need to stock jumper cords of various sizes.

11.3 Analysis

- *FC* connectors' floating ferrule provides good mechanical isolation. FC connectors need to be mated more carefully than the push-pull types due to the need to align the key, and due to the risk of scratching the fiber end face while inserting the ferrule into the jack. FC connectors have been replaced in many applications by SC and LC connectors.[1]

- There are two incompatible standards for key widths on FC/APC and polarization-maintaining FC/PC connectors: 2 mm ("Reduced" or "type R") and 2.14 mm ("NTT" or "type N").[13] Connectors and receptacles with different key widths either cannot be mated, or will not preserve the angle alignment between the fibers, which is especially important for polarization-maintaining fiber. Some manufacturers mark reduced keys with a single scribe mark on the key, and mark NTT connectors with a double scribe mark.

- *SC* connectors offer excellent packing density, and their push-pull design reduces the chance of fiber end face contact damage during connection; frequently found on the previous generation of corporate networking gear, using GBICs.

- *LC* connectors have replaced SC connectors in corporate networking environments due to their smaller size; they are often found on small form-factor pluggable transceivers.

- *ST* connectors have a key which prevents rotation of the ceramic ferrule, and a bayonet lock similar to a BNC shell. The single index tab must be properly aligned with a slot on the mating receptacle before insertion; then the bayonet interlock can be engaged, by pushing and twisting, locking at the end of travel which maintains spring-loaded engagement force on the core optical junction.

- In general the insertion loss should not exceed 0.75 dB and the return loss should be higher than 20 dB. Typical insertion repeatability, the difference in insertion loss between one plugging and another, is 0.2 dB.

- On all connectors, cleaning the ceramic ferrule before each connection helps prevent scratches and extends the connector life substantially.

- Connectors on polarization-maintaining fiber are sometimes marked with a blue strain relief boot or connector body, although this is far from a universal standard. Sometimes a blue buffer tube is used on the fiber instead.[14]

- *MT-RJ* (*Mechanical Transfer Registered Jack*) uses a form factor and latch similar to the 8P8C (*RJ45*) connectors. Two separate fibers are included in one unified connector. It is easier to terminate and install than ST or SC connectors. The smaller size allows twice the port density on a face plate than ST or SC connectors do. The MT-RJ connector was designed by AMP, but was later standardized as FOCIS 12 (Fiber Optic Connector Intermateability Standards) in EIA/TIA-604-12. There are two variations: pinned and no-pin. The pinned variety, which has two small stainless steel guide pins on the face of the connector, is used in patch panels to mate with the no-pin connectors on MT-RJ patch cords.

- *MPO* (*Multi-fiber Push On*) is a connector for ribbon cables with four to twenty-four fibers.[15] Connectors for singlemode fiber have angled ends to minimize back-reflection, while multimode fiber versions typically have flat ends. *MTP* is a brand name for a version of the MPO connector with improved specifications. MTP and MPO connectors intermate.

- *Hardened Fiber Optic Connectors (HFOCs) and Hardened Fiber Optic Adapters (HFOAs)* are passive telecommunications components used in an Outside Plant (OSP) environment. They provide drop connections to customers from fiber distribution networks. These components may be provided in pedestal closures,[note 1][16] aerial and buried closures and terminals, or equipment located at customer premises such as a Fiber Distribution Hub (FDH) or an Optical Network Terminal or Termination (ONT) unit.

  These connectors, which are field-mateable and hardened for use in the OSP, are needed to support Fiber to the Premises (FTTP) deployment and service offerings. HFOCs are designed to withstand climatic conditions existing throughout the U.S., including rain, flooding, snow, sleet, high winds, and ice and sand storms. Ambient temperatures ranging from –40°C (–40°F) to +70°C (158°F) can be encountered.

Telcordia GR-3120 [17] contains the industry's most recent generic requirements for HFOCs and HFOAs.

11.4 Testing

Glass fiber optic connector performance is affected both by the connector and by the glass fiber. Concentricity tolerances affect the fiber, fiber core, and connector body. The core optical index of refraction is also subject to variations. Stress in the polished fiber can cause excess return loss. The fiber can slide along its length in the connector. The shape of the connector tip may be incorrectly profiled during polishing. The connector manufacturer has little control over these factors, so in-service performance may well be below the manufacturer's specification.

Testing fiber optic connector assemblies falls into two general categories: factory testing and field testing.

Factory testing is sometimes statistical, for example, a process check. A profiling system may be used to ensure the overall polished shape is correct, and a good quality optical microscope to check for blemishes. Optical Loss / Return Loss performance is checked using specific reference conditions, against a reference-standard single mode test lead, or using an "Encircled Flux Compliant" source for multi-mode testing. Testing and rejection ("yield") may represent a significant part of the overall manufacturing cost.

Field testing is usually simpler. A special hand-held optical microscope is used to check for dirt or blemishes. A power meter and light source or an optical loss test set (OLTS) is used to test end-to-end loss, and an optical time-domain reflectometer may be used to identify significant point losses or return losses.

11.5 Notes

[1] Pedestal terminal closures are intended to house passive telecommunications components used in an Outside Plant (OSP) environment. According to Telcordia GR-13, these closures may house such components as copper terminal blocks, coaxial taps, or passive fiber optic distribution equipment used for the distribution of telephone service and broadband services.

11.6 See also

- Optical fiber cable Color coding of connector boot and fiber cable jackets
- Optical attenuator Fiber optic attenuator
- Gap loss Attenuation sources and causes
- Index-matching material liquid/gel to reduce Fresnel reflection

11.7 References

[1] "Connector identifier". The Fiber Optic Association. 2010. Retrieved Oct 18, 2014.

[2] Alwayn, Vivek (2004). "Fiber-Optic Technologies". Retrieved Aug 15, 2011.

[3] "DMI datasheet". DIAMOND SA. Retrieved 6 Oct 2014.

[4] Keiser, Gerd (August 2003). *Optical Communications Essentials*. McGraw-Hill Networking Professional. p. 132–. ISBN 0-07-141204-2.

[5] "Fiber Optic Connectors". Retrieved Oct 18, 2014.

[6] "Small Form Factor Fiber Optic Connectors Tutorial". Fiberstore. June 3, 2014. Retrieved Oct 18, 2014.

[7] US patent 20140126875, Lou Guzzo, Inman, SC (US), "Connector Ferrule Holder", issued 2014-05-08

[8] Shimoji, Naoko; Yamakawa, Jun; Shiino, Masato (1999). "Development of Mini-MPO Connector". *Furukawa Review* (18): 92.

[9] "Frequently asked questions". US Conec. Retrieved 12 Feb 2009.

[10] "The Importance of Geometry for Fiber Optic Connectors" (pdf). Corning Cable Systems. April 2006.

[11] Yin, Ling; Huang, H.; Chen, W.K.; Xiong, Z.; Liu, Y.C.; Teo, P.L. (May 2004). "Polishing of fiber optic connectors". *International Journal of Machine Tools and Manufacture* **44** (6): 659–668. doi:10.1016/j.ijmachtools.2003.10.029.

[12] GR-1081, Generic Requirements for Field-Mountable Optical Fiber Connectors, Telcordia.

[13] Sezerman, Omur; Best, Garland (December 1997). "Accurate alignment preserves polarization". *Laser Focus World*. Retrieved March 12, 2009.

[14] "Polarization maintaining fiber patchcords and connectors" (pdf). *OZ Optics*. Retrieved Feb 6, 2009.

[15] "MTP/MPO Fiber Solution".

[16] GR-13-CORE, Generic Requirements for Pedestal Terminal Closures, Telcordia.

[17] GR-3120, Generic Requirements for Hardened Fiber Optic Connectors (HFOCs) and Hardened Fiber Optic Adapters (HOFAs), Telcordia.

11.8 External links

- Fiber Optic Connector Reference
- How To Terminate Fiber Optic Connectors
- Fiber optic connector termination processes
- SC Connector termination anaerobic processes (Video)

Chapter 12

BNC connector

The **BNC (Bayonet Neill–Concelman) connector** is a miniature quick connect/disconnect radio frequency connector used for coaxial cable. It features two bayonet lugs on the female connector; mating is fully achieved with a quarter turn of the coupling nut. BNC connectors are used with miniature-to-subminiature coaxial cable in radio, television, and other radio-frequency electronic equipment, test instruments, and video signals. The BNC was commonly used with 10BASE2 computer networks. BNC connectors are made to match the characteristic impedance of cable at either 50 ohms or 75 ohms. They are usually applied for frequencies below 4 GHz[1] and voltages below 500 volts.[2]

Similar connectors using the bayonet connection principle exist, and a threaded connector is also available. United States military standard MIL-PRF-39012 entitled *Connectors, Coaxial, Radio Frequency, General Specification for* (formerly MIL-C-39012) covers the general requirements and tests for radio frequency connectors used with flexible cables and certain other types of coaxial transmission lines in military, aerospace, and spaceflight applications.[3]

12.1 Use

Rear of a video switcher with an array of BNC connectors

The BNC was originally designed for military use and has gained wide acceptance in video and RF applications to 2 GHz. The BNC uses a slotted outer conductor and some plastic dielectric on each gender connector. This dielectric causes increasing losses at higher frequencies. Above 4 GHz, the slots may radiate signals, so the connector is usable, but not necessarily stable up to about 11 GHz. Both 50 ohm and 75 ohm versions are available. The BNC connector is used for signal connections such as:

- analog and serial digital interface video signals
- amateur radio antennas
- aerospace electronics (avionics)
- test equipment.

BNC Tee Connectors with resistive load terminators

The BNC connector is used for composite video on commercial video devices. Consumer electronics devices with RCA connector jacks can be used with BNC-only commercial video equipment by inserting an adapter. BNC connectors were commonly used on 10base2 thin Ethernet network cables and network cards. BNC connections can also be found in recording studios. Digital recording equipment uses the connection for synchronization of various components via the transmission of word clock timing signals.

Typically the male connector is fitted to a cable, and the female to a panel on equipment. Cable connectors are often designed to be fitted by crimping[4] using a special power or manual tool.[5] Wire strippers which strip outer jacket, shield braid, and inner dielectric to the correct lengths in one operation are used.[6]

12.2 Origin

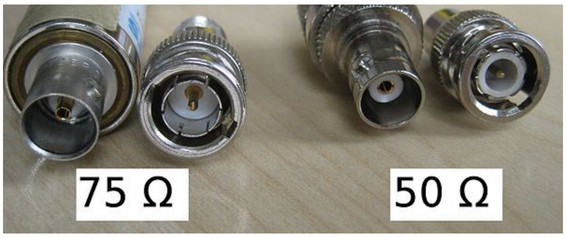
The connector was named the *BNC* (for Bayonet Neill–Concelman) after its bayonet mount locking mechanism and its inventors, Paul Neill and Carl Concelman.[1] Neill worked at Bell Labs and also invented the N connector; Concelman worked at Amphenol and also invented the C connector. A backronym has been mistakenly applied to it: British Naval Connector.[7]

The basis for the development of the BNC connector was largely the work of Octavio M. Salati, a graduate of the Moore School of Electrical Engineering of the University of Pennsylvania. In 1945, while working at Hazeltine Electronics Corporation, he filed a patent for a connector for coaxial cables that would minimize wave reflection/loss. The patent was granted in 1951.[8]

Reverse-polarity BNC (RP-BNC) is a variation of the BNC specification which reverses the polarity of the interface. In a connector of this type, the female contact normally found in a jack is usually in the plug, while the male contact normally found in a plug is in the jack. This ensures that reverse polarity interface connectors do not mate with standard interface connectors.[2] The SHV connector is a high-voltage BNC variant that uses this reverse polarity configuration.

Smaller versions of the BNC connector, called Mini BNC and High Density BNC (HD BNC), are manufactured by Amphenol. While retaining the electrical characteristics of the original specification, they have smaller footprints giving a higher packing density on circuit boards and equipment backplanes. These connectors have true 75 ohm impedance making them suitable for HD video applications.

12.3 Types and compatibility



BNC connectors. From left to right: 75 Ω female, 75 Ω male, 50 Ω female, 50 Ω male.

12.3.1 Types

BNC connectors are most commonly made in 50 and 75 ohm versions, matched for use with cables of the same characteristic impedance. The 75 ohm types can sometimes be recognized by the reduced or absent dielectric in the mating ends but this is by no means reliable. There was a proposal in the early 1970s for the dielectric material to be coloured red in 75 ohm connectors, and while this is occasionally implemented, it did not become standard. The 75 ohm connector is dimensionally slightly different from the 50 ohm variant, but the two nevertheless can be made to mate. The 50 ohm connectors are typically specified for use at frequencies up to 4 GHz and the 75 ohm version up to 2 GHz. A 95 ohm variant is used within the aerospace sector, but rarely elsewhere. It is used with the 95 ohm video connections for glass cockpit displays on some aircraft.

Video (particularly HD video signals) and DS3 Telco central office applications primarily use 75 ohm BNC connectors, whereas 50 ohm connectors are used for data and RF. Many VHF receivers used 75 ohm antenna inputs, so they often used 75 ohm BNC connectors.

12.3.2 Compatibility

The different versions are designed to mate with each other,[2] and a 75 ohm and a 50 ohm BNC connector which both comply with the 1978 standard, IEC 169-8, will mate non-destructively. At least one manufacturer[9] claims very high reliability for the connectors' compatibility.

At frequencies below 10 MHz the impedance mismatch between a 50 ohm connector or cable and a 75 ohm one has negligible effects.[10] BNC connectors were thus originally made only in 50 ohm versions, for use with any impedance of cable. Above this frequency, however, the mismatch becomes progressively more significant and can lead to signal reflections.

12.4 BNC inserter/remover tool

Rear view of a patch panel with BNC jacks in close proximity.[11]

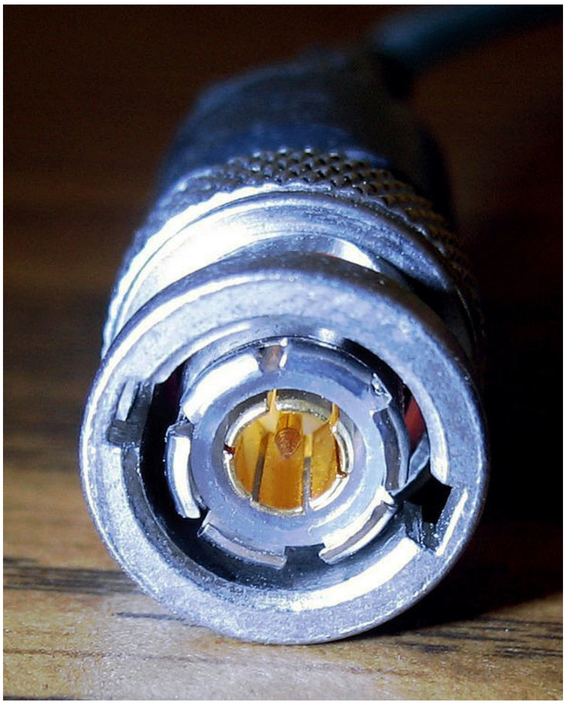
A **BNC inserter/remover tool** also called a **BNC tool**, **BNC extraction tool**, **BNC wrench**, or **BNC apple corer**, is used to insert or remove BNC connectors in high density or hard-to-reach locations, such as densely wired patch panels in broadcast facilities like central apparatus rooms.

BNC tools are usually light weight, made with stainless steel, and have screw driver type plastic handle grips for applying rotating torque. Their shafts are usually double the length of a standard screw driver.

They help to safely, efficiently and quickly connect and disconnect BNC connectors in jack fields. BNC tools facilitate access and minimize the risk of accidentally disconnecting nearby connectors.

12.5 Similar connectors

Main article: RF connector



Triaxial BNC connector

12.5.1 SR-50 and SR-75

Main article: SR-50 connector
Main article: SR-75 connector

In the USSR, BNC connectors were copied as SR-50 (CP−50 in Cyrillic) and SR-75 (CP−75 in Cyrillic) connectors. As a result of recalculating from imperial to metric measurements their dimensions differ slightly from those of BNC. They are however generally interchangeable with them, sometimes with force applied.

12.5.2 TNC (Threaded Neill–Concelman)

Main article: TNC connector

A threaded version of the BNC connector, known as the TNC connector (for **Threaded Neil-concelman**) is also available. It has superior performance to the BNC connector at microwave frequencies.

12.5.3 Twin BNC or twinax

Twin BNC (also known as **twinax**) connectors use the same bayonet latching shell as an ordinary BNC connector but contain two independent contact points (one male and one female), allowing the connection of a 78 ohm or 95 ohm shielded differential pair such as RG-108A.[12] They can operate up to 100 MHz and 100 volts. They cannot mate with ordinary BNC connectors. An abbreviation for twinax connectors has been BNO (Sühner).

12.5.4 Triaxial

Triaxial (also known as **triax**) connectors are a variant on BNC that carry a signal and guard as well as ground conductor. These are used in sensitive electronic measurement systems, such as those made by Keithley Instruments. Early triaxial connectors were designed with just an extra inner conductor, but later triaxial connectors also include a three-lug arrangement to rule out an accidental forced mating with a BNC connector. Adaptors exist to allow some interconnection possibilities between triaxial and BNC connectors. The triaxial may also be known as a Trompeter connection.

12.5.5 High voltage connectors

For higher voltages (above 500 V), MHV and SHV connectors are typically used. MHV connectors are easily mistaken for BNC type, and can be made to mate with them by brute force. The SHV connector was developed as a safer alternative, it will not mate with ordinary BNC connectors and the inner conductor is much harder to accidentally contact.

12.5.6 Miniature connectors

BNC connectors are commonly used in electronics, but in some applications they are being replaced by LEMO 00 miniature connectors which allow for significantly higher densities. In video broadcast industry, the DIN 1.0/2.3 and the HD-BNC connector are used for higher density products

12.6 See also

- Coaxial cable
- RF connector
- UHF connector
- SMA connector, SMB connector, SMC connector
- TNC connector, N connector, C connector

12.7 References

[1] Thomas H. Lee, *Planar microwave engineering: a practical guide to theory, measurement, and circuits, Volume 1* Cambridge University Press, p. 111 (2004). ISBN 0-521-83526-7.

[2] BNC Connector specifications, Amphenol Connex

[3] MIL-PRF-39012

[4] Typical crimp BNC connector

[5] Typical manual crimp tool for fitting BNC and other coaxial connectors to cables

[6] Typical coax one-operation stripper

[7] "Extended Definition: BNC connector". *Webster's Online Dictionary*. Retrieved 13 June 2013.

[8] Electrical connector. US Patent 2,540,012 by Octavio M. Salati

[9] Canford. "In over 15 years and many million BNC connectors we have no first hand experience of incompatibility between 50 ohm and 75 ohm types, other than extremely rare (and very obvious) manufacturing faults."

[10] BNC Connectors, The Canford Group

[11] *Trompeter Product Catelog*. Trompeter. p. 51. Retrieved 24 January 2015.

[12] E-Base Interactive. "Twin BNC connector series". Amphenol RF. Retrieved 26 November 2011.

12.8 External links

- Media related to Connectors at Wikimedia Commons
- Media related to BNC connectors at Wikimedia Commons

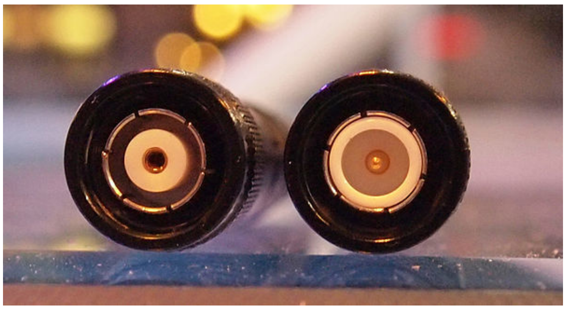
Chapter 13

TNC connector

The **TNC** (**Threaded Neill–Concelman**) connector is a threaded version of the BNC connector. The connector has a 50 Ω impedance and operates best in the 0–11 GHz frequency spectrum. It has better performance than the BNC connector at microwave frequencies. Invented in the late 1950s and named after Paul Neill of Bell Labs and Carl Concelman of Amphenol, the TNC connector has been employed in a wide range of radio and wired applications.[1]

13.1 Variations

13.1.1 Reverse-polarity TNC



Left, an RP-TNC connector from a 2.4GHz antenna. Right, a standard TNC connector on a UHF antenna.

Reverse-polarity TNC (RP-TNC, sometimes RTNC) is a variation of the TNC specification which reverses the polarity of the interface. This is usually achieved by incorporating the female contacts normally found in jacks into the plug, and the male contacts normally found in plugs into the jack.[2]

Because they were not readily available, RP-TNC connectors have been widely used by Wi-Fi equipment manufacturers to comply with specific local regulations, such as those from the FCC,[3] which are designed to prevent consumers from connecting antennas which exhibit gain and therefore breach compliance. The FCC considered that the RP-TNC was acceptable in preventing consumers changing the antenna; but by 2000 it regarded them as readily available,[4] though delaying its ruling indefinitely.[5] As of 2013, leading manufacturers are still using RP-TNC connectors on their Wi-Fi equipment.[6]

13.1.2 75 ohm TNC

Most TNC connectors are 50-ohm type even when used with coaxial cable of other impedances, but a 75-ohm series is also available, providing a good SWR to about 1 GHz.[7] These can be recognized by a reduced amount of dielectric in the mating ends. They are intermatable with standard types.

13.2 Retail uses

Linksys, owned by Belkin,[8] a manufacturer of consumer networking equipment, uses RP-TNC connectors for several of its Wi-Fi-certified routers, including the popular WRT54G.

Telex Communications, a manufacturer of hearing aids and audio equipment, uses TNC connectors on its Radiocom BTR-800 partyline intercom base station for the transmit and receive antennas.

Camplex, a Camera multiplexing unit, uses TNC connectors to send power/tallies/intercom to a camera. The camera sends back audio, video, and intercom.[9]

Icom, a mobile telecommunications equipment manufacturer, uses TNC antenna output terminals in some models intended for the professional VHF PMR market.

Electro-Voice, a pro audio manufacturer, uses these style connectors on their wireless microphone systems.

13.3 See also

- RF connector
- SMA connector, SMB connector, SMC connector
- BNC connector, N connector
- Optical fiber connector

13.4 References

[1] E-Base Interactive. "TNC Connector Series". Amphenol RF. Retrieved 2011-01-12.

[2] "RP-TNC Connector".

[3] U.S. Code of Federal Regulations: 47 CFR 15.203, available at http://www.ecfr.gov

[4] FCC public notice, "OET clarifies antenna connector requirements for Part 15 Unlicensed Transmitters", http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-00-1087A1.pdf

[5] FCC public notice, "OET extends effective data of antenna connector requirement indefinitely" http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-00-2225A1.pdf

[6] Getting Started Guide: Cisco 3600 Series Access Points http://www.cisco.com/en/US/docs/wireless/access_point/3600/quick/guide/ap3600getstart.html#wp59090

[7] "HUBER+SUHNER TNC 75 Ohm series (EN)". Hubersuhner.com. 2010-10-28. Retrieved 2011-01-12.

[8] "Belkin completes acquisition of Linksys from Cisco". Retrieved 2014-06-16.

[9] "Innovation in Motion". Camplex. Retrieved 2011-01-12.

Chapter 14

N connector

Type N connector (female)

The **N connector** (in full, **Type N connector**) is a threaded, weatherproof, medium-size RF connector used to join coaxial cables. It was one of the first connectors capable of carrying microwave-frequency signals, and was invented in the 1940s by Paul Neill of Bell Labs, after whom the connector is named.[2]

14.1 Design

Originally, the connector was designed to carry signals at frequencies up to 1 GHz in military applications, but today's common Type N easily handles frequencies up to 11 GHz. More recent precision enhancements to the design by Julius Botka at Hewlett Packard have pushed this to 18 GHz. The male connector is hand-tightened (though versions with a hex nut are also available) and has an air gap between the center and outer conductors. The coupling has a 5/8-24 thread. The center coaxial contacts are identical to TNC and BNC connectors. Amphenol [2] suggests tightening to a torque of 15 inch-pounds (1.7 N·m), while Andrew Corporation suggest 20 inch-pounds (2.3 N·m) for their hex nut variant. As torque limit depends only on thread quality and cleanliness, whereas the main operational requirement is good RF contact without significant steps or gaps, these values should be seen as indicative rather than critical.

14.2 Power rating

The *peak* power rating of an N connector is determined by voltage breakdown/ionisation of the air near the center pin. The *average* power rating is determined by overheating of the centre contact due to resistive insertion loss, and thus is a function of frequency. Typical makers' curves for a new clean connector with a perfect load (VSWR=1.0) give limits of ≈5000 W at 20 MHz and ≈500 W at 2 GHz.[3] This square root frequency derating law is expected from the skin depth decreasing with frequency. At lower frequencies the same maker recommends an upper bound of ≈1000 V RMS. To achieve reliable operation in practice over an extended period, a safety factor of 5 or more is not uncommon, particularly when generic parts may be substituted, or the operating environment is likely to lead to eventual tarnishing of the contacts.

14.3 Impedance options

The N connector follows the MIL-STD-348 standard, defined by the US military, and comes in 50 and 75 ohm versions. The 50 ohm version is widely used in the infrastructure of land mobile, wireless data, paging and cellular systems. The 75 ohm version is primarily used in the infrastructure of cable television systems. Connecting these two different types of connectors to each other can lead to damage, and/or intermittent operation due to the difference in diameter of the center pin.[4]

Unfortunately, many type N connectors are not labeled, and it can be difficult to prevent this situation in a mixed impedance environment. The situation is further complicated by some makers of 75 ohm sockets designing them with enough spring yield to accept the larger 50 ohm pin without irreversible damage, while others clearly do not, and expect users to segregate their connectors and adaptors. In general a 50 ohm socket is not damaged by a 75 ohm pin, but the loose fit means the contact quality is not

Picture showing the similarity between 50Ω (bottom) and 75Ω (top) Type N connectors

guaranteed; this can cause poor or intermittent operation, with the thin 75 ohm male pin only barely mating with the larger 50 ohm socket in the female.

The 50 ohm type N connector is favored by enthusiasts who create their own Wireless LAN antenna systems, which run at 2.4 GHz or 5 GHz. The Cantenna is one such design. The enthusiasts have settled on using the N connector as a standard connection for homebrew antennas. By using a cable with an N connector one can easily interchange homebrew antennas. 50Ω N connectors are also commonly used on amateur radio devices (e.g., transceivers) operating in UHF bands.

14.4 Variations

SnapN was originally designed by Rosenberger Hochfrequenztechnik in 2006 and is a quick locking replacement for the threaded interface of the widely applied Type N connector. Though part of the Quick Lock Formula Alliance (QLF), engineers at Rosenberger independently designed the SnapN in order to correct the performance problems of QLF's version of the quick lock N connector, QN. This design achieves better electronic performance because, unlike the QN, this new version maintains the basic structural parameters of the original Type N in which the inner dimensions of the outer conductor are 7.00 mm, and the inner conductor's outer dimensions are 3.04 mm.

14.5 See also

- RF connector
- SMA connector, SMB connector, SMC connector
- UHF connector (aka PL-259 Connector)
- Optical fiber connector

14.6 References

[1] Radiall R191381000 datasheet

[2] Amphenol, *N type datasheet*

[3] *RF Coaxial Connectors General Catalogue*. Huber+Suhner. 2007/2008. pp. 275–276. Check date values in: |date= (help)

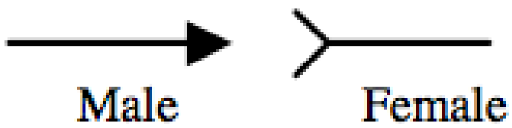
[4] Golio, Mike (2008). *The RF and Microwave Handbook, Second Edition*. CRC. pp. 8–7. ISBN 978-0-8493-7217-9.

^ N type connectors from Cmpter Electronics

Chapter 15

Electrical connector

Back of an audio power amplifier features a variety of electrical connectors



Electronic symbols for male-ended and female-ended connectors

An **electrical connector** is an electro-mechanical device for joining electrical circuits as an interface using a mechanical assembly. Connectors consist of plugs (male-ended) and jacks (female-ended). The connection may be temporary, as for portable equipment, require a tool for assembly and removal, or serve as a permanent electrical joint between two wires or devices.[1] An adapter can be used to effectively bring together dissimilar connectors.

There are hundreds of types of electrical connectors. Connectors may join two lengths of flexible copper wire or cable, or connect a wire or cable to an electrical terminal.

In computing, an electrical connector can also be known as a **physical interface** (compare physical layer in OSI model of networking). Cable glands, known as *cable connectors* in the US, connect wires to devices mechanically rather than electrically and are distinct from quick-disconnects performing the latter.

15.1 Properties of electrical connectors

Electrical connectors are characterised by their pinout and physical construction, size, contact resistance, insulation between pins, ruggedness and resistance to vibration, resistance to entry of water or other contaminants, resistance to pressure, reliability, lifetime (number of connect/disconnect operations before failure), and ease of connecting and disconnecting.

They may be keyed to prevent insertion in the wrong orientation, connecting the wrong pins to each other, and have locking mechanisms to ensure that they are fully inserted and cannot work loose or fall out. Some connectors are designed such that certain pins make contact before others when inserted, and break first on disconnection; this protects circuits typically in connectors that apply power, e.g. connecting safety ground first, and sequencing connections properly in hot swapping applications.

It is usually desirable for a connector to be easy to identify visually, rapid to assemble, require only simple tooling, and be inexpensive. In some cases an equipment manufacturer might choose a connector specifically because it is *not* compatible with those from other sources, allowing control of what may be connected. No single connector has all the ideal properties; the proliferation of types is a reflection of differing requirements.

Fretting is a common failure mode in electrical connectors that have not been specifically designed to prevent it.[2]

15.1.1 Keying

Many connectors are **keyed**, with some mechanical component which prevents mating except with a correctly oriented matching connector. This can be used to prevent incorrect or damaging interconnections, either preventing pins from being damaged by being jammed in at the wrong angle or fitting into imperfectly fitting plugs, or to prevent damaging connections, such as plugging an audio cable into a power outlet. For instance, XLR connectors have a notch to ensure proper orientation, while Mini-DIN plugs have a plastic projection, which fits into a corresponding hole in the socket and prevent different connectors from being pushed together (they also have a notched metal skirt to provide secondary keying).

15.1.2 Locking mechanisms

Some connector housings are designed with locking mechanisms to prevent inadvertent disconnection or poor environmental sealing. Locking mechanism designs include locking levers of various sorts, screw locking, and toggle or bayonet locking. Depending on application requirements, housings with locking mechanisms may be tested under various environmental simulations that include physical shock and vibration, water spray, dust, etc. to ensure the integrity of the electrical connection and housing seals.

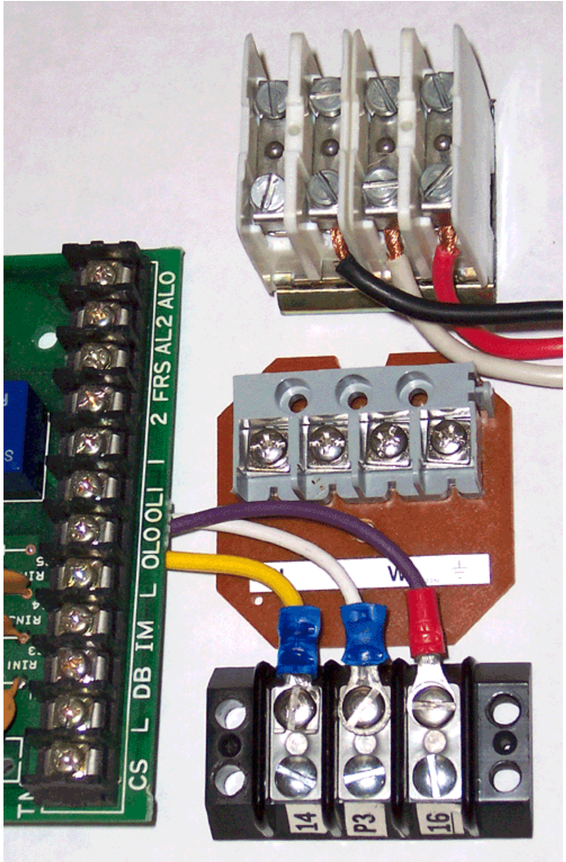
15.2 Types of electrical connectors

A *terminal* is a simple type of electrical connector that connects two or more wires to a single connection point. Wire nuts are another type of single point connector.

15.2.1 Terminal blocks

Terminal blocks (also called terminal *boards* or *strips*) provide a convenient means of connecting individual electrical wires without a splice or physically joining the ends. They are usually used to connect wiring among various items of equipment within an enclosure or to make connections among individually enclosed items. Since terminal blocks are readily available for a wide range of wire sizes and terminal quantity, they are one of the most flexible types of electrical connector available. Some disadvantages are that connecting wires is more difficult than simply plugging in a cable and the terminals are generally not very well protected from contact with persons or foreign conducting materials.

One type of terminal block accepts wires that are prepared only by removing (*stripping*) a short length of insulation from the end. Another type accepts wires that have ring or spade terminal *lugs* crimped onto the wires. Printed circuit board (PCB) mounted terminal blocks allow individual wires to be connected to the circuit board. PCB mounted terminal blocks are soldered to the board, but they are available in a pull-apart version that allows the wire-connecting half of the block to be unplugged from the part that is soldered to the PCB.



Terminal blocks of various types.

15.2.2 Posts

Main article: Binding post

A general type of connector that simply screws or clamps bare wire to a post; such connectors are frequently used in electronic test equipment and audio. Many, but not all binding posts will also accept a banana connector plug.

A binding post (red and black) adaptor.

15.2.3 Crimp-on connectors

Main article: Crimp connection

A type of solderless connection.

15.2.4 Insulation displacement connectors

Main article: Insulation-displacement connector

Since stripping the insulation from wires is time-consuming, many connectors intended for rapid assembly use insulation-displacement connectors so that insulation need not be removed from the wire. These generally take the form of a fork-shaped opening in the terminal, into which the insulated wire is pressed and which cut through the insulation to contact the conductor within. To make these connections reliably on a production line, special tools are used which accurately control the forces applied during assembly. If properly assembled, the resulting terminations are gas-tight and will last the life of the product. A common example is the multi-conductor flat ribbon cable used in computer disk drives; to terminate each of the many (approximately 40) wires individually would be slow and error-prone, but an insulation displacement connector can terminate all the wires in (literally) one stroke. Another very common use is so-called punch-down blocks used for terminating telephone wiring.

Insulation displacement connectors are usually used with small conductors for signal purposes and at low voltage. Power conductors carrying more than a few amperes are more reliably terminated with other means, though “hot tap” press-on connectors find some use in automotive applications for additions to existing wiring.

15.2.5 Plug and socket connectors

See also: Gender of connectors and fasteners and Pinout

Plug and socket connectors are usually made up of a male plug (typically pin contacts) and a female receptacle (typically socket contacts), although *hermaphroditic* connectors exist, such as the original IBM token ring LAN connector. Plugs generally have one or more pins or prongs that are inserted into openings in the mating socket. The connection between the mating metal parts must be sufficiently tight to make a good electrical connection and complete the circuit. When working with multi-pin connectors, it is helpful to have a pinout diagram to identify the wire or circuit node connected to each pin.

Jack commonly refers to a connector often with the female electrical contact or socket, and is the “more fixed” connector of a connector pair. *Plug* commonly refers to a movable connector, often (but not always) with the male electrical contact or pin, and is the movable (less fixed) connector of a connector pair.

Some connector styles[3] may contain both pin and socket connection types.

A jack is properly described as a connector that is designed to be fixed on the surface of a bulkhead or enclosure; “The stationary (more fixed) connector of a mating pair shall be designated J or X”[4] where J means jack.[5] Its counterpart, the “plug,” is designed to attach to a wire, cable or removable electrical assembly; “The movable (less fixed) connector of a mating pair shall be designated P” [6] where P means plug. This convention is currently defined in ASME Y14.44-2008 which is the current actively maintained follow on to the withdrawn IEEE 200-1975; IEEE 200-1975 was derived from the long withdrawn MIL-STD-16 which dates back at least to the 1950s which highlights the heritage of this connector naming convention. IEEE 315-1975 works alongside ASME Y14.44-2008 to define J, P and X references.

A plug is properly described as a connector that is designed to be attached to a wire, cable or removable electrical assembly: “The movable (less fixed) connector of a mating pair shall be designated P”[6] where P means plug.[5]

The term *jack* occurs in several related terms:

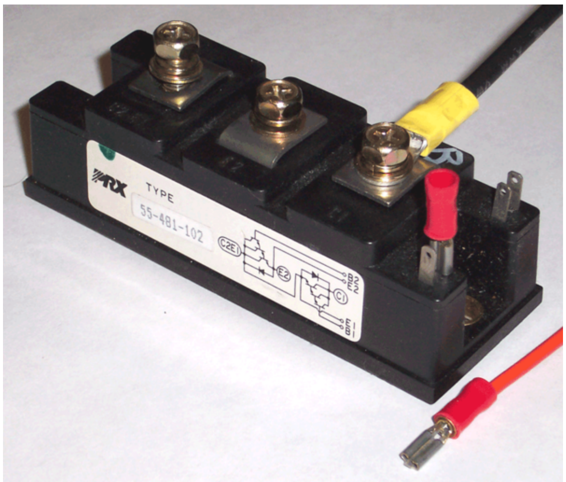
- The "registered jack" in RJ11, RJ45 and similar connectors, and includes the modular jacks used in modern telephone systems and computer network interfaces (for example, "Ethernet jack”).
- The telephone jack of manual telephone switchboards, which is the socket fitting the original 1/4” telephone plug. This open-frame, open-circuit accepts 1/4” mono phone plugs.
- The 1/4” phone jack common to many electronic applications, either in a 2-conductor tip-sleeve (TS) or 3-conductor tip-ring-sleeve (TRS) configuration.
- The RCA jack, also known as a “phono jack”, common to consumer electronics.
- The EIAJ jack designed for consumer appliances requiring less than an 18.0 volt power supply.

When the description includes a diameter, the term refers to the jack that matches the corresponding diameter of plug. For example:

- 6.35 mm or 1/4” jack
- 3.5 mm (1/8”) miniature jack
- 2.5 mm (3/32”) subminiature

A headphone (or earphone) jack is commonly one of the three standard sizes of 3-conductor TRS headphone jacks, but the term could refer to any socket used for this purpose.

15.2.6 Component and device connectors



High-power transistor switch module with large screw connectors and small crimped-on "Fast-on" connectors

Electrical and electronic components and devices sometimes have plug and socket connectors or terminal blocks, but individual screw terminals and fast-on or quick-disconnect terminals are more common. Small components have bare lead wires for soldering. They are manufactured using casting.

15.2.7 Blade connector

[[Image:Kabelschuh verschiedene commons.jpg |thumb|Blade connectors (lower half of photo). Ring and spade terminals (upper half).]] A **blade connector** is a type of single wire connection using a flat conductive blade which is inserted into a blade receptacle. Usually both blade connector and blade receptacle have wires attached to them either through of the wire to the blade or crimping of the blade to the wire. In some cases the blade is an integral manufactured part of a component (such as a switch or a speaker unit), and a blade receptacle is pushed onto the blade to form a connection.

A common type of blade connector is the "Faston". While Faston is a trademark of TE Connectivity (formerly Tyco Electronics), it has come into common usage. Faston connectors come in male and female types. They have been commonly used since the 1970s.

Ring style wire end blade connectors are normally sold in lots.

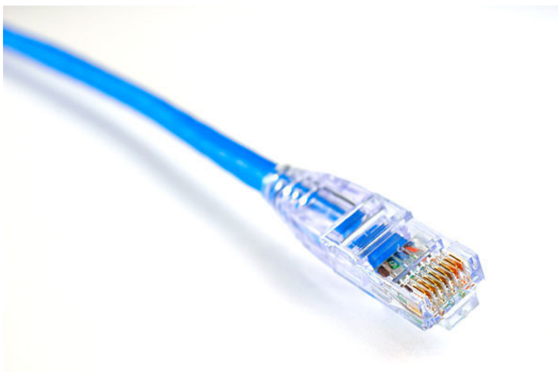
15.2.8 Ring and spade terminals

The connectors in the top row of the image are known as **ring terminals** and **spade terminals** (sometimes called fork or split ring terminals). Electrical contact is made by the flat surface of the ring or spade, while mechanically they are attached by passing a screw or bolt through them. The spade terminal form factor facilitates connections since the screw or bolt can be left partially screwed in as the spade terminal is removed or attached. Their sizes can be determined by the size of the conducting wire AWG and the screw/bolt diameter size designation.

15.3 Commonly used connectors

15.3.1 8P8C connector

Main article: 8P8C
8P8C is short for "eight positions, eight conductors", and



8P8C Connector crimped to cable

so an 8P8C modular connector (plug or jack) is a modular connector with eight positions, all containing conductors. The connector is probably most famous for its use in Ethernet and widely used on CAT5 cables.

The 8P8C modular plugs and jacks look very similar to the plugs and jacks used for FCC's registered jack RJ45 variants, although the specified RJ45 socket is not compatible with 8P8C modular plug connectors. It neither uses all eight conductors (but only two of them for wires plus two for connecting a programming resistor) nor does it fit into 8P8C because the true RJ45 is "keyed".

15.3.2 D-subminiature connectors

Main article: D-subminiature

The D-subminiature electrical connector is commonly

A male DE-9 plug.

used for the RS-232 serial port on modems and IBM compatible computers. The D-subminiature connector is used in many different applications, for computers, telecommunications, and test and measurement instruments. A few examples are monitors (MGA, CGA, EGA), the Commodore 64, MSX, Apple II, Amiga, and Atari joysticks and mice, and game consoles such as Atari and Sega.

Another variants of D-subminiature are the Positronic D-subminiature connector which have PosiBand closed entry contact option, solid machined contacts, thermocouple contact options, crimp and PCB mount.;[7] and the Positronic Combo D-subminiature which have Large Surface Area (LSA) contact system that is for low contact resistance and saves energy, and sequential mating options.[8]

15.3.3 USB connectors

Main article: USB

The **Universal Serial Bus** is a serial bus standard to interface devices, founded in 1996. It is currently widely used among PCs, Apple Macintosh and many other devices. There are several types of USB connectors, and some have been added as the specification has progressed. The most commonly used is the (male) series "A" plug on peripherals, when the cable is fixed to the peripheral. If there is no cable fixed to the peripheral, the peripheral always needs to have a USB "B" socket. In this case a USB "A" plug to a USB "B" plug cable would be needed. USB

A male USB series A plug

"A" sockets are always used on the host PC and the USB "B" sockets on the peripherals. It is a 4-pin connector, surrounded by a shield. There are several other connectors in use, the mini-A, mini- B and mini-AB plug and socket (added in the On-The-Go Supplement to the USB 2.0 Specification).

15.3.4 Power connectors

See also: AC power plugs and sockets, DC connector, NEMA connectors and Industrial and multiphase power plugs and sockets

Power connectors must protect people from accidental

A panel-mounted IEC 60320 C14 male connector designed to accept AC line power

contact with energized conductors. Power connectors often include a safety ground connection as well as the power conductors. In larger sizes, these connectors must also safely contain any arc produced when an energized circuit is disconnected or may require interlocking to prevent opening a live circuit.

Socket, is the general term, in British English, but there are numerous common alternatives for household connectors, including *power point*,[9] *plug socket*,[10] *wall socket*,[11] and *wall plug*.[12]

Receptacle and *outlet* are common in American English, for household connectors, sometimes with qualifiers such as *wall outlet*, *electrical outlet* and *electrical receptacle*.[13]

15.3.5 Radio frequency connectors

Main article: RF connector
For more details on this topic, see Impedance matching and Signal reflection.

Connectors used at radio frequencies must not change

A male 50 ohm BNC connector

the impedance of the transmission line of which they are part, otherwise signal reflection and losses will result. A radio-frequency connector must not allow external signals into the circuit, and must prevent leakage of energy out of the circuit. At lower radio frequencies simple connectors can be used with success, but as the radio frequency increases, transmission line effects become more important, with small impedance variations from connectors causing the signal to reflect from the connector, rather than to pass through. At UHF and above, silver-plating of connectors is common to reduce losses. Common types of RF connectors are used for television receivers, two-way radio, certain Wi-Fi devices with removable antennas, and industrial or scientific measuring instruments using radio frequencies.

15.3.6 DC connectors

Main article: DC connector
See also: Coaxial power connector

A DC connector is an electrical connector for supplying direct current (DC) power. For portable consumer electronic devices, the coaxial power connector is frequently used, but many other types of connectors also exist.

15.3.7 Hybrid connectors

Hybrid connectors have housings with inserts that allow the intermixing of many connector types, such as those mentioned above. These housings may also allow intermixing of electrical and non-electrical interfaces, examples of the latter being pneumatic line connectors, and optical fiber connectors. Because hybrid connectors are modular in nature, they tend to simplify assembly, repair, and future modifications. They also allow the creation of composite cable assemblies that can reduce equipment installation time by reducing the number of individual cable and connector assemblies.

15.3.8 Banana

Banana connectors are used to connect single wires to electrical equipment. They are often used with testing equipment.

15.3.9 Barrier Strip/Spade Lug

A connector that locks a metal spade to a terminal by screwing them together..

15.3.10 Crimp

Crimp connectors can be used for fast and friction-type connections in DC applications where connections are broken repeatedly.

15.3.11 Alligator/Crocodile clip

Alligator connectors are often used as temporary test leads.

15.3.12 Screw terminal

A screw terminal is a type of electrical connector where a wire is held by the tightening of a screw.

15.3.13 Phone

Phone connectors can be used as connectors in microphone cables and for low-voltage, low-current applications.

15.3.14 RCA

RCA connectors can be used in audio connections.

15.3.15 DIN

A DIN connector is suitable with multiple conductor wires for interconnecting audio and computer accessories.

15.3.16 Tee

A Tee connector is an electrical connector that connects three cables together.

15.4 Electrical cables

See also: Power cable and Wire

15.4.1 Termination and gender

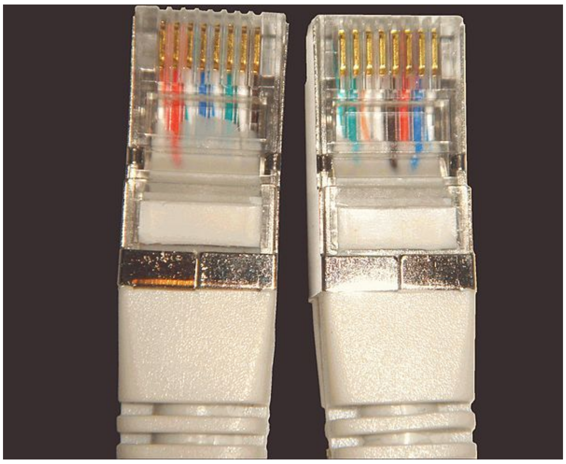
Main article: Gender of connectors and fasteners

When used to terminate cables, in some applications both ends of the cable are terminated using identical connectors (generally male), as in registered jack telephone cables or Ethernet over twisted pair network cables, while in other applications the two ends are terminated differently, either with male and female of the same connector (as in an extension cord), which ends can be connected to each other in a loop, or with incompatible connectors, in an adapter cable.

15.4.2 Wiring and pinouts

For more details on this topic, see Pinout.
See also: Crossover cable

When a cable is terminated by a connector, the various wires in the cable are connected to contacts (pins) in the connector. The most common methods of connecting pins to individual wires are soldering, insulation displacement, insulation piercing, screw clamping, axial screw termination, cage clamping, crimping, press-in termination, and wire wrapping. Some of these wiring methods can be accomplished without specialized tools. Other methods, while requiring a special tool, can assemble connectors to a cable much faster and more reliably, and make repairs easier.



Ethernet crossover cable, showing wiring at each end

If one has specified wires within a cable (for instance, the colored Ethernet cable wires in TIA/EIA-568-B), then the order in which different color wires are attached to different connector pins defines the wiring scheme. Different ways of wiring numbered connector pins at the two ends of a cable creates different assemblies, which may appear identical but behave differently.

If both ends of a cable have the same connector, or male and female versions of a connector, or even similar connectors (such as RJ11 and BS 6312, both of which often have 6P4C (6 positions and 4 contacts)), there is a notion of straight through cable and crossover cable:

- In a straight through cable, pins on one end correspond exactly to the corresponding pins on the other end (pin 1 to pin 1, pin 2 to pin 2, etc.).

  Using the same wiring (a given color wire connects to a given number pin, the same at both ends) at each end yields a straight through cable.

- In a crossover cable, pins do not so correspond; most often in crossover cables some cables are swapped, meaning that if pin 1 on one end goes to pin 2 on the other end, then pin 2 on the first end goes to pin 1 on the second end, and not to pin 3 or some other: such crossover cables are symmetric, meaning that they work identically regardless of which way you plug them in (if you turn the cable around, it still connects the same pins as before).

  Using different wiring (a given color wire connects to one number pin at one end, and a different number pin at the other) at each end yields a crossover cable.

A well-known crossover cable is the Ethernet crossover cable, which converts between T568A and T568B termination.

What matters specifically is not “which contact corresponds to which wire”, but rather “which contact on one connector corresponds to which contact on the other connector": to illustrate the distinction, T568A straight through cables and T568B straight through cables are electrically identical: pin 1 on one end corresponds to pin 1 on the other end, though in the T568A it is a green/white striped wire that connects them, while in T568B it is an orange/white striped wire that connects them. However, a cable wired with T568A at one end and T568B at the other is a crossover cable.

The name “straight through” is suggestive but slightly misleading: if one has a ribbon cable, such that all wires are in fact straight and in a line, the pinouts at the two ends are the *mirror* of each other: the left-most wire on one end is the right-most wire on the other.

15.5 See also

- Adapter
- Audio and video connector
- Electrical network
- Electrical termination
- Gender of connectors and fasteners
- Optical fiber connector
- Tube socket
- Wire nut

15.5.1 Connectors

- Banana connector
- Battery holder
- Battery terminals
- Edge connector
- Pin header
- RJ-XX connector
- Dock connector
- JST connector

15.6 References

[1] Robert S. Mroczkowski, *Electrical Connector Handbook Theory and Applications*, McGraw Hill, 1998 ISBN 0-07-041401-7, chapter 1

[2] TE Connectivity. "Ribbon Cable Interconnect Solutions" p. 30 "By its design the traditional failure mode in tin plated connections, fretting corrosion, is prevented."

[3] *The Art of Electronics, 2nd Edition, p56*. Cambridge University Press. 1989.

[4] *Reference Designations for Electrical and Electronics Parts and Equipment: ASME Y14.44-2008 : Section 2.1.5.3 (2)*. ASME, Fairfield, NJ. 2008.

[5] *Graphic Symbols for Electrical and Electronics Diagrams (Including Reference Designation Letters): IEEE-315-1975 (Reaffirmed 1993): Section 22*. IEEE and ANSI, New York, NY. 1993.

[6] *Reference Designations for Electrical and Electronics Parts and Equipment: ASME Y14.44-2008 : Section 2.1.5.3 (1)*. ASME, Fairfield, NJ. 2008.

[7] "Positronic D-subminiature". *Fclane*. Retrieved September 24, 2013.

[8] "Positronic Combo D-subminiature". *Fclane*. Retrieved September 24, 2013.

[9] Collins (2006), "Power Point", *Essential English Dictionary* (2nd ed.), The Free Dictionary

[10] , Building Surveys and Reports, James Douglas, John Wiley & Sons, 2010, p.254 (retrieved 1 March 2013 from Google Books)

[11] , Computer Networking First-Step, Wendell Odom, Cisco Press, 2004, p.38 (retrieved 1 March 2013 from Google Books)

[12] , Building Technology: Mechanical and Electrical Systems, Benjamin Stein, John Wiley & Sons, 1997, p.723 (retrieved 1 March 2013 from Google Books)

[13] , Tamper Resistant Receptacles, Electrical Safety Foundation International, 2009, (retrieved 1 March 2013 from ESFI)

- Foreman, Chris, "Sound System Design", *Handbook for Sound Engineers*, Third Edition, Glen M. Ballou, Ed., Elsevier Inc., 2002, pp. 1171–2.

15.7 External links

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15.8.1 Text

- **Phone connector (audio)** *Source:* http://en.wikipedia.org/wiki/Phone%20connector%20(audio)?oldid=655497200 *Contributors:* Damian Yerrick, AxelBoldt, The Anome, Heron, Frecklefoot, Darkwind, Andrewa, Dysprosia, Radiojon, Furrykef, Omegatron, Ed g2s, Denelson83, Giftlite, KenBentubo, Macrakis, Beland, Comics, Sfoskett, Speedeep, Dcandeto, Mr Bound, Discospinster, Rich Farmbrough, Smyth, Warpflyght, Alistair1978, Dmr2, Cmdrjameson, Zetawoof, Hooperbloob, Jhertel, Blahma, Atlant, Mikething, JimParsons, PeteVerdon, Ravenhull, Wtmitchell, Stephan Leeds, Dtcdthingy, Jackerhack, Gene Nygaard, Pol098, Plrk, Seidenstud, Petree, Bubba73, Ekimdrachir, TiagoTiago, Nowhither, RAMChYLD, Who, Scottrainey, Burnte, Jamesmorrison, Pip2andahalf, MMuzammils, Hydrargyrum, ErkDemon, Veezay, SixSix, Ospalh, Jeh, Light current, Deville, HereToHelp, Mikus, TheY4Kman, SmackBot, Kentyman, Slashme, AnOddName, Commander Keane bot, Unforgettableid, Hmains, Bluebot, Thumperward, Oni Ookami Alfador, Nbarth, Alphathon, Nahum Reduta, Pissant, PetesGuide, Vivigatt, John Bentley, Hanii Puppy, Dicklyon, AxG, Peter Horn, Kvng, Aaaidan, Vanisaac, Davidbspalding, N2e, DanielRigal, W.F.Galway, Altaphon, Thijs!bot, Electron9, Gioto, Mk*, Smartse, Kauczuk, Adams13, John a s, Swpb, Nikevich, Wherman, TonyBrooke, Frotz, DerHexer, Mrtechguy, IlliterateSage, Misarxist, CitizenB, Jim.henderson, Eplack, Leson2403, Thaurisil, LordAnubisBOT, McSly, Hm john morse, LoopTel, WarddrBOT, A4bot, CHfish, Zybez, Bodybagger, Raymondwinn, Jhawkinson, SieBot, Bachcell, VVVBot, Jerryobject, Dillard421, Stephen Shaw, JohnnyMrNinja, Onlyonefin, AndyONeil BP, Segrub, Binksternet, Poterxu, Mild Bill Hiccup, Niceguyedc, DnetSvg, Lbaum, Borsak, Alexbot, Anon lynx, Nicholas6313, Eeekster, Doctortwohearts, Zootboy, Out wrong, Olires, Abhishek727, DumZiBoT, Funtaff, AlanM1, XLinkBot, Addbot, Rmsydiaha, Sm201294, MrOllie, Ryreinc, Oldmountains, Tide rolls, Lightbot, PlankBot, Luckas-bot, Yobot, Cousin's name, Amirobot, Dafyddperry, AnomieBOT, Fatal!ty, Jim1138, JackieBot, Cyberkid ua, Unara, Flewis, Martin Homuth-Rosemann, Materialscientist, Xqbot, Sharkstfont, R0pe-196, Michielo, Nasa-verve, Nkornblum, 2ndAccount, Immibis, FrescoBot, Fortdj33, OgreBot, A412, Duskb, Crcwiki, Kallikanzarid, Russot1, Lotje, Danielulfe, Auscompgeek, Dogflap, Unbitwise, AXRL, Rx5674, Wiki559, EmausBot, Dewritech, Robertminard, ThatDamnBlueCollarTweaker, Solarra, Clusternote, ZéroBot, Mkratz, Ὁ οἶστρος, Mac John Concord, Evan-Amos, ClueBot NG, Jeroen Claes, Awesomeness95, Jacobspeeds2, Molecat1, Helpful Pixie Bot, Artiepenguin, Wbm1058, Mataresephotos, BG19bot, Roberticus, Ceradon, Zollo9999, Zhoushimin, CitationCleanerBot, Imaadwhd, BattyBot, Riley Huntley, Rompica, Keepssouth north, ChrisGualtieri, YFdyh-bot, Wakawakwiki, AK456, LezFraniak, Cwobeel, Memes11, TwoTwoHello, Kruzen510, Agent..551, Serpinium, Petrius, Makkachin, Maorosh11, Fordfilomeno, Aloz1 and Anonymous: 208
- **Edge connector** *Source:* http://en.wikipedia.org/wiki/Edge%20connector?oldid=626760169 *Contributors:* Maury Markowitz, Edward, RTC, Mahjongg, Radiojon, Brouhaha, Canterbury Tail, AdorableRuffian, Hooperbloob, RJFJR, Sparkit, Who, PZ, YurikBot, Museo8bits, SmackBot, Thumperward, Al Lemos, Nicolaasuni, Belovedfreak, BOTones, Audiofish, Amikake3, PixelBot, Addbot, Yobot, Xqbot, Erik9bot, EmausBot, ClueBot NG, Osda, Wbm1058, Dsprc, Terrytexasbutler and Anonymous: 10
- **DIN connector** *Source:* http://en.wikipedia.org/wiki/DIN%20connector?oldid=655338639 *Contributors:* The Anome, Heron, David Martland, Norm, Andrewa, Bevo, Boffy b, DavidCary, VampWillow, Bobblewik, Mobius, Stephan Leclercq, Tooki, Cab88, Hobart, Canterbury Tail, Slady, Plugwash, Tjic, Nigelj, Cwolfsheep, Hooperbloob, PaulHanson, Atlant, Virtualplay, ProhibitOnions, Wtshymanski, Gpvos, Glitch010101, Armando, ThorstenS, Lgreen, FlaBot, Dustin Howett, Travisowens@hotmail.com, Hellbus, Hydrargyrum, Rsrikanth05, Swen, Zwobot, DeadEyeArrow, Thumperward, Apple2gs, Nbarth, PetesGuide, MegA, Harryboyles, MilborneOne, Kvng, Altaphon, ColinCameron, Travelbird, PizzaMan, Thijs!bot, Joeyhagedorn, Electron9, Peace01234, Ashankar, Disconnect 6, Gioto, Richard Poole, JAnDbot, Nicolaasuni, Jacobko, R'n'B, ISC PB, Little Professor, SJP, STBotD, Bamsefar75, VolkovBot, Zneo, The Wild Falcon, Mspritch, Mickea, OKBot, Sitush, Kingrattus, Bbb2007, Addbot, E5frog, LaaknorBot, Oldmountains, OlEnglish, Luckas-bot, Yobot, AnomieBOT, Flewis, Materialscientist, Abce2, Psychlohexane, Zaheer031, MinimanDragon32, Bibulus, TobeBot, BPK, Lotje, Cheetah88, EmausBot, WikitanvirBot, Mkratz, ClueBot NG, Matthiaspaul, Multimat, Wbm1058, D.plomat, Makecat-bot, JRYon, Jupiter-4, Mpeg2fan, ArmbrustBot and Anonymous: 77
- **DIN 41612** *Source:* http://en.wikipedia.org/wiki/DIN%2041612?oldid=643834220 *Contributors:* Oliver Sedlacek, DavidCary, Abdull, Wtshymanski, Unixxx, GregorB, Lmatt, Alaibot, Why Not A Duck, CultureDrone, Wdwd, Vocem, Addbot, Luckas-bot, Bunnyhop11, V85, Kulcat, Tom md de, BG19bot and Anonymous: 3
- **Modular connector** *Source:* http://en.wikipedia.org/wiki/Modular%20connector?oldid=654962403 *Contributors:* Leandrod, Typhoon, Baylink, Andrewa, Glenn, Gutza, Tim Ivorson, Pne, Bender235, Plugwash, Kwamikagami, Geocachernemesis, Giraffedata, Atlant, Wtshymanski, Woohookitty, Pol098, Nightscream, XP1, Bubba73, Srleffler, NetVicious, SixSix, Scheinwerfermann, SmackBot, Incnis Mrsi, Speight, Thumperward, Nbarth, Wundermac, Zac67, Natsakis.anastasios, Dfred, Kvng, Raysonho, Altaphon, Dmbaty, Thijs!bot, Nick Number, Stybn, Jet14, Rico402, CosineKitty, John a s, Enquire, STBot, Jim.henderson, R'n'B, Dispenser, Funandtrvl, VolkovBot, Gillyweed, Kbrose, RJaguar3, RBeast, Fishnet37222, ImageRemovalBot, Sylvain Leroux, Lambtron, Johnuniq, Nepenthes, Dsimic, Addbot, Mortense, Tothwolf, Robert.Harker, Yobot, Crispmuncher, AnomieBOT, Jim1138, JackieBot, LilHelpa, Xintiandi, Webwat, TV Mann, Mbennett555, DivineAlpha, Full-date unlinking bot, ItsZippy, BillyPreset, Kilopi, Rocketrod1960, ClueBot NG, Gareth Griffith-Jones, NULL, Justin.kueser, Widr, Reify-tech, Helpful Pixie Bot, Wbm1058, DBigXray, BG19bot, Digital Brains, Superyoure, K7L, Cj7man80, Lgfcd, 99guspuppet, Lagoset, Omikrofan, Jherbs02 and Anonymous: 78
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Bot, HMSSolent, BG19bot, Rajee vran, Sallyfiber, BattyBot, Fb35523, Wyf2012, Dexbot, Maqian163, Precision1, Fiberguru, Liliansusu, Jonnyalter, Mattghali, Aecannon12, Monkbot, Filedelinkerbot, Deadplc, Sunmorph and Anonymous: 117

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