Handbook of DC Power Connectors (Electrical Components)

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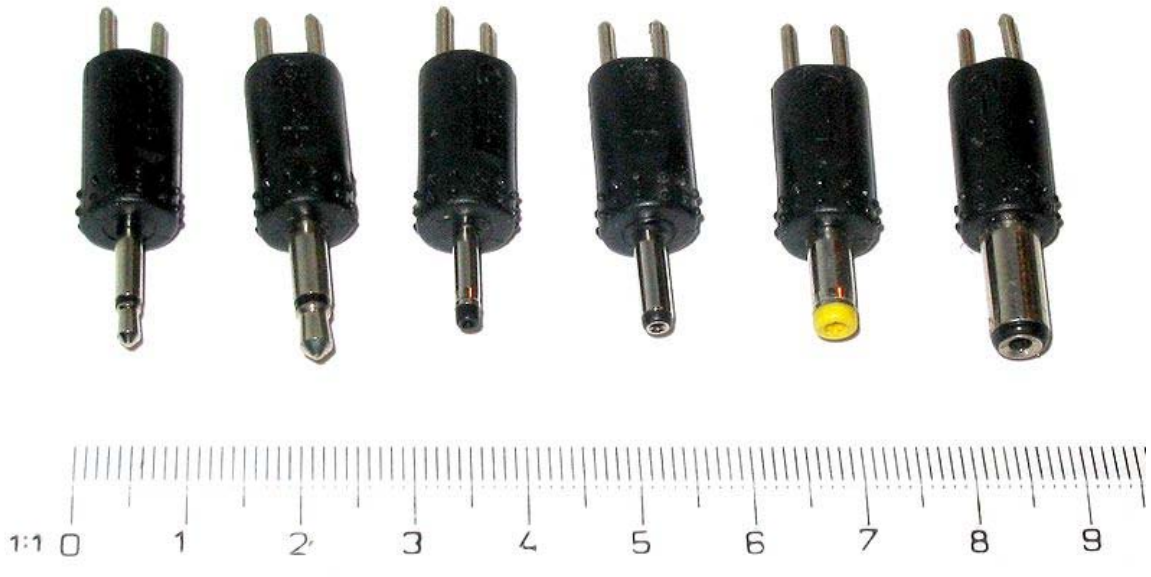
Chapter 1

DC Connector

A **DC connector** is an electrical connector for supplying direct current (**DC**) power. DC connectors in general are not standardized, compared to domestic AC power plugs and sockets. **DC plug** is a common name used for one common type of cylindrical two-conductor plug available in a range of sizes and used to power small pieces of electronic equipment. It is also used to describe some older multi-pin plugs.

The dimensions and arrangement of DC connectors can be chosen to prevent accidental interconnection of incompatible sources and loads.

Cylindrical types



Common DC power connectors shown with a rule marked in cm/mm

Also known as **barrel connectors**, **concentric barrel connectors** or **tip connectors**, small cylindrical connectors come in an enormous variety of sizes.

The intended use of these plugs is on the cable connected to a power supply. The matching jack or socket is then mounted in the equipment to be powered. Some of these jacks contain a normally closed contact, which can be used to disconnect internal batteries whenever the power supply is connected, avoiding the risk of battery leakage or explosion posed by incorrect recharging of the batteries.

Cylindrical plugs generally have an insulated tip constructed to accept insertion of a pin. The outer body of the plug is one contact, most often but not always the negative side of the supply. A pin mounted in the socket makes contact with a second internal contact. The outer plug contact is often called the *sleeve*, while the inner one is called the *tip*.

There are a wide variety of sizes and designs for these power connectors, and many appear quite similar to each other yet are not quite mechanically or electrically compatible. In addition to a plethora of generic designs (whose original designer is unknown) there are at least two different national standards—EIAJ in Japan and DIN in Germany, plus the JSBP connector used on some laptop computers. The Japanese EIAJ standard includes five different sizes, with each supporting a specified range of voltages. Most of the other coaxial DC power connectors have no specified voltage association, however.

The most common plugs are 5.5 mm in outside diameter (OD) and 9.5 mm in length. Two pin sizes are common in the jacks for this size plug body, 2.1 mm and 2.5 mm, and the plugs should ideally match. Generic plugs are often named for the pin diameter they are designed to take, so these types will be seen described as "2.1 mm DC plugs" and "2.5 mm DC plugs" respectively. These two sizes are easily confused unless seen together.

Contact ratings vary from unspecified (and probably less than 1 A in practice) up to 5 A, with 2 A typical. 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. The *tip* (i.e. the inner conductor) *usually* carries the positive (+) pole.

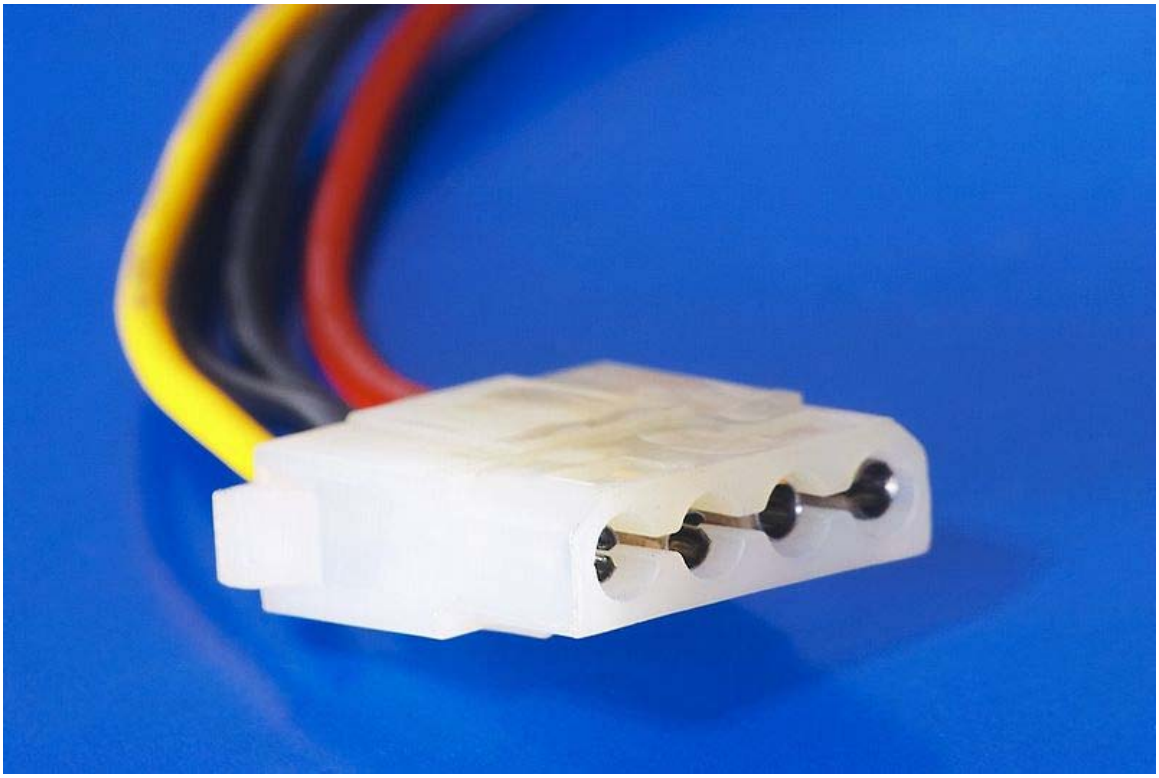
Snap and lock DC power connectors

These connectors look similar to Mini-DIN connectors, but have either 3 or 4 thicker pins and a slightly larger mating shell. Because of this they do not mate with any of the Mini-DIN connectors. They can usually be identified by an engraved symbol on the backs of the plug, consisting of two wide arrows pointing in opposite directions, but parallel to each other, or sometimes one wide arrow inside a box, pointing towards the end of the male connector. Some devices, however, do use a standard 4-pin Mini-DIN connector, presenting the possibility for users to mate the connector with the wrong port (such as an S-Video output on a video card).

- Also known as Power Mini-DIN or Power DIN
- The male plug's mating shell outer diameter is 10 mm (0.394 inch), and the pins are 1.5 mm diameter
- Standard may include a limit of 20 V at 7.5 amperes

- 3-pin
  - Hosiden part number TCP8927-53
  - Kycon part number KPP-3P (obsolete) or KPPX-3P (RoHS)
- 4-pin
  - Kycon part number KPP-4P (obsolete) or KPPX-4P (RoHS)

Molex connector



Molex connector

The connector design most commonly called Molex connector has frequently been used to supply DC power, most frequently on personal computers, for supplying power to drives and other peripherals. It has four pins, +5 V (red), 2 com/ground (black), and +12 V (yellow).

IEC 60906-3:1994

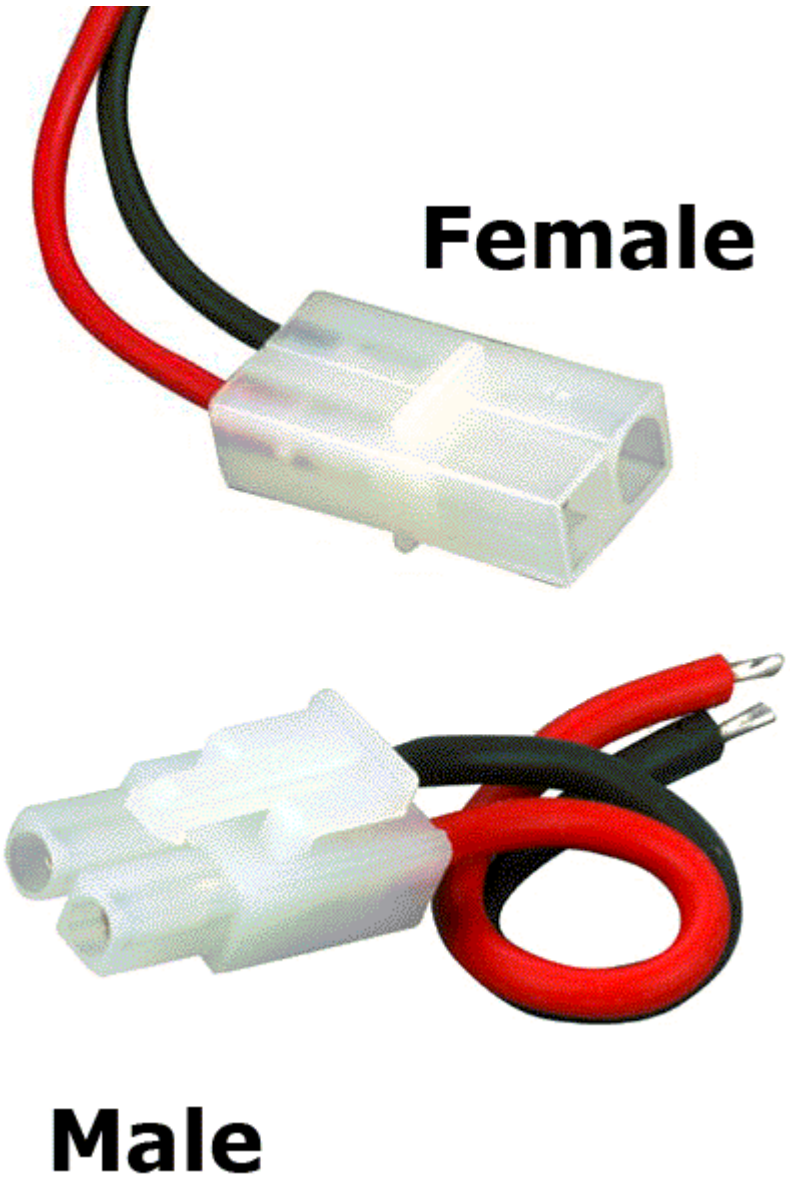
The International Electrotechnical Commission (IEC) has produced a standard for a system of plugs and socket-outlets for household and similar purposes in fixed and portable applications. Safety extra-low voltage (SELV) plugs and socket-outlets for 16 amperes and 6, 12, 24, or 48 volts AC and DC. For use either indoors or outdoors.

The dimensions are as follows:

Parameter	Value
Pin-2-Pin distance	7 mm ± 0.1 mm
Pin diameter	3.5 mm +0/-0.075 mm
Female sleeve	4 mm
Pin length	10 mm
Connector diameter	19.4 mm

Tamiya connector

- Commonly used on radio-control (toy) vehicle battery packs and chargers.
- Also commonly used on airsoft guns.



Tamiya connector

As shown, the usual wiring has the positive (red) wire running to the terminal with a square profile, and the negative (black) wire running to the half-circle, half-square terminal. This is true for both male and female connectors.

Some confusion exists in the market place between which is male or female. The male housing has female pins and the female housing has male pins. Some companies reference the housing gender while others reference the pin gender.

There are two sizes of Tamiya connectors, small and large. The rectangular portion of the small housing is approx 0.375 in (9 mm) wide and the large is approx 0.5 in (13 mm) wide. They are not compatible without an adapter.

Tamiya connectors are useful because they do not come undone easily, and are therefore child-safe, hence their use in remote-controlled cars and the like.

Deans connectors

- Popular with higher-end radio-control vehicle battery packs and chargers.
- W.S. Deans Web site

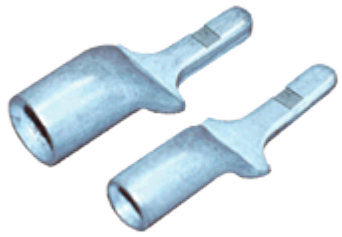
JST RCY connector

- Also known in RC circles as the BEC connector, or the P connector.

Locking Molex connector

- Available in 3, 4, and 6 terminal configurations.

Inverter tabs/lugs



Inverter lugs

- Available in 2, 4, and 8 gauge. Designed to pass very high currents at voltages up to 600 V DC to and from battery packs, inverters, and other high-current loads to a terminal bus.

Airline in-seat power supply system

Two different airline in-seat power supply system (ISPSS) standards for DC power have been used in the past.

American Airlines has in the past used an automotive cigar lighter socket, but using 14.7 V instead of the automotive 12 V.

Most other airlines that provide DC power use the EmPower system, which has a 4-pin Hypertronics' D-series connector smaller in diameter and overall size than a cigar lighter plug. It uses 15 volts maximum 5 amperes.

Anderson Powerpole connectors

The Anderson Powerpole has been adopted by the amateur radio community as their standard 12-volt DC power connector for everything from radios to accessories. It is a bit more expensive than the older de facto standard of the 2-wire trailer plug and Molex connector, but provides a more reliable electrical connection (both mechanically and electrically) and is easier to adapt to a wider range of wire gauges. Powerpole connectors are physically and electrically hermaphroditic, thus avoiding the need to worry about which end is the plug and which the socket, or which end has the correct polarity, as is the case with the physically but not electrically hermaphroditic 2-wire trailer plug.

For use in amateur radio, the community has adopted a standard polarity for assembling the Singlepole connectors, using one red and one black housing, as well as a mnemonic for remembering the arrangement for the positive connector: *Red Right—Tongue Top*. Before this polarity standard was adopted, some amateur radio groups had chosen the opposite polarity, so it is wise to double-check the polarity before blindly plugging devices together. The ham standard is nominal 12 volts (actually 13.8 volts), with red positive and black negative. Compare with the Anderson recommendations below.

Anderson Powerpole connectors with crimping tool

Although many sizes of the Powerpoles are available, the size most commonly used is the 15/30/45 ampere variety (but are available up to 180 A). These sizes all use the same plastic housing in multiple colors, differing only in the metal contact inserted into the housing (selected based on the ampacity and wire size). Larger Powerpole connectors (the SB/Multipole series) with 2 or 3 contacts in one molded housing are commonly used

in various industrial settings, including as a battery connection for some UPS devices, removable vehicle winches, many electric forklifts, and other electric powered vehicles.

For the larger Multipole design, which is available in up to 700 A sizes, each color is keyed so as to mate only with a like colored connector, and Anderson publishes a list of recommended voltages for each color:

- 12 V: Yellow
- 18 V: Orange
- 24 V: Red
  - Used by Warn for its 12 V winches (should have used yellow multipole)
  - Used by Tripp-Lite for some of its 24 V external UPS battery packs
  - Used by FIRST Robotics Competition for 12V battery connection (should have used yellow multipole)
- 36 V: Gray
  - Used by Tripp-Lite for some of its 38 V external UPS battery packs
  - Used by APC for some of its 24 V external UPS battery packs (should have used red multipole)
- 48 V: Blue
  - Used by Tripp-Lite and APC for 48 V external UPS battery packs
- 72 V: Green
- 80 V: Black
- 96 V: Brown
- 120 V: Purple
- 144 V: White

Some manufacturers have ignored this color coding recommendation. One should always test the connection with a voltmeter if unsure. For example, winch manufacturer Warn uses a red housing for its winches, even though they are powered by 12 V DC, not 24 V DC.

The connectors are also starting to be used by Radio Control hobbyists, including robot builders and the R2-D2 Builders Club.

In model railways, the NTRAK Modular Railroading Society has since 2005 recommended the use of the Powerpole PP30 as an alternative to the Cinch Jones connector, while retaining the widely-used latter within its standards.

This connector design was created by Anderson, but the patent on its design has apparently lapsed, and there are other manufacturers of this connector now, including AMP and Sermos.

SAE connector

The *SAE connector* is a hermaphrodite two-conductor, DC connector commonly used for automotive applications (also motorcycles). It is so named for the Society of Automotive Engineers who created its specifications.

This connector is typically used for applying a maintenance charge to a vehicle battery. The polarity of the connector, when installed in a vehicle and attached to a battery, is always such that no short circuit will occur if the exposed terminal were to touch the vehicle chassis. In most vehicles, this means that the exposed terminal connects to the negative terminal of the battery.

Conversely, the positive terminal on a battery charger is exposed, to mate with the concealed one on the vehicle side.

Although there is a risk of short-circuiting a battery charger, the risk is minimal and often mitigated by the circuitry of the battery charger itself. On the other hand, the short circuit current of the lead-acid batteries installed in vehicles is sufficiently great, that a short circuit could result in a fire or explosion. The priority is therefore given to avoiding short circuits of the vehicle battery, rather than of the charger.

Cigar lighter sockets and plugs

The car cigarette lighter socket is also called a cigar lighter receptacle, since it was originally designed as a lighter for cigars—hence its rather large size (and unheated center barely large enough to light a cigarette).

These sockets were not originally designed to provide DC power, and are not an ideal DC connector for several reasons, notably the fact that three sizes exist (one for 6 V DC and two for 12 V DC) and the mating of the different sized 12 V DC plugs and jacks is problematic. Because of this, and the small gauge wiring sometimes used, they can sometimes provide only unreliable and current-limited power connections.

The polarity for 12 V DC sockets is center pin positive (+), outer collar negative (−). Reversed polarity will damage some electronic devices.

DIN 4165 connector

Similar in concept to an automotive cigar lighter, the DIN 4165 connector is shorter and smaller, and found most frequently on motorcycles.

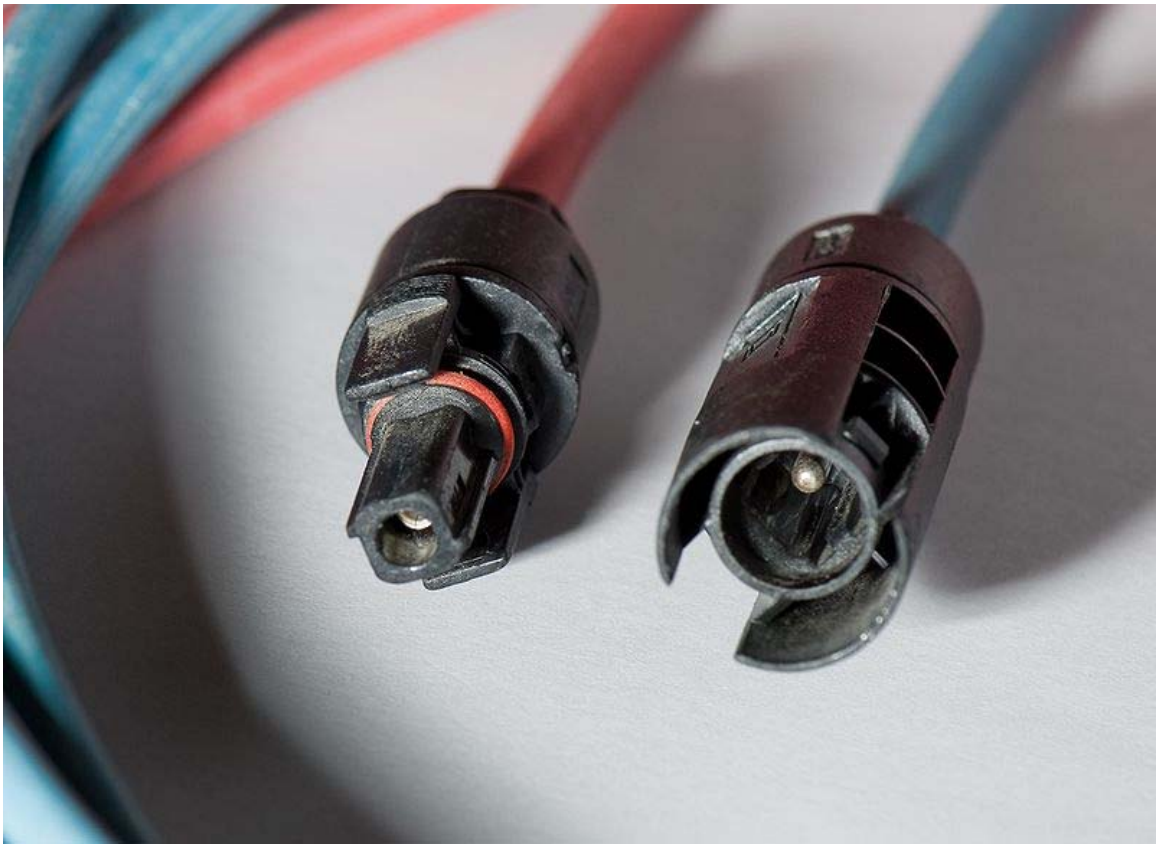
- Also known as Powerlet connector, BMW Accessory connector or Hella plug

XLR connectors used for power

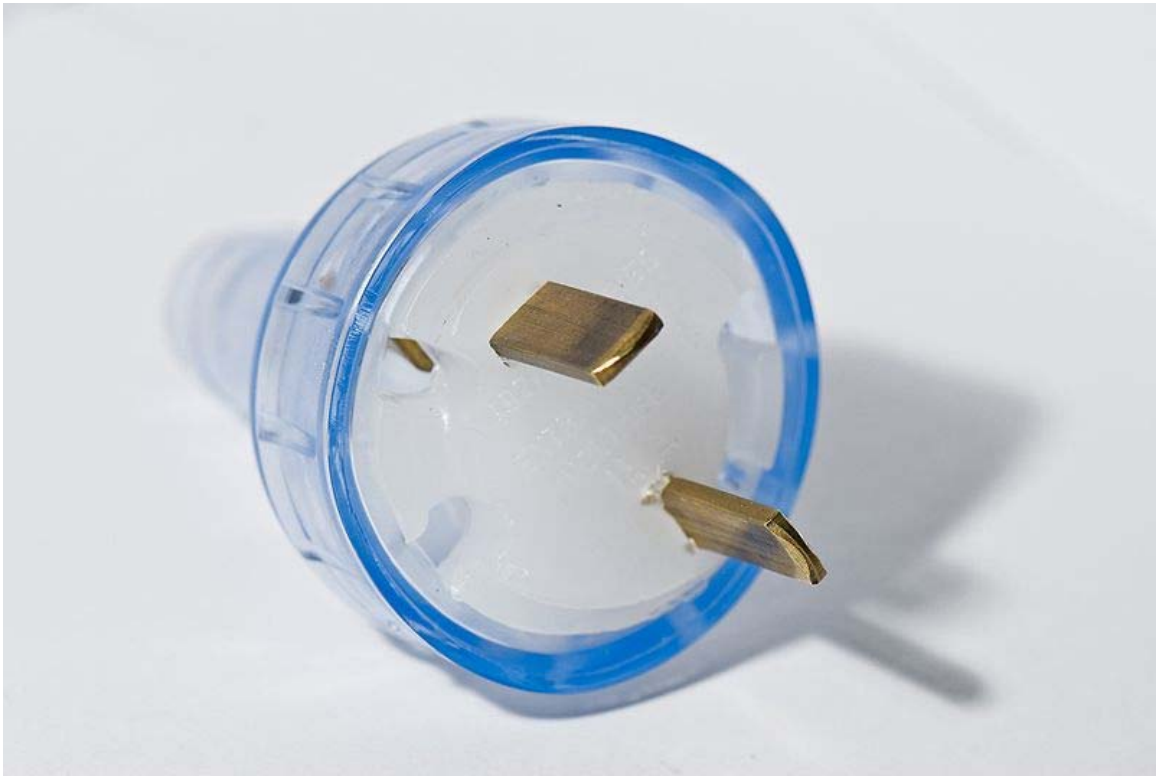
In the broadcast, film and television industries, the 4-pin XLR connector is the standard for 12 V power. The connectors are wired pin 1 negative, pin 4 positive. Often pins 1 and 2 will be negative, 3 and 4 positive for a higher current rating. Female connectors are used as supply and male connectors are used on loads. Most battery belts and power supplies output 13.2 V, but equipment can usually handle a range of 11–18 volts to accommodate battery packs of varying voltages and charging while operating.

The readily available XLR3 is also used by some manufacturers as power supply plugs despite their being a well-accepted standard for other purposes.

Other DC connectors



Weatherproof DC connectors designed for connecting photovoltaic panels.



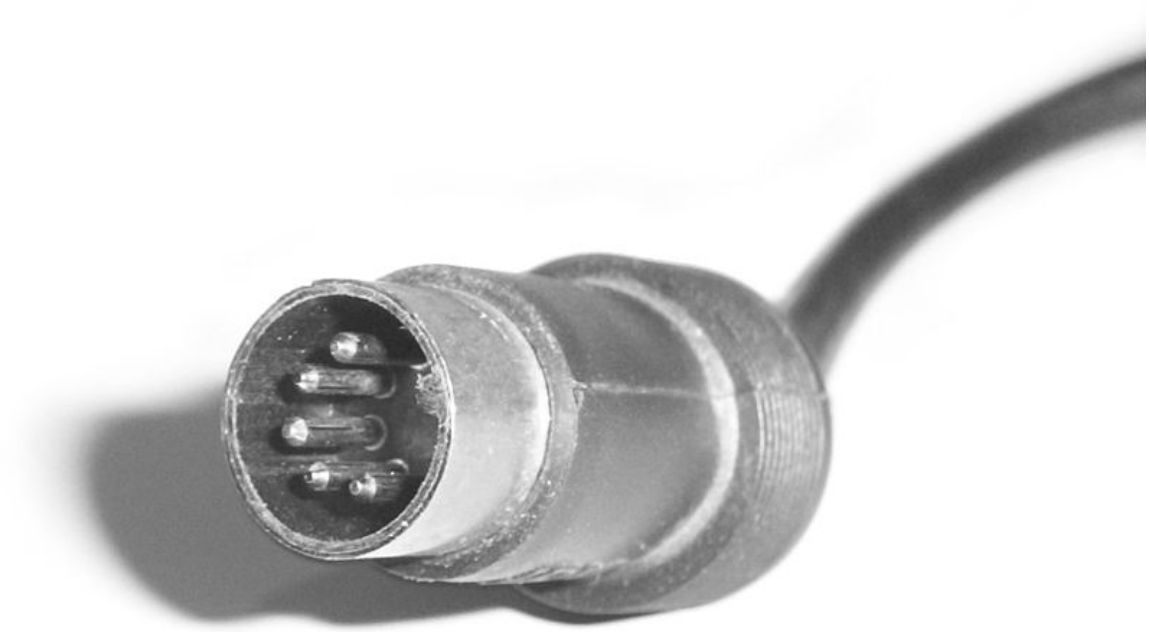
DC plug, not wired. Flat pin connectors in T configuration. Often used for extra-low voltage in stand-alone power system (SAPS) or on boats.

- Fly RC magazine: Connectors Connection describes most or all of the connectors used by RC users.
- There are a number of similar design PC board power connectors, including Molex Mini-Fit SR, Molex Mini-fit jr., MOLEX MICROFIT and Molex SABRE connectors, and AMP DUAC connectors that look similar to each other.
- Some plugs with three, four, five or more pins are also called **DC plugs**. These were common on vacuum tube equipment and continue to be used where several voltages are supplied. On vacuum tube equipment the pins are normally on the equipment side of the join for safety reasons.
- Many mobile phones use DC connectors that are unique to the manufacturer, or even a specific phone. In the interest of improved interoperability of phone battery chargers, major manufacturers have agreed to standardize on the micro-USB connector for new phone chargers from 2010.
- Many manufactures make special-purpose DC power connectors for battery packs, instruments, medical equipment, communications equipment and other devices.

In Australia, a T-configuration socket is used for DC power outlets, such as in stand-alone power systems (SAPS) or on boats. For this use, the horizontal slot is on top and is positive. This is also used for temporary equipment in emergency vehicles. In Victoria the top of the T is taken to look like a minus sign, and is therefore negative. Outside Victoria the vertical pin is meant to be earth/chassis ground, consistent with Australian Standards for Type I 240 volt outlets; therefore, the top of the T is positive on a negative-earth vehicle. Older positive-earth vehicles are still in service, so actual polarity at the outlet can be random.

Chapter 2

DIN Connector



Five-pin male 180° DIN connector

A **DIN connector** is a connector that was 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"). 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 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.

Circular connectors

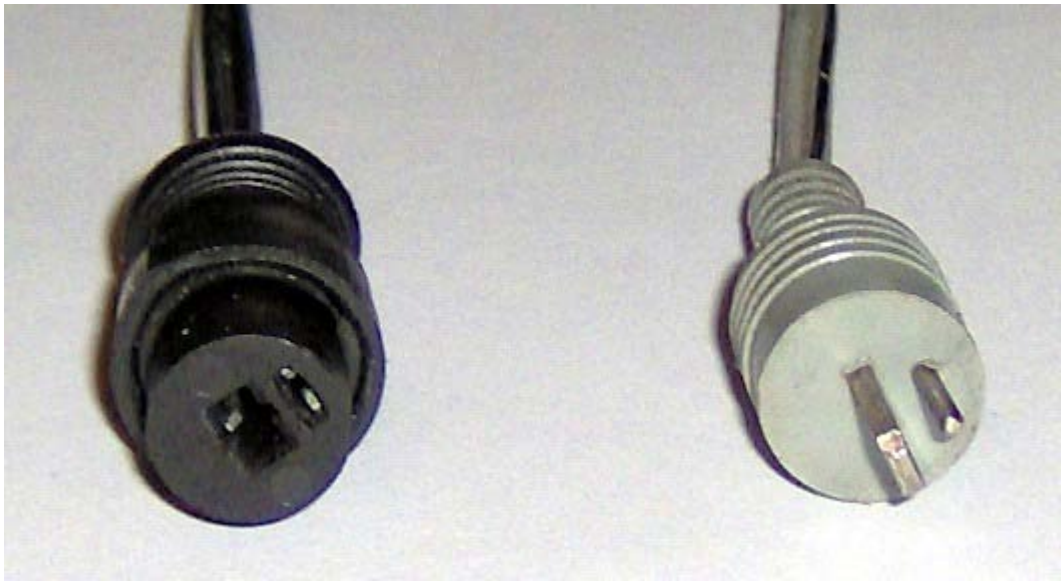
All male connectors (plugs) of this family of connectors feature a 13.2 mm diameter metal shield with a notch that limits the orientation in which plug and socket can mate. A range of connectors of the same form that differ only in their pin configuration exist and have been standardized originally in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

The plugs consist of a circular shielding metal skirt protecting a number of straight round pins. 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 seven-pin and eight-pin connectors, one where the outer pins form 360° and one where they form 270°. 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. Some high-range equipment used seven-pin connectors where the outer two carried digital system data: 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. 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.

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 should be connected to the positive line (red) while the spade should be connected to the negative line (black).

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 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.

Applications

Analog audio

The 3/180° and 5/180° connectors were originally standardized and widely used in Germany, Czech republic, and, later, in USSR and 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.

application		connector		pin function				
				1	4	2	5	3
amplifier	monophonic		5/180°	audio out			audio in	
	stereophonic			left out	right out	screen/return	right in	left in
tape recorder	monophonic		5/180°	audio in			audio out	
	stereophonic			left in	right in	screen/return	right out	left out

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 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).
- 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)
- Connecting two controllers for radio controlled model aircraft together for training purposes.

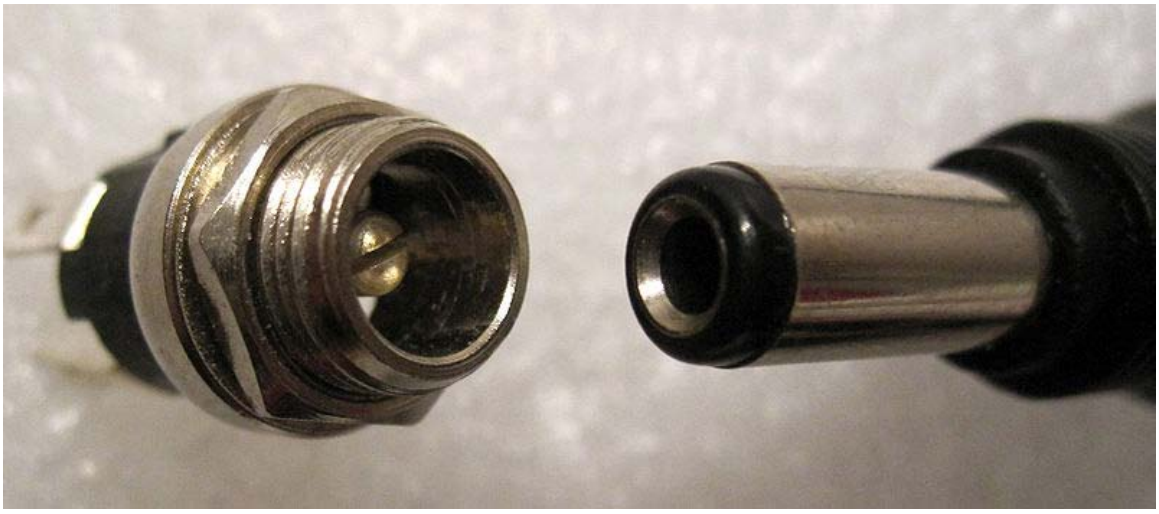
The DIN connector saw several other uses outside of audio. The AT keyboard uses a 5-pin DIN connector; the TurboGrafx-16 game console used a 5-pin DIN for its A/V output. Oddly, the Atari XEGS as well as Commodore C64 and Elektronika BK used a DIN connector for their AC Adapter. Also, early C64s that only supported composite video out used a 5-pin DIN for A/V - however, the newer C64s that supported chroma/luma output used 8-pin DIN to carry the extra signals. The Sega Genesis, 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. The Dragon 32 also used 4 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 it's composite video, analog RGB, audio, and +12Volt for an RF modulator.

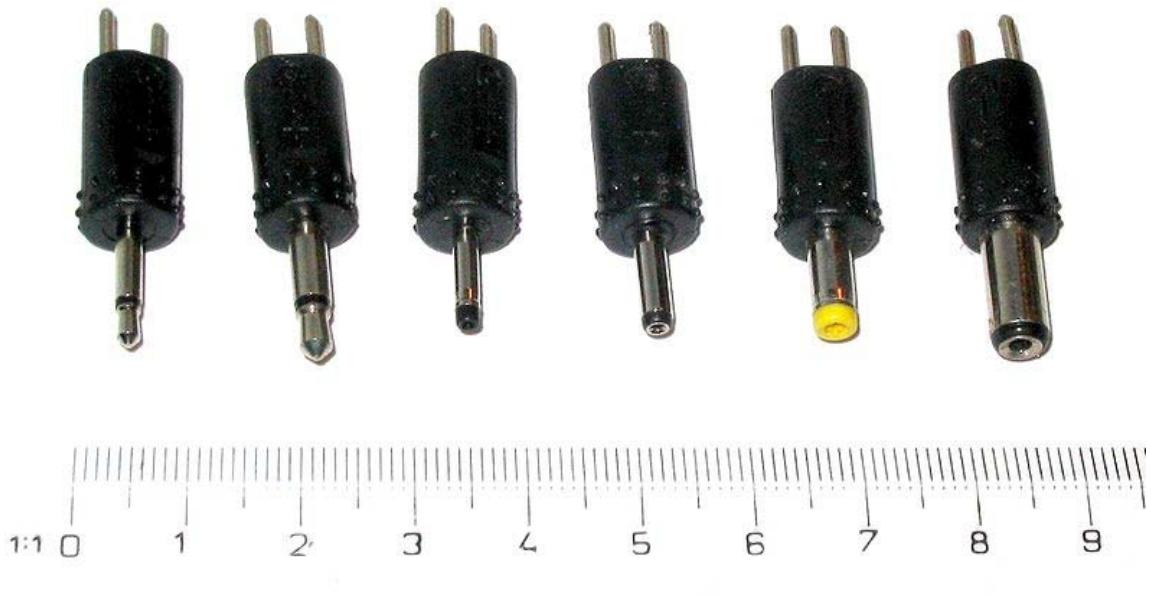
In the Soviet Union, 3-pin and 5-pin DIN connectors named ОНЦ-ВГ, could be seen on many pieces of equipment, as well as factory-made audio equipment. Radio amateurs and small cooperatives quickly discovered these reliable connectors and began to put them into almost every low frequency signal device, 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.

Chapter 3

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 a miniature 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.

The primary use of these plugs is as a DC connector (or sometimes AC) on the cable that comes from an external power supply. The matching jack or socket is then mounted in the equipment to be powered. Some of these jacks contain a normally closed switch; the switch can disconnect internal batteries whenever the external power supply is connected, to avoid the risk of battery leakage or explosion posed by incorrect recharging of the batteries.

Connector construction and terminology

Some power plugs are merely miniaturized phone plugs which have been pressed into service as power connectors. The two connectors on the left of the picture above are subminiature and miniature phone plugs respectively, the subminiature size being 3/32 inch and the miniature being 1/8 inch in diameter. The original application of these connectors was for audio microphones and headsets. Miniaturized phone plugs are typically 3/32 inch, 1/8 inch, 2.5 mm, or 3.5 mm in diameter, whereas the original full-sized telephone plug was 1/4 inch in diameter. Phone plug connectors were not originally designed to carry power, and there is a possibility of momentary or continuous short circuiting the power supply when mating the connector.

By contrast, coaxial power connectors were specifically designed to carry electrical power, and usually have features intended to make connections safer and more reliable.

Typically, the outer body of the plug is one metallic contact, most often but not always connected to the negative side of the power supply. Coaxial power connectors generally have a cylindrical hollow insulated tip constructed to accept insertion of a pin (note that exceptions are described later). A pin mounted in the corresponding socket connects with this second contact, which is an internal metallic surface lining the inside of the tip of the plug.

The outer plug contact is usually called the **barrel** or **sleeve**, and the inner contact is called the **tip** (by analogy to the same terms used for phone plugs), although in the case of most coaxial power connectors the very end of the tip itself is a non-conductive ring.

Technically, most coaxial power plugs are considered to be of "female" gender, and most coaxial power jacks are considered to be "male". As a notable exception, some special-purpose coaxial power connectors typically used for higher power levels are male gender, e.g. the larger size EIAJ plugs.

In a typical coaxial power configuration, the mating jacks or sockets have a somewhat oversized circular opening with a pin in the center. There is typically a single spring-loaded contact at the side of the opening, so some variation in mating plug barrel diameters can be accommodated. If the central pin of the jack is too large for the opening in the plug tip, it is not possible to make the connection. The pin should be designed to be just slightly smaller than the hole, to make a reliable connection. If the pin is substantially smaller, the connection may appear to work but may also be somewhat loose and unreliable.

Most coaxial power connectors are not sealed against entry of water or dust, but at least one manufacturer (Switchcraft) has announced a series of water-resistant coaxial power plugs and jacks.

Many different sizes

There are many different sizes of coaxial power connectors

Contact ratings vary from unspecified (and probably less than 1 A in practice) up to 5 A, with 2 A typical. 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.

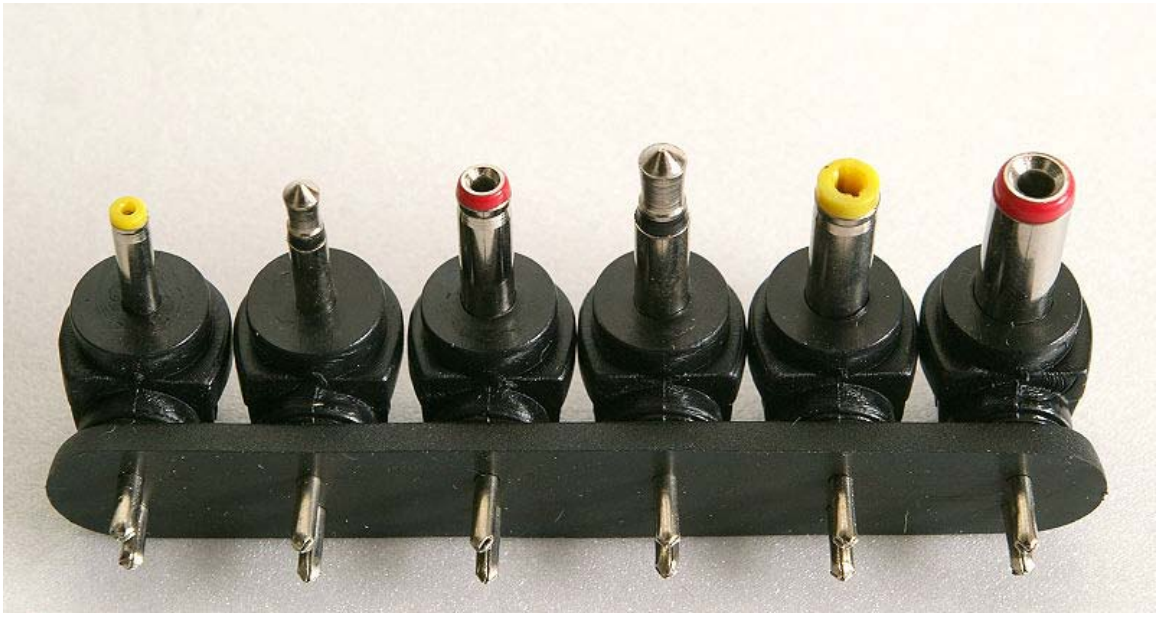
It is quite possible that new sizes will continue to appear and disappear. The most likely reason for a new size is that a particular manufacturer wishes to discourage use of third-party power supplies, either for technical reasons or to promote use of their own products, or both.

Furthermore, sometimes there is no rhyme or reason to the choice of which connector is used in an application. For example, one manufacturer might use a particular size connector for its 12 V 1 A product; a second manufacturer might use a different

connector for its 12 V 1 A product. Although the power supplies may be otherwise identical, they are not interchangeable because the connectors are different.

A more disastrous situation occurs when different manufacturers use the identical connectors for very different power supply voltages and currents. Use of the wrong power supply may cause severe equipment damage, or even fire.

Common sizes and interchangeability



Some common DC power connectors

The most common plugs are 5.5 mm in outside diameter (OD) and 9.5 mm in length. Two pin sizes are common in the jacks for this size plug body, 2.1 mm and 2.5 mm, and ideally the plugs should match. Generic plugs are often named for the pin diameter they are designed to take, so these types will be seen described as *2.1 mm DC plugs* and *2.5 mm DC plugs* respectively. These two sizes are easy to visually confuse, unless compared side by side. Slightly smaller 5.0 mm OD plugs are sometimes used in both 2.1 mm and 2.5 mm pin sizes, and are also frequently misidentified. Plug connector barrels for all of these sizes are typically 8 mm to 14 mm in length, with 9.5 mm most common.

After the two common 5.5 mm OD plugs, the next most common size is 3.5 mm OD to take a 1.3 mm pin, commonly 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.

There are also 6.5 mm OD plugs taking a 3 mm pin, 3.8 mm OD plugs taking either a 1.35 mm or a 1.05 mm pin, 3.5 mm plugs for a 1.3 mm pin, and many less common sizes.

Use of a plug designed for a larger pin, for example a 2.5 mm pin plug in a 2.1 mm pin jack, may work adequately depending on the design of the jack, but often the result is an unreliable contact or occasionally no contact at all. A pin that is too large for the plug will not allow insertion of the plug at all. Similarly, a larger plug barrel (OD) may not fit at all; a smaller one may fit but may not make a reliable contact. Length is less critical than the diameters but is sometimes a consideration; in general a longer plug is no great problem but a shorter one may fail to contact the pin reliably or at all.

It is possible to obtain connector size adapters with a DC coaxial female connector on one end, and a different-sized DC coaxial male connector on the other end.

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. Its presence or absence can cause confusion when distinguishing very similar sizes and variants. Some of the sizes listed appear to always include a high-retention feature, while others include it only in designs from certain manufacturers. Typically, this feature is a conical cut-back section of the tip, just behind the insulator that separates the inner from outer contact surfaces. In particular, the EIAJ (JEITA RC-5320A) standard connectors appear to specify a high-retention design.

The preceding very common feature must not be confused with the much-less-prevalent **lock-ring DC coaxial connector** which uses a captive threaded ring or collar to secure the connection between the plug and jack. Manufacturers known to offer this variant on at least some connectors include CUI, Kobiconn, Philmore, and Switchcraft. Note that this design requires that the lock-ring threading size be compatible with sufficiently protruding threads on a mating panel jack, and that some manufacturers (notably Switchcraft) have used a mix of metric and inch dimensioning. The lock-ring design, when fully engaged, offers strong resistance to unplugging; it is so secure that if the power cord is accidentally pulled forcefully, severe mechanical damage to equipment is likely.

An alternate design, the even rarer **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. This is a mechanical way to provide a "safe breakaway" feature somewhat like the magnetic latch used in the Apple Inc. proprietary MagSafe design. Kobiconn and Lumberg have offered some lock-tab variants, and there may be other manufacturers as well.

To insure that locking connectors operate properly, it is important to specify and to test this feature. It is likely that mating connectors from a single manufacturer will interlock correctly, but even in this case, compatibility should be verified.

A *completely different* series of locking connectors is the **snap and lock DC connector**, which is not a coaxial power connector, and is covered in a separate article on DC connectors. These multi-pin DC power connectors typically have 3 or 4 or more pins, and somewhat resemble mini-DIN connectors, except that the connector pins are thicker, to carry more current.

Standards

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

In an ideal world, specifying a voltage and a current for a power supply would also determine the connector, and it would be physically impossible to connect damaging voltages to a powered device. The world is far from that situation, but a few tentative steps have been taken in that direction.

At least two different national standards have been established, by EIAJ in Japan and DIN in Germany. In addition, several conventions have been adopted by specific manufacturers, notably by Sony, to indicate voltage by plug size.

Over time, there has been a trend to de facto standardize with **negative** DC voltage on the **barrel** (or sleeve) of a coaxial power connector. For example, Sony reversed its corporate standard during the 1990s, and adopted a barrel negative convention. One advantage of the barrel negative setup is its lower risk of short circuiting in automotive applications, since grounding the negative terminal of car batteries to the chassis has become an

almost-universal standard. But barrel positive polarity is still occasionally seen, along with the continued usage of coaxial power connectors for *low voltage AC* power as well.

Some generic power supplies allow the polarity to be reversed by use of a switch, or by an unpolarized 2-pin plug and socket arrangement. There appear to be *at least two* not-quite-compatible standards in existence for these 2-pin connectors, and official specifications are hard to find.

One "standard" used by RadioShack for its Adaptaplug brand features pins measuring 1.5 mm in diameter, 6 mm long, spaced 4 mm apart (center-to-center). Another "standard" features asymmetrical pins measuring 1.3 mm and 1.9 mm in diameter, 5 mm long, spaced 4.4 mm apart (center-to-center). There are probably other "standards" in use as well; it is not known how many different 2-pin connector systems of this type exist.

RadioShack, Kobiconn, and Philmore sell these types of 2-pin adapter connectors, and they also sell DC power cables with mating 2-pin female connectors.

EIAJ power connectors

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)

Unlike most DC plugs, the larger two EIAJ sizes have an internal male pin in the plug. The smaller three sizes do not, and are similar to the generic plugs in structure. The plug length is 9.5 mm in all cases, and current rating is 2 A.

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.

DIN 45323 power connectors

The German national standards organization DIN (Deutsches Institut für Normung — German Institute for Standardization) has issued DIN 45323, which apparently defines two DC power plug 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, as the German standard has not been translated into English as of yet.

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

- 6.00 mm OD, 1.98 mm ID

Universal power supplies

A six-way connector on a "universal" DC power supply, consisting of a 4-way X connector and two separate individual connectors. The X-connector here provides 3.5 and 2.5 mm phone plugs and two sizes of coaxial power connector

External AC power adaptors (or **wall warts**) have become almost universal, because they free product designers from worrying about some safety issues. The designer builds a product to run off a low voltage (obtained through the coaxial power connector) and does not have to worry about hazardous high voltages inside the product enclosure. By employing external power supplies tested and certified by safety agencies such as Underwriters Laboratories (UL) and TÜV, a low-power electronic product can be produced and later modified, without the expensive and time-consuming recertification that would be required if the high voltage components were not external to the product. Nevertheless, care should be taken if more than a few watts are supplied to a product, even at low voltages, since a malfunction could still start a fire. Thus, an internal fuse, circuit breaker, or thermal limiter may be useful in a powered product, even when a safety-certified external power supply is used.

Other advantages of external power supplies are that heat and electrical noise are removed from the interior of the electronic product. The weight and bulk of a power supply can be shed from portable or handheld devices. Power supplies are prone to failure, and external ones can be replaced separately when necessary. Externally powered electronic products can be used with different power sources (e.g. 120VAC, 240VAC, 12VDC, or external battery pack) as needed, resulting in a more versatile device and simplified product distribution.

However, one inherent disadvantage of external power adaptors is that they can get separated from the product they are intended to power.. Consequently, there is a market for replacement adaptors. Not only must the replacement match voltage, current, and polarity requirements, but it must also match the connector. Many products are poorly labeled with information about the power supply they require, so it is prudent to record the specifications of the original power supply in advance, to ease replacement if the original is later lost. Careful labeling of power adaptors can also reduce the likelihood of a disastrous mixup which could cause equipment damage.

Some so-called "universal" replacement power supplies allow the voltage and polarity to be switched, which can ease the matching problem. In addition, the power connector must be matched.

Four-way **X connectors** or six-way **star connectors**, also known as **spider connectors**, with multiple plug sizes and types are common on generic power supplies. Other replacement power supplies have arrangements for changing the power connector, with from four to nine different alternatives available when purchased in a set. RadioShack sells universal AC adaptors of various capacities, branded as "Enercell Adaptaplug", and fitted with 2-pin female sockets compatible with their Adaptaplug connector lineup. This allows many different configurations of AC adaptors to be put together, without requiring soldering. Philmore and other competing brands offer similar AC adaptors with interchangeable connectors.

A suitable power supply for a particular use must have the matching plug dimensions, the matching DC (or AC) voltage and polarity, and the ability to supply at least the required current. The input voltage must match the wall socket (115/230 VAC at 60/50 Hz) or other power source, such as 12VDC automotive battery power.

But the label on a power supply may not be a reliable guide to the actual voltage it supplies under varying conditions. Most low-cost power supplies are "unregulated", in that their voltage can change appreciably with load. If they are lightly loaded, they may put out much more than the nominal "name plate" voltage, which could damage the load. If they are heavily loaded, the output voltage may droop appreciably, in some cases well below the nominal label voltage even within the nominal rated current, causing the equipment being supplied to malfunction or be damaged. Cheap external power supplies of traditional design with undersized transformers tend to have poor regulation, whether originally-supplied or replacement units.

In general, more modern high-quality switched-mode power supplies are smaller, more efficient, and put out a much more constant voltage even as the input voltage and the load current may vary. Configurable switched-mode power supplies have come down considerably in price, and they are especially convenient for use when traveling because of their decreased weight and size.

Guidelines for power connector selection

With more than 40 different designs of coaxial power connectors in existence which are used to power electronic products, the lack of a clear starting point for selecting one has helped lead to the wide inconsistencies among various power plugs and devices. Here are some guidelines that can be drawn from the few power connector designs that have clear voltage specifications associated with them.

- 1.5 V devices
  - EIAJ-01
- 3.0 V devices
  - EIAJ-01
- 4.5 V devices
  - EIAJ-02
  - EIAJ RC-5321
- 6.0 V devices
  - EIAJ-02
  - EIAJ RC-5321
- 7.5 V devices
  - EIAJ-03
- 9.0 V devices
  - EIAJ-03
- 10.5 V devices
  - EIAJ-03
- 12.0 V devices, including automotive electrical systems
  - EIAJ-04
  - EIAJ RC-5322 for automotive use
  - ARINC 628/EmPower for automotive or airplane use
- 13.5 V devices
  - EIAJ-04
  - EIAJ RC-5322 for automotive use
  - ARINC 628/EmPower for automotive or airplane use
- 15.0 V devices
  - EIAJ-05
  - ARINC 628/EmPower for automotive or airplane use
- 16.5 V devices
  - EIAJ-05
- 18.0 V devices
  - EIAJ-05

Note that the special ARINC 628/EmPower connector (which strictly speaking is *not* a coaxial power connector) is used aboard commercial airlines to provide electrical power to passenger's electronic equipment.

Comprehensive listing of DC coaxial connectors

This list attempts to show all known sizes, and is annotated with some manufacturers producing selected types (based on those found in the Mouser, Digi-Key, Newark, Allied, EVG and other online catalogs), 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.

By convention, connector size is often listed in the format *A.AA x B.BB x C.CC*, where *A.AA* is the Outside Diameter (OD), *B.BB* is the Inside Diameter (ID), and *C.CC* is the Length of the connector barrel, all measured in millimeters (mm). However, some manufacturers arbitrarily reverse the A and B dimensions, sometimes within the same page of their catalog. It appears that the most common barrel length is 9.50 mm, but shorter and longer connector barrels are in use.

A further distinction is made between the Inside Diameter (ID) and the Center Pin Diameter (CPD) for certain larger coaxial power plugs equipped with a *male pin*, which are often used for higher power applications such as portable computers. Some equipment manufacturers (e.g. Apple Computer, before it switched to its even more proprietary MagSafe connector) use designs that are incompatible in subtle aspects. Connectors for these applications must be specified carefully to avoid severe equipment damage or even fire, due to the higher power carried by these designs.

An *alternate* connector size convention uses the format *W.WW x X.XX x Y.YY x Z.ZZ*, where the dimensions are arranged in an ascending size order. In this labeling scheme, *W.WW* is the Center Pin Diameter (CPD) of an *optional* male center pin, *X.XX* is the Inside Diameter (ID), *Y.YY* is the Outside Diameter (OD), and *Z.ZZ* is the Length of the connector barrel, all measured in millimeters (mm).

It is apparent that there are *many* partially overlapping standards in this product category. There are ad hoc minor variations in specs, and illogical inconsistencies in part numbers, even among the offerings of a single manufacturer. Confusion and irregularity are widespread, requiring a close reading of the specifications or testing of physical prototypes, or both, to insure connector compatibility. This table is provided primarily for convenience in comparing information from a wide range of possible sources, and may contain errors; it is recommended to double-check before relying upon the specs listed.

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. Also, there are minor tolerancing and measuring variations and discrepancies in the dimensions given; further work should be done to determine the original specifications for size, and then to list the similar sizes that are intended to be compatible.

OD (mm)	ID (mm)	CPD (mm)	Barrel Length (mm)	Adaptaplug	Standard	Volts	Plug Part Numbers	Jack Part Numbers	Notes
2.35	0.70		9.5	A	EIAJ-01	0–3.15 V	Kobicon n 3218-EX Lumberg 1636 01	Kobiconn 0307-EX (inline)	
2.40	0.70						Egston 212		possibly a rounded -off represen tation of EIAJ-01
2.40	0.80						Egston 213		
3.00	1.00								
3.00	1.10			G			CUI Inc. PP-019 Egston 214		
3.20	0.90						CUI Inc. PP-017		
3.40	1.30			H			Kobicon n 3210-E	Kobiconn 0309-EX (inline)	
3.40	1.35						Egston 218 Medical, 220		
3.40	1.40						Lumberg NES/J 135		
3.50	1.10						CUI Inc. PP3–002C Philmore 202		

3.50	1.30					Egston 238 Philmore 204,2049	Kobiconn 0308-EX (inline) Philmore 256 (inline)
3.50	1.35					CUI Inc. P7 CUI Inc. PP3–002D Egston 215 Kobicon n PA35135-E	
3.60	1.15					Egston 216	
3.80	1.10		I			CUI Inc. P9 but with 1.05 mm ID	
3.80	1.30					Egston 217	
3.80	1.35					CUI Inc. P8	
4.00	1.70	9.5	B	EIAJ-02	3.15–6.3 V	Kobicon n 3219-EX Lumberg 1636 02	Kobiconn 0311-EX (inline)
4.75	1.70	9.5	C	EIAJ-03	6.3–10.5 V	Kobicon n 3220-EX Lumberg 1636 03	Kobiconn 0310-EX (inline)
4.75	?.??	2.5 protrudin g	C	EIAJ RC-5321			
5.00	1.50		J				
5.00	2.00			DIN 45323?		Egston 206,207, 219	
5.00	2.10		K			CUI Inc. P3	
5.00	2.50		L			CUI Inc.	

				P4		
5.50	1.50		S			
5.50	2.10		M	CUI Inc. P5 CUI Inc. PP3–002A Kobiconn 3217-EX Philmore 210, 210L, 2109 Switchcraft S-760, S-765	CUI Inc. PR-002A (inline) Kobiconn 0302 (inline) Philmore 257 (inline) Switchcraft 722A (panel)	2.1 mm center pin
5.50	2.10			CUI Inc. P10 Kobiconn 7391 Philmore 2560 Switchcraft S760K		2.1 mm center pin, **lock-ring**
5.50	2.10			Kobiconn 0721-EX	Kobiconn 1000-EX (panel)	2.1 mm center pin, **lock-tab**
5.50	2.50		N	CUI Inc. P6 CUI Inc. PP3–002B Egston 222 Kobiconn 0702-EX Philmore 250, 250L, 2509 Switchcraft 760, 765	CUI Inc. PR-002B (inline) Kobiconn 0303 (inline) Philmore 258 (inline) Switchcraft 712A (panel)	2.5 mm center pin

5.50	2.50						CUI Inc. P11 Kobicon n 7395 Philmore 2560 Switchcr aft 760K		2.5 mm center pin, **lock-ring**
5.50	2.50						Kobicon n 0725-EX	Kobiconn 1100-EX (panel)	2.5 mm center pin, **lock-tab**
5.50	2.80			O					
5.50	3.30	1.00	9.5	D	EIAJ-04, JSBP4	10.5–13.5 V	Lumberg 1636 04		Microsoft Xbox 360 HD DVD drive
5.50	3.80	1.80		P					
6.00	1.98				DIN 45323		Lumberg 1632 01		
6.30	3.00			Q					
6.50	?.??				EIAJ RC-5322				
6.50	3.00								
6.50	3.10	1.00					Philmore 285		
6.50	3.40	1.40	9.0			18 VDC @5A	Kobicon n 6014-E		used often for laptop computers
6.50	4.10/ 3.10	1.00		U					same as Philmore 285?
6.50	4.30	1.40		T	EIAJ-05, JSBP5	13.5–18.0 V	Lumberg 1636 05		OD is of ring at tip
6.90	4.20	0.70		R					
7.00	??	1.00					Philmore 48-412		

RadioShack Adaptaplug conversion matrix

Adapter plugs that convert from the earlier-described two-pin non-polarized connector to various DC power plugs are widely sold by RadioShack. They have assigned a single-letter code to each "Adaptaplug", but have not provided any other official designation, nor their complete specifications and tolerances on barrel and pin dimensions. Note that the diameters listed on the RadioShack website are only specified to the nearest 0.1 mm, and sometimes differ slightly from the official EIAJ RC-5320A standards, when applicable. This list may include some discontinued parts, which are nevertheless retained for completeness.

Adaptaplug	**Outside**	**Inside**	**Pin**	**EIAJ**	**EIAJ**	**Ring**	**Radio Shack**
	Diameter	Diameter	Diameter	Type	Range	Color	Part Number
A	2.3 mm	0.7 mm		EIAJ-01	up to 3.15 V	Yellow	3807936
B	4.0 mm	1.7 mm		EIAJ-02	3.15 V to 6.3 V	Yellow	3780266
C	4.7 mm	1.7 mm		EIAJ-03	6.3 V to 10.5 V	Yellow	3780267
D	5.5 mm	3.3 mm	0.9 mm	EIAJ-04	10.5 V to 13.5 V	Yellow	3780268
E	2.5 mm (3/32" submini plug)					Black	3870005
F	3.5 mm (1/8" mini plug)					Black	3875411
G	3.0 mm	1.1 mm				Turquoise	3807935
H	3.4 mm	1.3 mm				Orange	3870006
I	3.8 mm	1.1 mm				Pink	3870007
J	5.0 mm	1.5 mm				Red	3870004
K	5.0 mm	2.1 mm				Purple	3807937
L	5.0 mm	2.5 mm				Dark Green	3807938
M	5.5 mm	2.1 mm				Navy	3807939
N	5.5 mm	2.5 mm				White	3807940

O	5.5 mm	2.8 mm				Brown	3780269
P	5.5 mm	3.8 mm	1.8 mm			Not Specified	3802153
Q	6.3 mm	3.0 mm				Yellow-Green	3780270
R	6.9 mm	4.2 mm	0.7 mm			Not Specified	3912655
S	5.5 mm	1.5 mm				Gray	3875405
T	6.5 mm	4.3 mm	1.4 mm	EIAJ-05	13.5 V to 18.0 V	Yellow	3875406
U	6.5 mm	4.1 mm / 3.10 mm	1.0 mm			Light Yellow	3875407

Chapter 4

Cigarette Lighter Receptacle

12 volt cigar lighter plug.

Metal and plastic sockets

The **cigarette lighter receptacle** in an automobile was initially designed to power a coil heater or electrically-heated lighter for cigarettes. It was later used as a de-facto standard DC connector to supply electrical power for portable accessories used in or near an automobile. Examples of devices that can be operated from a cigarette lighter receptacle include lights, fans, beverage heating devices, and small motorized tools such as compressors for inflating tires. Many portable electronic devices such as music players or mobile telephones use a cigarette lighter receptacle to recharge their internal batteries or to directly operate from the vehicle electrical system. Adapters for electronic devices may change voltage to be compatible with the supplied device. Devices that require alternating-current power at 120 volts or 240 volts can be operated with a plug-in inverter.

Currently, automobiles may provide several 12V receptacles that are intended primarily to operate accessories and are not to be used with a cigarette lighter. With the declining popularity of smoking in many countries (such as the USA), car manufacturers have stopped including an actual cigarette lighter with new cars, selling them as extra-cost accessories to customers who still want them. Usually, only one 12V receptacle near the driver will accommodate an actual cigarette lighter, with the remaining receptacles (if present) being designated as "12V auxiliary power outlets".

While the cigarette lighter receptacle is a convenient and nearly universal feature of automobiles, as a DC power connector it has the disadvantage of relatively low current rating and poor contact stability.

History

In the United States cigar lighters started appearing as standard equipment in automobiles in 1925/26. In 1928 the Connecticut Automotive Specialty Company in Bridgeport patented the first automotive cigar lighter with cord and reel. The modern "automatic" automotive V-Coil lighter was developed by Casco in 1956.

In the reel-type lighters, the igniter unit was connected with a source of current by a cable which was wound on a spring drum so that the igniter unit and cable could be withdrawn from the socket and be used for lighting a cigar or cigarette. As the removable plug was returned to the socket, the wires were reeled back into it. The circuit was closed either by pressing a button or removing the igniter from its socket.

In 1921, the Morris U.S. Patent 1,376,154 was issued for a so-called "wireless" or "cordless" lighter. This lighter eliminated the cables and the mechanism for winding and unwinding them. The igniter was heated in the socket then removed for use.

Use as a lighter

Car cigar lighter

The traditional lighter is a metal or plastic cylinder containing a thin coil of nichrome wire, through which high current (~10 amperes) passes when the device is activated, usually by pushing it into the socket as though it were a button. When pushed in, the lighter is held against the force of a spring by a hook attached to a bi-metallic strip. The heating element becomes glowing orange hot in seconds, causing the bimetallic strip to bend and unhook the mechanism, and the handle pops out. If the lighter is then promptly removed from its socket, it is capable of setting cigarettes, cigars and tinder (among other things) on fire.

In newer cars, the socket often ships with a plastic dummy plug, without the lighter heating element due to declining popularity (and legality) of smoking. However, the socket continues to exist to power consumer electronics in cars as the primary purpose. Often, a vehicle may come with several outlets for convenience, some in the rear passenger area of the vehicle. Even the cargo area may be supplied with sockets for such purposes as powering portable GPS devices, recharging telephones, or powering a tire pump or a vacuum cleaner. These usually have a plastic cap tethered to them, and are usually labeled as being only for DC power since they are not intended to withstand the heat produced by an electric cigarette lighter.

Use as an electrical outlet

Twelve volt automobile plugs are standardized in the United States by the "UL standard 2089" regarding vehicle battery adapters. This standard covers plugs and cord sets that insert into cigarette lighter receptacles. In Europe, 12 volt plugs and sockets are regulated and require approvals to be able to display the CE mark.

Technical details

The sockets and mating plugs are defined in the ANSI/SAE J563 specification.

For the 12-volt systems, the "contact point," which is the center part of the plug when viewed end-on, carries the positive voltage, whereas the "can" part, which is the outer part of the connector, carries the negative voltage (which is the "ground" connection for most automobiles, which have a negative ground electrical system).

12 volt auto connectors are made to comply with a standard by Underwriters Laboratories for safety. UL2089 was developed to cover the requirements for portable adapters rated 24 v dc or less that are intended to be supplied from the battery powered electrical system of a vehicle. Products covered by the standard include cord assemblies of a plug that mates with the standard cigarette receptacle found in automobiles.

12V Sockets normally comply with SAE standard J563.

6-volt cigar lighter receptacle and plug

- Receptacle inside diameter: 21.34 - 21.46 mm (median 21.4 mm)
- Plug body diameter: 21.08 - 21.23 mm (median 21.155 mm)

12-volt cigar lighter receptacle and plug, size A

- Receptacle inside diameter: 20.93 - 21.01 mm (median 20.97 mm)
- Plug body diameter: 20.73 - 20.88 mm (median 20.805 mm)
- Most often used in American automobiles.

12-volt cigar lighter receptacle and plug, size B

- Receptacle inside diameter: 21.41 - 21.51 mm (median 21.455 mm)
- Plug body diameter: 21.13 - 21.33 mm (median 21.18 mm)
- Most often used in European automobiles, and sometimes as a second socket in American automobiles expressly for DC power connections.

Plugs often include a pilot light to indicate a connection has been made.

Design considerations

Since the cigar lighter socket was designed to heat a cigar lighter, using these sockets as power connectors can lead to many problems. In addition to the issues with incompatible sizes, plugs can vibrate out of the socket under normal driving conditions, owing to poor retention. There have been reports of melted plug tips.

A second problem is that nominally "Twelve-Volt" power in cars fluctuates widely. The actual voltage will be approximately 12.5 volts when dormant, (less when cold) approximately 14.5 volts when the engine and the alternator/generator are operating, (more when cold) and may briefly drop as low as 5-6 volts during engine start. DC/DC converters will usually compensate for these small fluctuations.

Rarely, more extreme cases of voltage fluctuation can occur when the car battery is disconnected while the engine is running, or when the car receives a jump start. When the battery is disconnected, a load dump transient can produce very high voltages. A car receiving a jump start from a truck will be subject to its 24 V electrical system. A "double battery jump-start" is performed by some tow truck drivers in cold climates.

Design wise one has to take into account intermittent contact, and voltages outside the nominal 12 V DC like top voltage 9-16 V continuously, top voltage at 20 V during 1 hour, 24 V during 1 minute, 40 V during 400 ms. Protection component tolerance example ratings are +50 to -60 V DC Besides this there's also varying temperatures between -40 till +85 °C to contend with that can affect humidity and condensation. Equipment connected this way must tolerate large variations in electrical- and climate environment.

Chapter 5

Mini-DIN Connector

The **mini-DIN** connectors are a family of multi-pin electrical connectors used in a variety of applications. Mini-DIN is similar to the larger, older DIN connector. Both are standards of the Deutsches Institut für Normung, the German standards body.

Standard connectors

Mini-DIN connectors are 9.5 mm in diameter and come in seven patterns, with the number of pins from three to nine. Each pattern is keyed in such a way that a plug with one pattern cannot be mated with any socket of another pattern. An important aspect of why each of these 7 mini-DIN connectors are *official standards* is because they are each drastically different from the other, with no simultaneously and directly overlapping similarities in (1) pin arrangement, (2) square key size and position, (3) circular shielding metal skirt notches & metallic additions - unlike the nonstandard mini-DIN connectors which may have directly overlapping characteristics to each other or to the standard mini-DIN connectors.

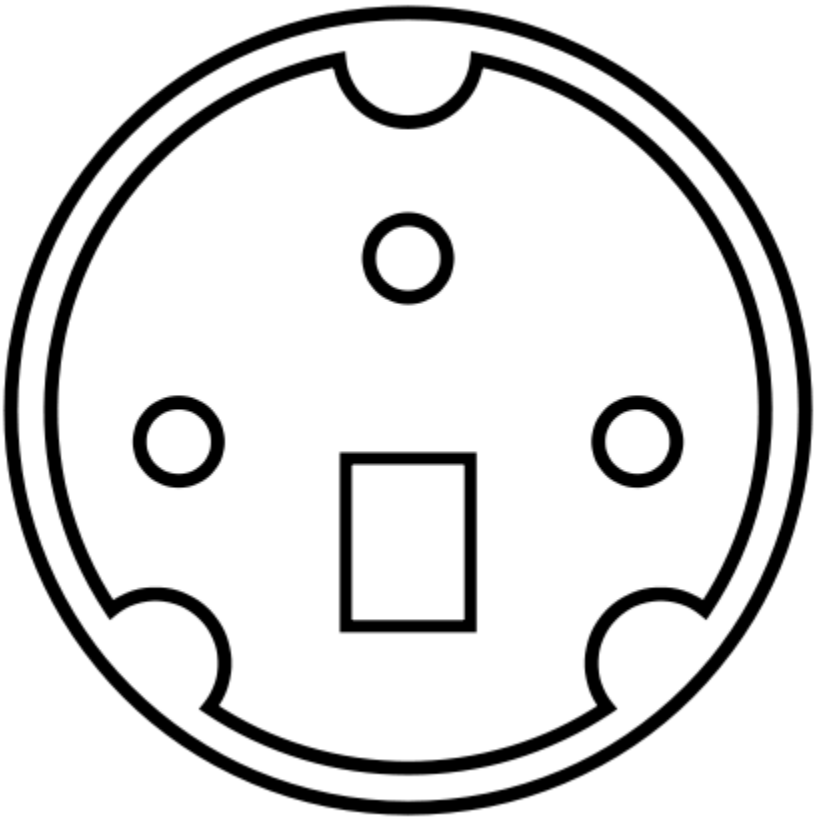
(The plug or male connectors shown, as visible when unplugged looking into the connector.)

The pin numbering for the plugs shown above is done left to right, bottom row to top row. Pin 1 will be on the lower left, and the highest pin number will be on the upper right.

WARNING. No references are cited for these pin arrangements. The mini-DIN 9-pin diagram is not the standard; the standard is nonuniform spacing on the first row and

uniform spacing on the second. See, for example, a data sheet for mini-DIN 9 connector that shows a nonuniform spacing on the top row.

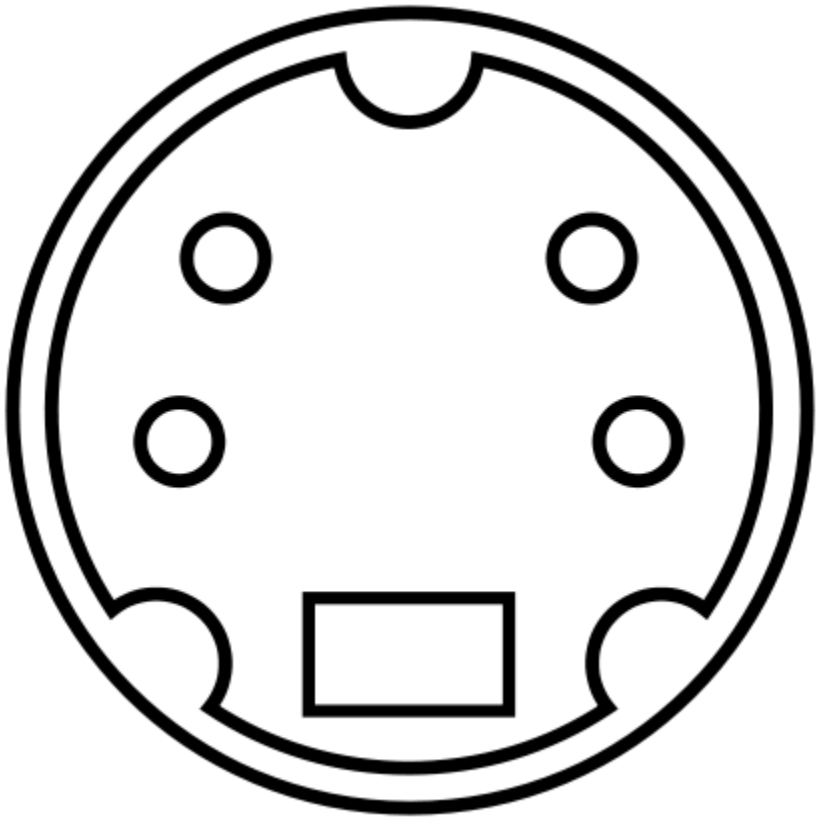
3-pin



- Apple LocalTalk Network
- VESA Stereo
- SGI StereoView (pinout diagram)
- Behringer Mixer Power Supplies
- Optoma EH1020 Projector
- TOPFIELD TF5400 PVR Combo Receiver

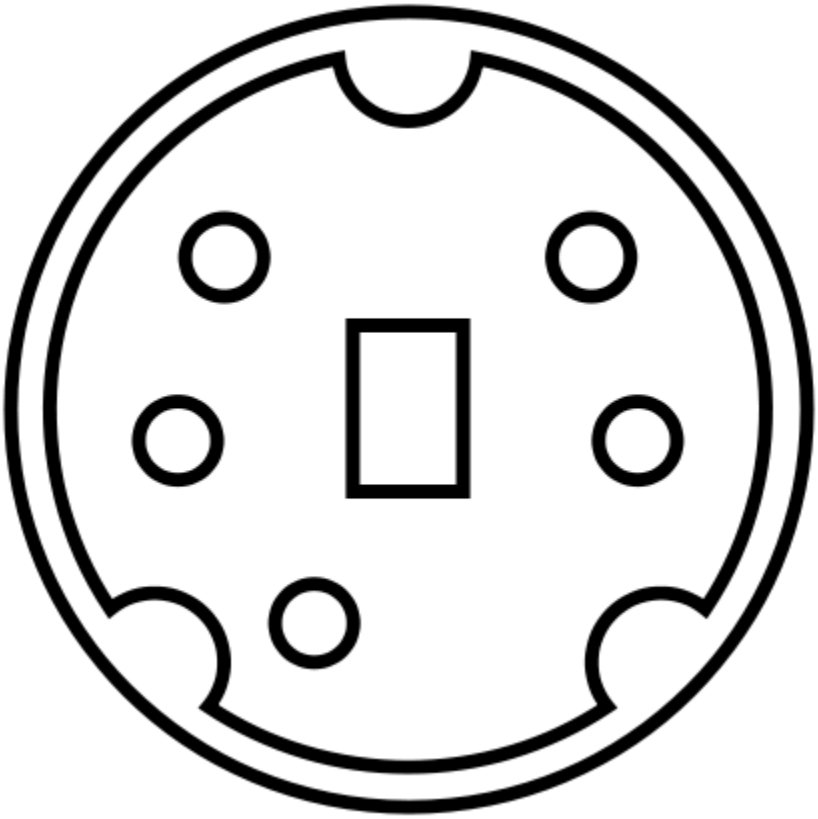
4-pin

4 pin mini-DIN for S-Video



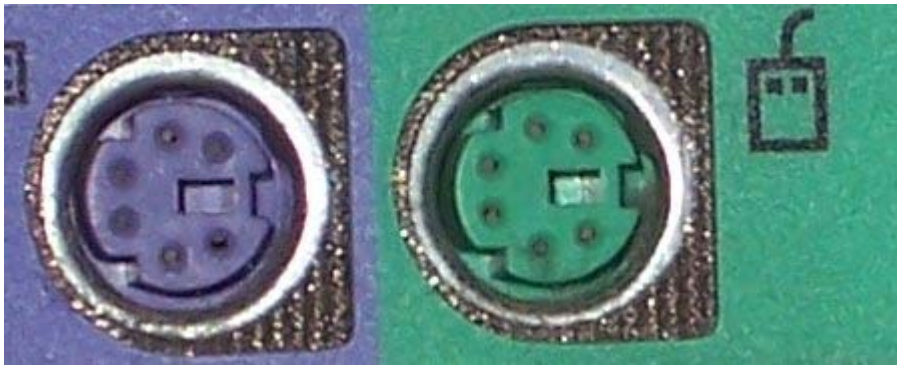
- Apple Desktop Bus (Pinout diagram)
- S-Video (Pinout diagram)
- Thomson SpeedTouch 605 Console Serial Port / DSL Router (pinout diagram)
- Low voltage power supplies like the Seagate Pushbutton External Drive Power Supply

5-pin

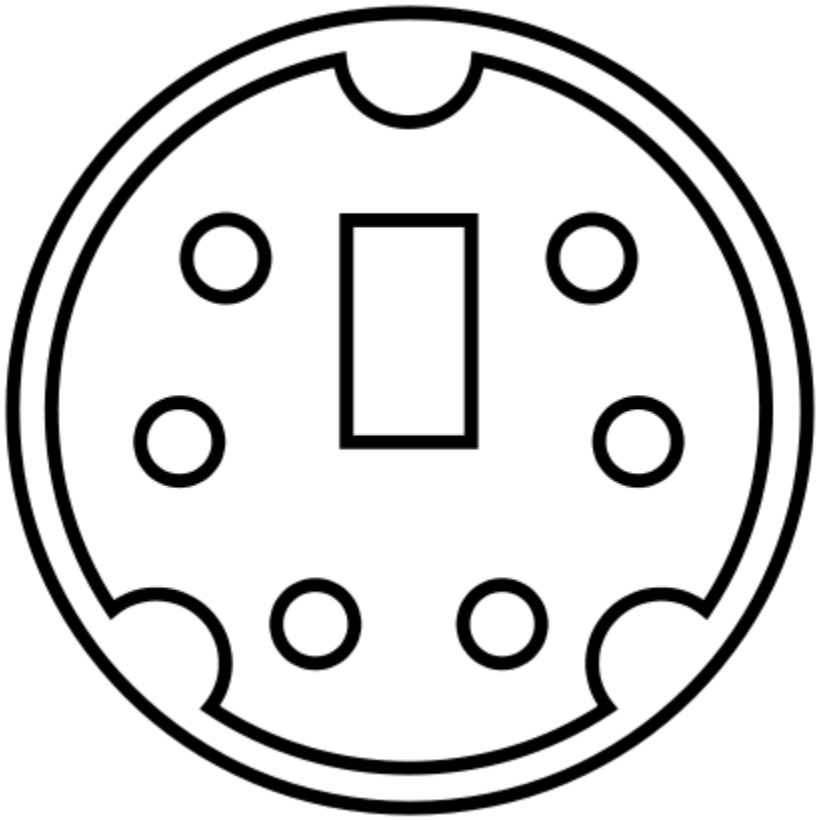


- Low-voltage power supply input connector on various pieces of equipment
- SONY LANC camcorder control interface (Pinout diagram)
- 5-pin MIDI input and output connectors used by the Creative Technology Sound Blaster X-Fi Front I/O Panel and the Creative LivedriveII (pinout diagram)
- Altec Lansing ACS 45 (2.1)

6-pin



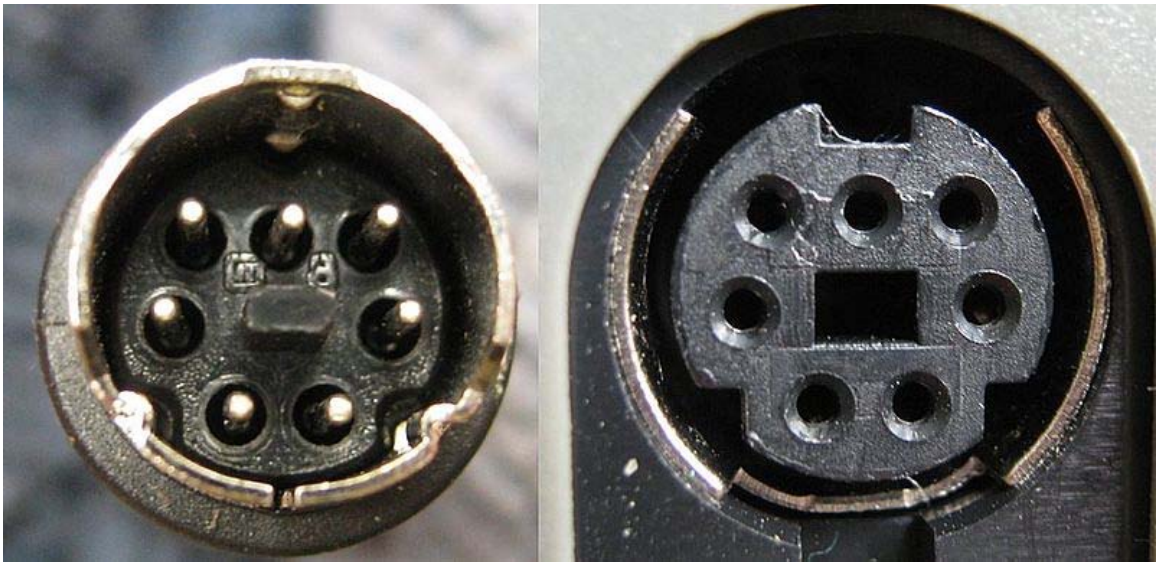
The color-coded PS/2 connection ports (purple for keyboards and green for mice)



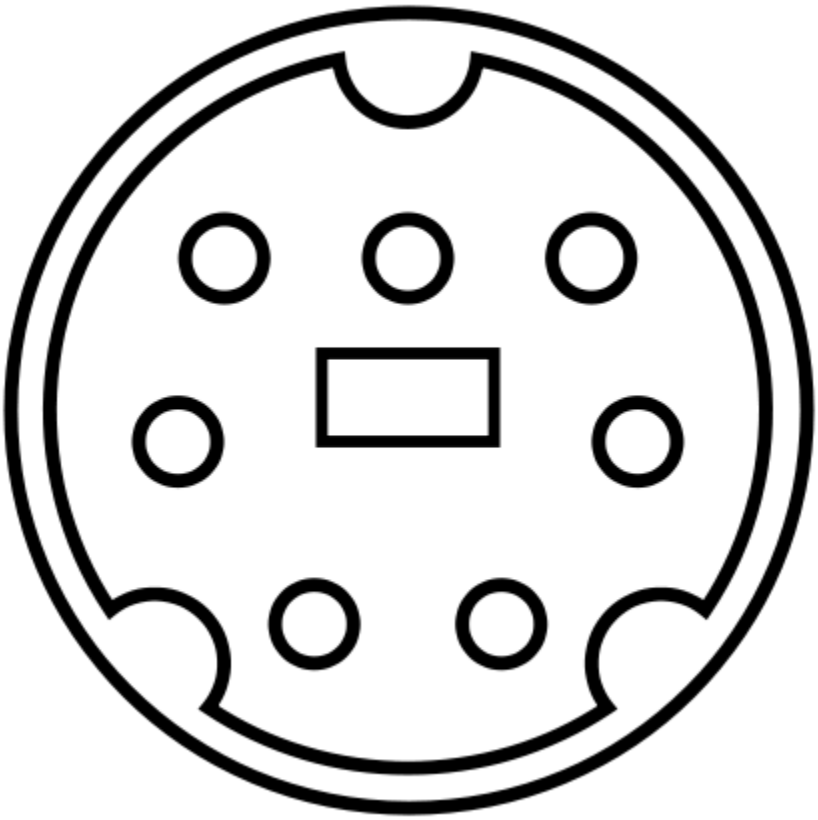
- IBM PC compatible PS/2 keyboard/mouse connector
- Amateur radio TNC modem-radio interface
- Power supply DC output for some electronic devices
- Acorn Archimedes keyboard
- Blitz DVD screen for cars
- Klipsch 2.1 channel audio system (2 speakers/1 subwoofer)
- Leadtek and VisionTek GeForce2 Ti cards as TV-out
- Saitek x52 Flight stick to throttle connection
- Creative Cambridge SoundWorks Ps 2000 Digital Connection from woofer to main volume
- Auxiliary control output on some Ferrograph dot matrix LED displays (call centre wallboards)
- All Chatterbox headsets
- Yaesu FT-450 DATA port (view of rear panel, 6-pin DATA port on far left)
- Yaesu FT-817 DATA port
- Yaesu FT-857D DATA port
- Neopost SE4PC postal scale
- Mitsubishi Q series PLC RS232 port
- Dell MP series projectors RS232 port
- Radio Shack CCTV monitor P/N 49-2514 and CCTV camera/motion sensor P/N 49-2515 proprietary pin-out

- Commonly used on GPS mice to connect the device to an adapter cable with a USB or RS232 connector.

7-pin

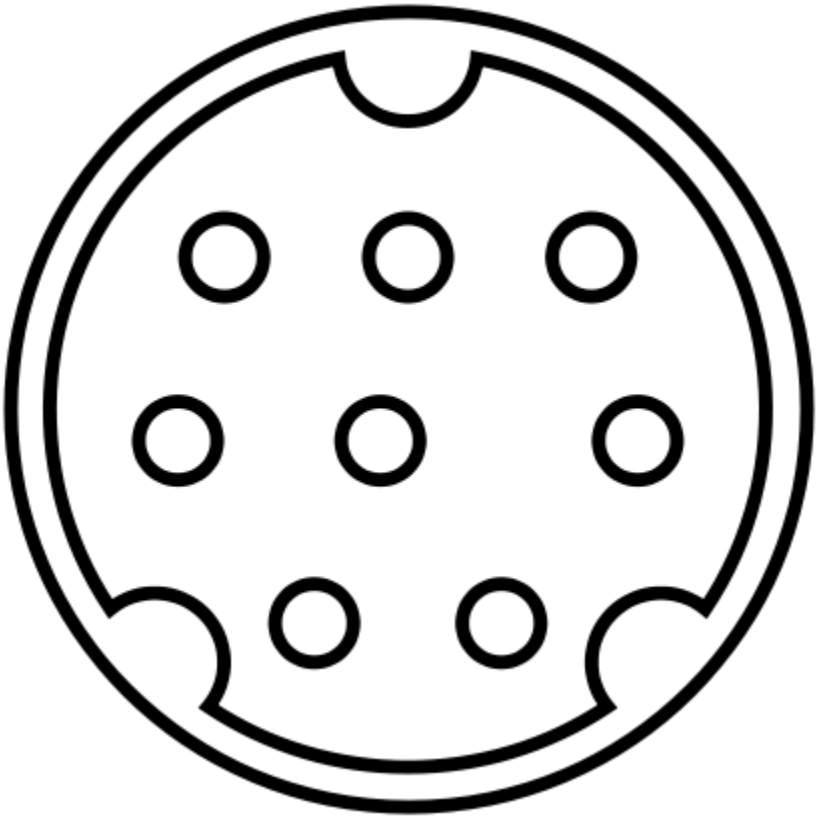


Example of the standard 7 pin mini-DIN connectors. These are from a Commodore 1531 datasette and its adapter.



- Commodore Plus/4
- iRobot Roomba serial connector
- Altec Lansing ATP3
- XO Vision headrest screen
- Digital Equipment Corporation DECserver 90L/90L+/90TL/90M
- Märklin 610479 10 pin to 7 pin adapter cable
- a standard 8 pin DIN plug below can be fitted into a standard 7 pin socket
- ATI Radeon Video Card - HDTV Out

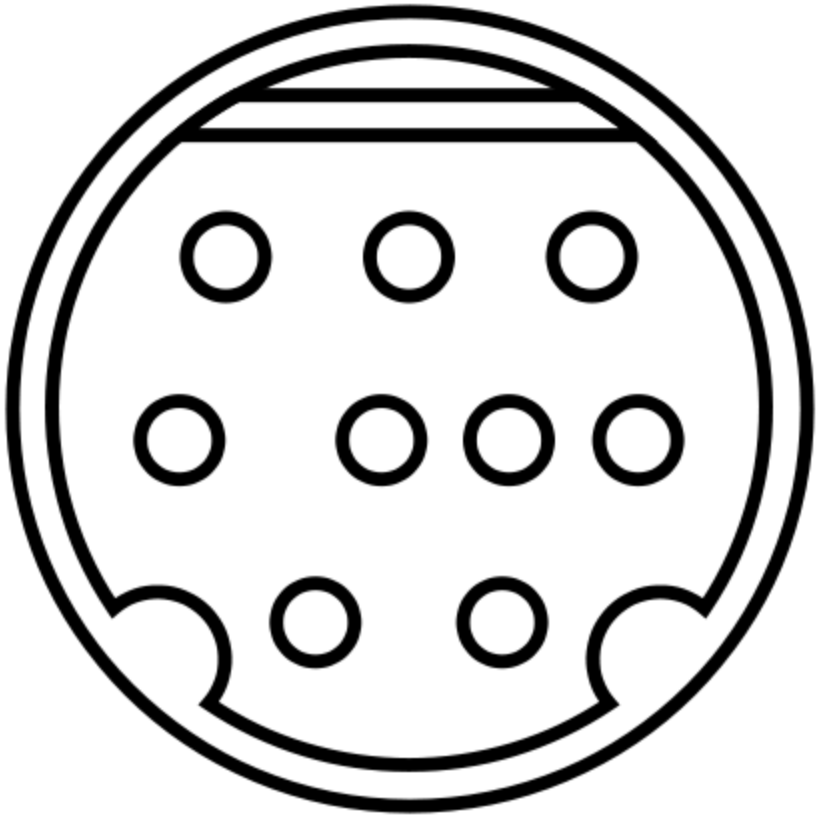
8-pin



- Sony VISCA Camera Control
- Apple Macintosh Serial Port
- Epson
  - Epson PX-8 and Epson PX-4 RS-232 *and* Serial port
  - Scanner TPU and automatic document feeder
- NEC Turbo Duo Controller Port
- Multimedia Extension Connector
- ATI Radeon 8-pin video connector.
- Legacy Roland serial port MIDI connectors (Mac/PC).
- Sanyo/Fischer Camcorder A/V out (older models)
- Mitsubishi FX series PLC RS422 port
- Shure SCM810 and FP410 automixers.
- Sun Microsystems
  - Serial Keyboard/Mouse connector (3/80 through UltraSPARC).
  - SPARCstation IPC & IPX Serial port.
  - SPARCstation IPC & IPX Audio In/Out port.
  - Sun Fire E25K Serial port.
- Directed Car Screens.
- SiriusConnect interface for Sirius satellite radios.

- Neptune Systems Aquacontroller serial and I/O port
- Kenwood TM-V71 - Radio to PC connector
- Yaesu
    - CAT (Computer aided transceiver) interface port
    - FT-450 TUNER port (view of rear panel, 8-pin TUNER port middle-left)
    - FT-817ND CAT/Linear port
    - FT-857D CAT/Linear port
    - FT-950 external tuner port
- Numark CDN25+G CD player remote
- Altec Lansing ADA885 left speaker connection
- Hewlett Packard ScanJet ADF (C5195)
- Idec PLC and HMI communication and programing ports
- Polycom VSX7000 series serial/VC control connector
- iSimple Gateway iPod/iPhone Interface Connectors

9-pin



WARNING. This mini-DIN 9-pin diagram is not the standard mini-DIN; the standard has nonuniform spacing on the first row and uniform spacing on the second. A data sheet for mini-DIN 9 connector shows this pattern.

These devices are the standard mini-DIN 9 because they have the non-uniform spacing on the top row:

- Magtek MICR Wedge Mini.

These devices are definitely NOT the standard mini-DIN 9 because they have non-uniform spacing on middle row:

- Logitech X-220 Speakers.
- Philips MC-D179 DVD Micro Theater

These devices may or may not be mini-DIN 9:

- Acorn Archimedes mouse
- Creative GigaWorks T40 (for Creative Docking Station X-30)
- Logitech Z-340 Speakers
- Logitech Z-3e Speakers
- Nvidia and ATI Technologies Video In Video Out (VIVO) port connector for GeForce and Radeon video cards
- Bus mouse
- Dension Gateway
- Vizualogic Car Screens
- Freebox HD (SCART to Mini-Din 9 plus 2 RCA : red and white)
- Kam, cetronic and numark dule CD DJ decks
- SCT XCAL2 Analog Inputs
- Harman/Kardon 395 3pc Speaker Set - Cable from subwoofer to the satellites for volume control

Non-standard connectors

Several non-standard sockets are designed to mate with standard mini-DIN plugs. These connectors provide extra conductors, and are used to save space by combining functions in one connector that would otherwise require two standard connectors.

Other non-standard connectors mate only with their matching connectors, and are mini-DIN connectors only in the sense of sharing the 9.5 mm plug body. These mini-DIN style plugs are *not* approved by the Deutsches Institut für Normung, the German standards body, and many applications could be considered proprietary.

(plug or male connector shown, as visible when unplugged; female sockets appear left-right reversed)

7-pin

Many laptops and video cards use a 7-pin video output jack compatible with a standard 4-pin mini-DIN plug. Pins 1-4 use the standard S-video pinout, enabling standard S-video cables to connect directly. A wider key prevents insertion of the matching plug into a standard 4-pin socket.

The use of the extra three pins varies from manufacturer to manufacturer, but commonly includes a composite video output which is available using the manufacturer's proprietary adapter. Alternatively a YPbPr signal may be provided. Later Dell laptops provide an SPDIF audio signal. Some proprietary adapters bridge specific pins in order to enable the signal on other pins, or to specify the type of signal to be delivered.

The keying and pin arrangement prevents the use of the standard 7-pin mini-DIN plug, but even if a suitable plug can be obtained, use of non-proprietary adaptors on these ports may cause problems. Some graphics hardware, for example, is not engineered to have both the S-video and composite video outputs in use at once, and attempts to do this using non-standard adapters will produce poor results at best, and possibly damage the video output circuitry.

- Dell Inspiron/Latitude Video/Digital Audio Output
- Also used for ATI Radeon 7-pin
- SendStation PocketDock AV for Apple iPod
- XFX (Nvidia) GeForce 8800GT Video Card TV-Out Port
- Apple PowerBook G3 Firewire (Setting Up Your PowerBook, page 7, reveals an included composite-to-S-video adapter cable, and page 20 shows the S-video output port)
- Apple PowerBook G4 15" & 17"
- Apple Beige G3, input on the Wings personality card
- ATI Xclaim TV (some product information is provided here)
- GeForce Go7400 output used in some HP laptop computers
- Acer Aspire 9302WSMi

- Aspenhome iPod Dock
- Hauppauge WinTV
- Samsung X20 notebook

8-pin

- Amstrad CPC6128 Plus Monitor
- SGI Personal IRIS 4D/30, 4D/35, Indigo, Indy, and Indigo2 Serial Port

8-pin (b)

- ATI All-in-Wonder 9700 Pro 8-pin video-In connector

9-pin

- Alternate Video In Video Out (VIVO) port connector

Some versions of the VIVO port on some ATI and Nvidia GeForce video cards used a 9-pin connector without the small metal bar to determine how the plug fit into the socket (instead, the 3 indentions in the outer ring were used.)

- 9-pin Apple GeoPort connector

The Apple GeoPort used a 9-pin jack compatible with either an 8-pin or a 9-pin mini-DIN plug, and was able to be used with devices designed for either the 8-pin mini-DIN Macintosh serial port connector, or the additional GeoPort protocols.

Apple pin numbering follows the 8-pin DIN assignments, for compatibility with earlier Macintosh serial ports using the standard 8-pin connector. The additional pin is numbered 9 by Apple, and corresponds to pin 5 of a 9-pin mini-DIN plug. It is used for a 5V 350mA power supply available to the peripheral. Pins 5-8 of the GeoPort socket and the mini-DIN-8 plugs used with it then correspond to pins 6-9 respectively of the standard mini-DIN-9 plug.

- This connector is close enough in specification to an Altec Lansing right speaker connection to be replaced with this connector plug.

9-pin (b)

- Sega Mega Drive II / 32X - This is larger than a standard mini-DIN 9.

- Hypercom T7 Eftpos terminal
- Nvidia GeForce S-Video 9 pin to YPbPr (YCbCr)
- Sigma EM8300 Video Card
- Cambridge Soundworks DTT2500 Digital
- Speed-link Medusa Amplifier
- Creative Inspire T7700 Speakers - Wired control unit connector.
- Creative X-fi elite pro unit - Cable to connect to the speakers for control.
- Creative Speaker mini din 9p pinout
- Philips A5.600 Seismic Power 600 - Center speaker controller unit and 5.1 audio connector.
- Harman/Kardon 395 3pc Speaker Set - Cable from subwoofer to the satellites for volume control.
- Various Sharp multimedia projectors RS-232C (DIN9B TO DB9 supplied with the projector)

10-pin

- Sega Saturn (shows pinouts)
- HANNspree monitors and televisions

10-pin (b)

- ATI All-in-Wonder 9700 Pro (shows pinouts) (Video Out)
- Matrox G450 eTV S-Video/Composite (shows pinouts)
- Amino AmiNET STB series (shows pinout)
- Märklin 60652 Mobile Station

- Märklin 610479 10 pin to 7 pin adapter cable

Other non-standard connectors

- JVC Mini-DIN 8
- Allen-Bradley Micrologix PLC Mini-DIN 8
- Beyerdynamic microphone connector

Chapter 6

Banana Connector & Molex Connector

Banana Connector

Adapter between a female BNC connector and banana plugs

Typical banana plugs connected to loudspeaker

A **banana connector** (commonly **banana plug** for the male, **banana jack** or **banana socket** for the female) is a single-wire (one conductor) electrical connector used for joining wires to equipment. The plugs are frequently used to terminate patch cords for electronic test equipment. They are also often used as the plugs on the cables connecting the amplifier to the loudspeakers in hi-fi sound systems.

The plug was invented in 1924 by Richard Hirschmann (former Richard Hirschmann GmbH & Co.).

Design

The plug consists of a cylindrical metal pin about 25 mm (one inch) long, with a diameter of 4 mm, which can be inserted into a matching 4 mm socket to make an electrical contact. The pin has one or more lengthwise springs that bulge outwards slightly. These press against the sides of the socket, improving the electrical contact and preventing the pin from falling out. The curved profile of these springs is probably the origin of the name "banana plug". The other end of the plug has a lug connector to which a length of flexible insulated equipment wire can be attached, which is either screwed, soldered, or crimped into place. An insulating plastic cover is usually fitted over this end.

The rear end of a 4 mm plug often has a 4 mm hole drilled in it, either transversely or axially, to accept the pin of another 4 mm plug. This type is called a stackable 4 mm plug.

For high voltage use, a special sheathed version of the banana plug and socket is used. This version has an insulating sheath around both the male and female connectors to avoid accidental contact. The sheathed male plug will not work with an unsheathed female socket, but an unsheathed male plug will fit a sheathed female socket.

Individual banana plugs and jacks are commonly color-coded red and black but are available in a wide variety of colors. Dual banana plugs are usually black with some physical feature such as a molded ridge marked "Gnd" indicating the relative polarity of the two plugs.

Besides plugging into specific banana jacks, banana plugs may plug into *five-way* or *universal* binding posts on audio equipment.

Derived plugs

A number of widely used plugs are based on combining 2 or more banana plugs with a plastic handle and other features for ease of use and to prevent accidental insertion in other such plugs. Many of these plugs are derived from the **double banana** plug consisting simply of two banana plugs spaced 3/4 inch (about 19mm) apart.

US-style double banana (pictured): A plastic housing containing two banana plugs, allowing simultaneous connection of a signal line and a ground (earth) line. The housing may allow the connection of individual wires, a permanently attached coaxial cable providing both signal and ground, or a coaxial connector such as the BNC connector shown in the photo. By convention, multiple full-sized banana connectors are spaced on ¾ inch centers.

Older European audio equipment used double banana plugs with a 3rd center pin (round 4mm banana for speakers, 4 mm banana or flat pin for turntable to amplifier connection) for audio signals. The center pin prevents accidental insertion in mains sockets, except the Italian "type L" socket.

Some specialized multi-pin plugs and sockets consist of 5 or more banana plugs arranged in a circle.

Miniature connectors

A miniaturized version of the banana connector was also produced. About 1/3 the size of the standard connector, these were useful in high-density applications but never achieved the same sort of popularity as the larger banana connectors. They are substantially more fragile than the larger connectors. Multiple miniature banana connectors are usually spaced on ½ inch centers.

Electrical safety

An exposed banana plug can obviously present electrical hazards if the wire to which it is attached is energized. A plug that is only partially inserted into a jack can also present a risk of accidental contact as the conductive surface of the plug will not be completely covered. The hazards include electric shock, electrocution, burns from accidental short circuits, and damage to the attached equipment.

Where electrical safety is an issue, various kinds of protected plugs and sockets are available. These have sliding covers on plugs and/or other devices to protect the user from accidental contact with live conductors, but are still largely compatible with the original design.

An adjustable switched-mode power supply for laboratory use with three safety banana jacks

A typical design is now required (IEC 61010) on digital voltmeter test leads and several other measurement and laboratory equipment. In this design, the metal banana plug is entirely sheathed in plastic and presses into a deep recess in the DVM. Alternatively, the DVM has the male part of the banana plug and it is deeply recessed; the test lead contains a sheathed banana jack.

In most European countries the standard mains power receptacle will accept banana and even US-style "double banana" plugs (the standard US pin spacing of 3/4 inch (19.05 mm) is close enough to the mains plug spacing of about 19 mm., and the pin diameter is also compatible), leading to a risk of electrical shock. For safety reasons, it can be difficult to purchase US-style laboratory "double banana" plugs in these countries.

Molex Connector

PC power supply with several connectors. From left to right: Molex Mini-fit Jr 20 and 4 pin, Molex KK, SATA connector, Molex 8981 and Molex mini-spox.

Molex connector is the vernacular term for a two-piece **pin and socket** interconnection, most frequently disk drive connectors. Pioneered by Molex Connector Company, the two-piece design became an early electronic standard. Molex developed and patented the first examples of this connector style in the late 1950s and early 1960s. First used in home appliances, other industries soon began designing it into their products from automobiles to vending machines to mini-computers.

In such a connector, cylindrical spring-metal pins fit into cylindrical spring-metal sockets. The pins and sockets are held in a rectangular matrix in a nylon shell. The connector typically has 2, 3, 4, 5, 6, 9, 12, or 15 circuits and is polarized to ensure correct

coupling. Pins and sockets can be arranged in any combination in a single connector, and each housing can be either male or female.

There are three typical pin sizes: 1.57 mm (0.062 in), 2.36 mm (0.093 in), and 2.13 mm (0.084 in). The 1.57 mm pin can carry 5 A of current, while the 2.36 mm can carry 8.5 A. Because the pins have a large contact surface area and fit tightly, these connectors are typically used for power.

This style of connector was first used as a computer disk drive connector in the late 1970s, initially on the Shugart floppy disk drive as well as Atari (1979) on its path to becoming a de facto standard. It is in this role that the vernacular term *molex connector* is most frequently used. AMP (now a division of Tyco International) developed the *MATE-N-LOK* 2.13 mm pin connector that is the same as the Molex 8981 power connector. This Molex and Amp connector configuration was the established standard for disk drive power connectors until the advent of SATA disk drives.

Desktop PC use

Several types of pin-and-socket connectors have become established for power connections in desktop PCs, because of the simplicity and reliability of the design. Certain Molex connectors are used for providing power to the motherboard, fans, hard disk drive, floppy disk drive, CD/DVD drive, video card, and others.

In practice, compatible connectors are available from a myriad of manufacturers, not just Molex and AMP.

Motherboard power connector (Molex Mini-fit Jr.)

In 20/24 pin configurations, the Mini-Fit Jr. connector may be used on ATX motherboards as the main power connector. 4, 6 and 8 pin configurations of the same style of connector are used for additional CPU power and graphics card power. This is changing as power, signal and speed requirements increase in sophistication and electronic requirements. More commonly, the Mini-Fit, Jr. can be found in consumer applications, such as white goods, requiring high density and high current.

These connectors are polarized so that they cannot be inserted incorrectly, and lock into position using a latch.

Standard pinout:

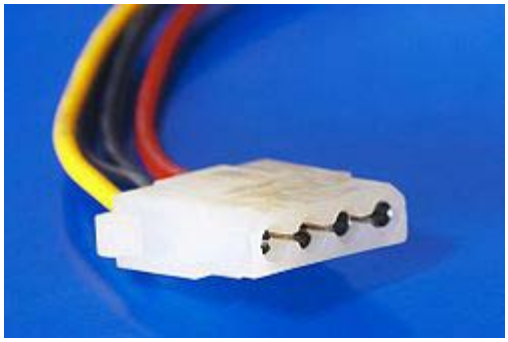
24-pin ATX12V 2.x power supply connector
(20-pin omits the last four: 11, 12, 23 and 24)

Color	Signal	Pin	Pin	Signal	Color
Orange	+3.3 V	1	13	+3.3 V	Orange
				+3.3 V sense	Brown

Orange	+3.3 V	2	14	−12 V	Blue
Black	Ground	3	15	Ground	Black
Red	+5 V	4	16	Power on	Green
Black	Ground	5	17	Ground	Black
Red	+5 V	6	18	Ground	Black
Black	Ground	7	19	Ground	Black
Grey	Power good	8	20	Reserved	N/C
Purple	+5 V standby	9	21	+5 V	Red
Yellow	+12 V	10	22	+5 V	Red
Yellow	+12 V	11	23	+5 V	Red
Orange	+3.3 V	12	24	Ground	Black

- Pins 8, 13, and 16 (shaded) are control signals, not power:
  - "Power On" is pulled up to +5V by the PSU, and must be driven low to turn on the PSU.
  - "Power good" is low when other outputs have not yet reached, or are about to leave, correct voltages.
  - The "+3.3 V sense" line is for remote sensing.
- Pin 20 (formerly −5V, white wire) is absent in current power supplies; it was optional in ATX and ATX12V ver. 1.2, and deleted as of ver. 1.3.
- The right-hand pins are numbered 11–20 in the 20-pin version.

Molex 8981 Series



Molex 8981 Power connector (female)

Type	Electrical power connector
Production history	
Designer	Molex
General specifications	

Width	21 mm
Height	6 mm
Pins	4
Electrical	
Signal	Yes
Max. voltage	12 V
Max. current	11 A/pin (30 °C rise)
Pin out	

Pin	Color	Type
Pin 1	Yellow	+12 V
Pin 2	Black	Ground
Pin 3	Black	Ground
Pin 4	Red	+5 V

18 AWG wire is typically used.

Power good goes high to indicate that voltages are stabilised and ready for use. *Power on* is internally driven high, and shorting this pin to ground will turn on the power supply.

Disk drive connector (Molex 8981 Series Power Connector)

The desktop computer hard-drive connector is pictured here. It has 4 conductors, with the standard pinout as follows:

Pin #	Color	Function
1	Yellow	+12 V
2	Black	Ground
3	Black	Ground
4	Red	+5 V

Sometimes, especially in older computers, the colors differ. The pins are 0.200 in (5.08 mm) apart (center to center). The connector housing has chamfered corners on one side to prevent the user from plugging it in incorrectly. The connector that provides power (e.g., on a power supply) has female pins and a male housing; the connector that receives power (e.g., on a peripheral) has male pins and a female housing.

The connector is standard on all PATA disk drives and low-end SCSI disk drives; however, newer disk drives will employ a more advanced integrated serial interconnection. These new, advanced connection systems are being developed by Molex and other connector companies, often working together to develop interconnection standards.

Despite its widespread adoption, the connector has problems as a 30-year-old product. It is cumbersome and difficult to remove because it is held in place by friction instead of a latch, and some poorly constructed connectors may have one or more pins become unattached from the connector when plugged in.

Chapter 7

MagSafe & Battery Terminal

MagSafe

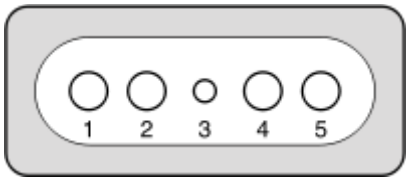
MagSafe

The MagSafe power adapter on a MacBook.

Type	Computer power connector
Production history	
Manufacturer	Apple Inc.
Produced	2006
Superseded	Apple Power Connector
General specifications	
Hot pluggable	Yes
External	Yes

Pins	5

Pin out



Male connector, front view

Pin 1	Ground
Pin 2	V+ @ 16.5 VDC
Pin 3	Charge control pin
Pin 4	V+ @ 16.5 VDC
Pin 5	Ground

Grey area indicates magnetic connector

The **MagSafe** is a power connector introduced in conjunction with the MacBook Pro at the Macworld Expo in San Francisco on January 10, 2006 by Apple Inc. The MagSafe connector is held in place magnetically so that if it is tugged on by someone tripping over the cord it will pull out of the socket safely, without damaging it, the computer, or potentially pulling the computer off of a table or desk. MagSafe is similar to the magnetic power connectors that many deep fryers and Japanese countertop cooking appliances have in order to avoid spilling their dangerously hot contents.

Features

The New Magsafe Power Adapter that now ships with all MacBook, MacBookPro & MacBook Air models.

The MagSafe connector pins are designed so that the rectangular connector can be inserted in either orientation (however the newer connector can only be fitted in one orientation without blocking neighbouring ports). LEDs on both sides show green if the computer battery is fully charged and amber if the battery is charging. MagSafe can be found on the MacBook Pro, MacBook and MacBook Air notebook computers, and also on the Apple LED Cinema Display.

Though the 60 W MacBook and 85 W MacBook Pro MagSafe connectors are identical, Apple recommends using only the adapter provided with the machine. The MacBook Air has a smaller 45 W version of the MagSafe adapter. (Note: The 13" MacBook Pro uses the 60 W Charger, while the 15" and 17" use the 85 W)

Apple's *MagSafe Airline Adapter* is available for DC hookups on certain airplanes. It will power the computer but not charge the battery.

Apple owns US Patent No. 7311526 , "Magnetic connector for electronic device", for this technology.

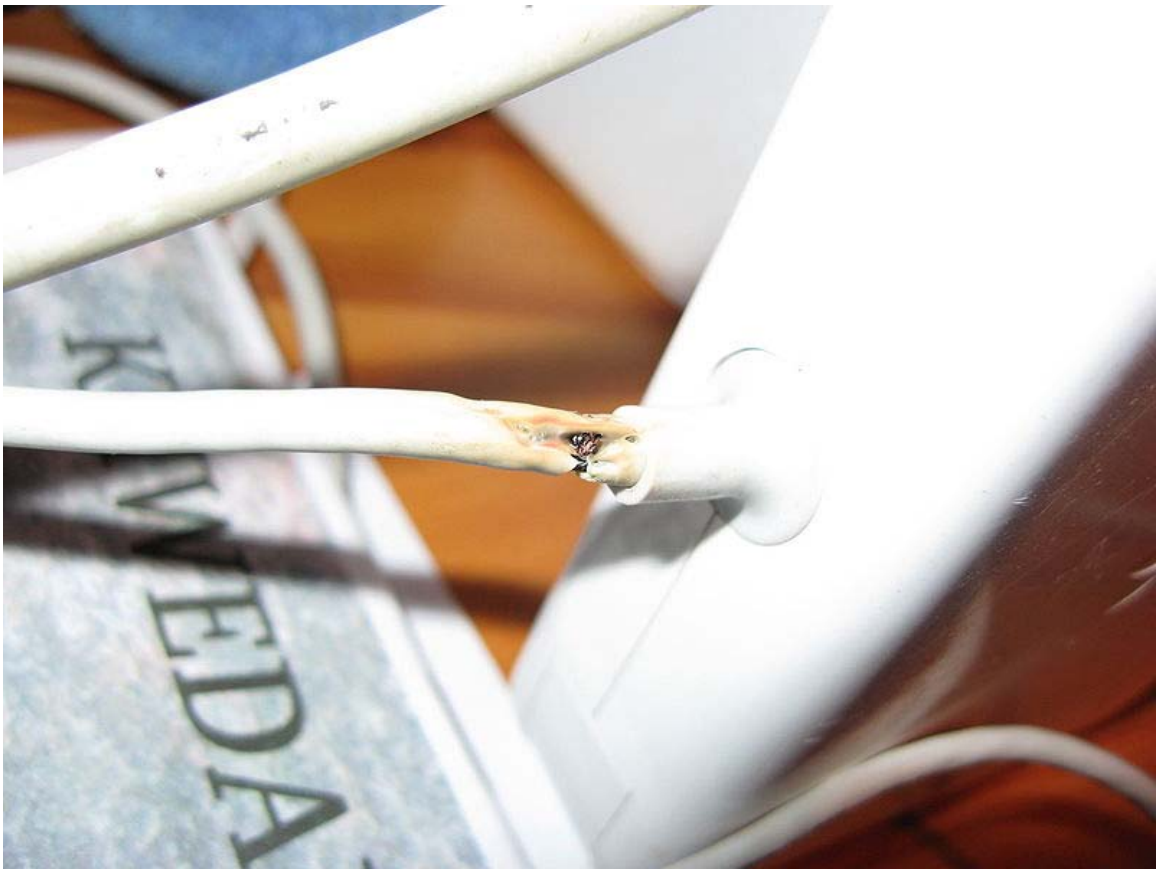
Pinout

The MagSafe connector pins are palindromic. The first and second pins on each side of the tiny central pin have continuity with their mirror pins.

- The inner large pin is V+ @ 16.5 VDC. Measuring with no load will give 6.86 VDC; the full 16.5 V is provided to the proper load.
- The outer large pin is ground.
- The tiny center pin appears to be a charge control pin to change LED color and possibly adapter switch off.

The rectangular metal shroud has no electrical function. Its purpose is solely for shielding the electrical pins and acting as a ferrous attractor for the magnets within the laptop's power receptacle.

Criticisms and defects



MagSafe with both frayed wires and melted casing, as alleged in the 2009 class action lawsuit

Apple does not license third-party products using the MagSafe connector, however manufacturers have devised a workaround: their MagSafe items use the actual connector

from Apple's AC adapter, grafted onto their own product. Since this uses an actual Apple product, purchased legally, manufacturers believe that no licensing agreements are needed and the patents are not violated. However in 2010 Apple still sued one such manufacturer, Sanho Corporation, for selling its very popular HyperMac battery extension products which Apple claimed violated their patents, resulting in Sanho ceasing to sell their connector cable for the Hypermac series of external batteries.

Some users have reported (as of April 16, 2008) problems with the quality of the construction of the MagSafe cords, giving the product low marks on the Apple Store's website. Common complaints include plug separating from the cord (fraying), transformer shorting, and pin springs losing elasticity.

Several methods have been devised to protect the MagSafe from failure, including wrapping the cable with tape or sliding protective plastic around the cable.

In 2008, Apple posted official response acknowledging problems with MagSafe adapters, which include incomplete circuit connection and adapter's white insulation separates from the magnetic end of the MagSafe connector. Following the release of Knowledge Base article, a class action lawsuit was filed in 2009-05-01 in California Northern District Court's San Jose office, alleging that the MagSafe power adapter is prone to frayed wires and overheating, and as such represents a fire hazard. Apple has released a new connector to remedy the defects.

Unfortunately, due to the magnetism of the MagSafe's socket on the product (as of August 20, 2009, solely the line of MacBooks) metallic particles and debris may be attracted to and adhere on and within the socket, potentially leading to electrical shorts on attachment of the power cable. It may be difficult to remove the foreign material. However, there are very few reports of this complication.

There have been a variety of reports of the newer MagSafe AC-adapter not working with older MagSafe-powered MacBooks and MacBook Pros. However, Apple released a firmware update in October 2010 that resolves this issue.

Prior power systems

The iBook G3 puck and brick chargers. The puck was the first model of charger with this connector.

Close-up view of the brick plug on the left, and the puck plug on the right, with tip ring sleeve plugs and a metal ring around the plug. The puck charger simply had a dark gray shroud, while the brick added the clear plastic charge indicator ring.

Example of a damaged plug due to being pulled forcefully out of socket sideways. This strain is severe enough to also damage the power socket.

Prior to the development of MagSafe, early Apple laptop computers such as the PowerBook series used a shell and socket/pin arrangement similar to those seen on non-Apple laptops.

The iBook series introduced a new plug design similar in appearance to a mini-stereo plug, but with an additional metal ring around plug. The first puck-shaped iBook chargers simply had a silver plug body, but the square white chargers introduced a color-changing illuminated ring that indicated charging status.

Tripping on an iBook cord or yanking the cord out at an angle frequently damages the power socket by breaking the solder pads under the connector, resulting in a laptop that would fail to charge when connected to the cord, or would only charge if the inserted plug were propped up or pushed down at an angle. The spring contacts inside the socket connector could also become bent out of position due to angular pressure on the plug, and result in intermittent charging problems. In such situations the illumated power plug functions in an unusual manner which is undocumented. The earlier puck-shaped iBook chargers would also fail to charge if the socket were damaged, but those chargers could not indicate a problem.

In severe cable stress situations, the outer flange of the plug becomes flared and bent, and the tip of the power plug may break off and become lodged inside the socket.

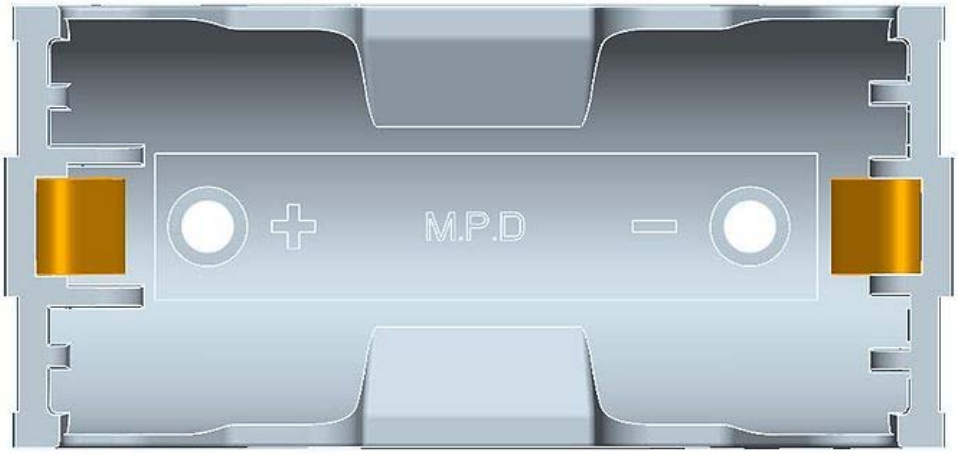
Due to the design of the early 12" G4 iBooks, replacing the damaged "DC-In Board" typically involved a complex 50-step laptop disassembly process, resulting in an expensive labor-intensive repair process.

The development of MagSafe prevented the cable strain problems, and eliminated most power connector damage and repair costs for Apple mobile device owners.

Battery Terminal

Battery terminals are the electrical contacts used to connect a load and/or charger to a single cell or multiple-cell battery. These terminals have a wide variety of designs, sizes, and features that are often not well documented.

Common battery contacts and terminals



Battery holders with pressure contacts

Automotive battery terminals

Automotive batteries typically have one of three types of terminals. In past years, the most common design was the *SAE Post*, consisting of two lead posts in the shape of truncated cones, positioned on the top of the battery, with slightly different diameters to ensure correct electrical polarity.

The "JIS" type is similar to the SAE but smaller, once again positive is larger than negative but both are smaller than their SAE counterparts. Most older Japanese cars were fitted with JIS terminals. You must ensure that when you are buying a new battery that you know which terminals you have. One must also look at the orientation of and which side of the old battery the terminals are on, otherwise you might find that if the terminals are oppositely oriented that the battery cables will not reach the new battery terminals.

General Motors, and other automobile manufacturers, have also begun using side-post battery terminals, which consist of two recessed female 3/8" threads into which bolts or various battery terminal adapters are to be attached. These side posts are of the same size and do not prevent incorrect polarity connections.

L terminals consist of an L-shaped post with a bolt hole through the vertical side. These are used on some European cars, motorcycles, lawn and garden devices, snowmobiles, and other light duty vehicles.

Marine battery terminals

Marine batteries typically have two posts, a 3/8"-16 threaded post for the positive terminal, and a 5/16"-18 threaded post for the negative terminal.

Zinc battery terminals

Zinc battery terminals are an environmentally friendly alternative to lead battery terminals. These types of battery terminals were designed as a result of regulatory directives, such as, Proposition 65 and ROHS. Zinc battery terminals offer advantages over lead alloy type battery terminals. These advantages include increased electrical conductivity (by as much as three times), increased corrosion resistance, and reduces lead removal costs.

SLA battery terminals

The most common sizes of sealed lead acid (SLA) batteries use Faston tabs, but some larger batteries use L terminals, while some very specialized designs use other, sometimes proprietary terminals, such as older Panasonic camcorder batteries (of the type used for VHS shoulder-mounted camcorders).

UPS battery terminals

Batteries designed for use inside an uninterruptable power supply (UPS) typically use Faston tabs, often with an adapter cable between those and the UPS's internal battery connectors. Larger external battery packs use a variety of connectors, including the Anderson PowerPole MultiPole series (as used by Tripp-Lite), which are color-coded and keyed for specific voltages.

Dry battery terminals

Most cylindrical dry batteries (such as the AA battery) have a projection at one end (positive) and a flat base (negative). These mate with metal strips or springs in the battery holder.

Six volt lantern batteries typically feature two coiled, cone-shaped spring terminals, designed to mate with flat contact plates on the inside of the battery compartment. Some lantern batteries instead feature screw terminals, while still others instead feature pin holes.

Nine-volt batteries have snap-on connectors.

Chapter 8

TRS Connector

TRS connector

53. Triple Contact Plug.—A triple contact plug is shown in Fig. 17. In this style there are three conductors, known as tip *t*, sleeve *s*, and ring *r*. The tip *t* is screwed on to a steel pin that runs back through the hard-rubber insulating sleeve to the connecting block to which the connecting screw is fastened, and in order that the cord conductor may not touch the connecting block *f*, an insulating washer *g*, is placed under the screw and washer *h*. The insulating washer is made large enough so that there will be no stray strands to short-circuit the plug. The sleeve *s* is made from brass tubing and passes through the insulating tube *k* to its

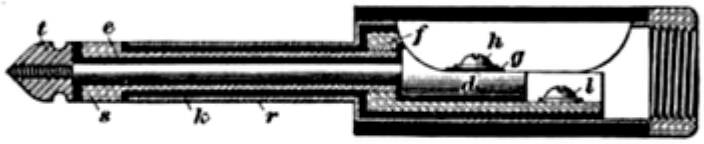


FIG. 17

connecting block *f*, within which it is screwed; the connection is made to the sleeve under the screw and washer *l*. The sleeve connection is made by bending back one of the conductors, when the cord is screwed into the shank of the plug. The strand is thus pinched tightly against the threads, making a good connection. The steel pin in the center, connecting the tip, should be soldered into the connecting block. Then, after the tip is screwed on, this end of the pin should be upset to prevent the tip from becoming unscrewed. If this precaution is not taken, the tip will come off and get lost in a jack and cause trouble.

54. Plugs should be made of brass, as hard as can be conveniently worked, the best grade of hard rubber for

"Triple contact plug" as described in 1907. The ring and sleeve are transposed in relation to modern usage.

A **TRS connector** (tip, ring, sleeve) also called an **audio jack**, **phone jack**, **phone plug**, **jack plug**, **stereo plug**, **mini-jack**, **mini-stereo**, or **headphone jack**, is a common analog audio connector. It is cylindrical in shape, typically with three contacts, although sometimes with two (a **TS connector**) or four (a **TRRS connector**).

The TRS connector was invented for use in telephone switchboards in the 20th century and is still widely used, both in its original ¼″ (exactly 6.35 mm) size and in miniaturized versions: 3.5 mm (approx. ⅛″) and 2.5 mm (approx. 3/32″). The connector's name is an

initialism derived from the names of three conducting parts of the plug: **T**ip, **R**ing, and **S**leeve – hence, **TRS**.

In the UK, the terms *jack plug* and *jack socket* are commonly used for the respectively male and female TRS connectors.

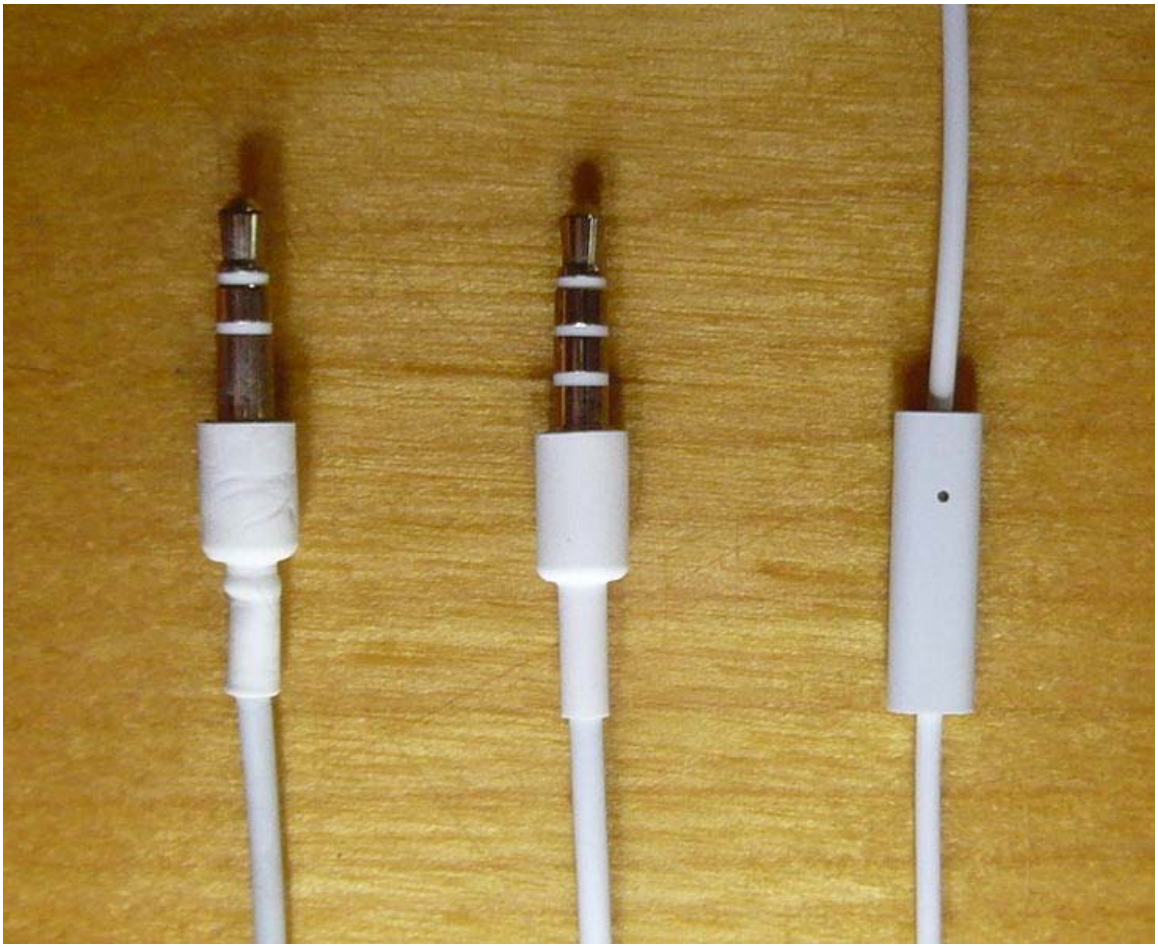
In the U.S., a stationary (more fixed) connector is called a jack. The terms *phone plug* and *phone jack* are sometimes used to refer to TRS connectors, but are also sometimes used colloquially to refer to RJ11 and older telephone plugs and the corresponding jacks that connect wired telephones to wall outlets (the similar terms *phono plug* and *phono jack* refer to RCA connectors though both plug types are used in tandem when a computer or MP3 player connects to a stereo). In conversation, the diameter is often added to specify which size: *quarter-inch phone plug* or *3.5 mm phone jack* for the unbalanced two-channel three-contact version, and *balanced TRS jack* or *TRS phone plug* for the balanced one-channel three-contact version.

Modern connectors

2.5 mm mono (TS), 3.5 mm mono (TS) and stereo (TRS), and 1/4″ (6.35 mm) stereo (TRS) jack plugs

Modern TS and TRS connectors are available in three standard sizes. The original 1/4″ (6.35 mm) version dates from 1878, for use in 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 and 2.5 mm sizes are also referred to as ⅛″ and 3/32″ 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 and on some mobile phones. There is also an optical connector used for TOSLINK (mainly on things like portable equipment; hi-fi separates and similar tend to use the standard square connector) that is the same size as a 3.5 mm jack. Sockets exist that can make either an optical connection to such a plug or an electrical connection to a stereo jack plug. These combination electrical/optical output jacks are present on all Apple Macbook, Macbook Pro and Intel iMac computers.



Earlier versions of the iPod used a TRS connector (left) while the iPhone uses a TRRS connector (center) for its headset (microphone and control button right). Newer models of the iPod also use TRRS connectors.

A three- or four-conductor version of the 2.5 mm plug is widely used on cell phone handsfree headsets, providing mono (three conductor) or stereo (four conductor) sound and a microphone input. Common stereo headphones with the 2.5 mm plug are often not compatible with this type of socket. A 3.5 mm version of this plug is now commonly available on mobile telephones as well. A 3.5 mm stereo-plus-mic jack is available that is compatible with standard 3.5 mm stereo headphones, e.g. Nokia has been widely using TRRS connectors with 3.5 mm diameter since 2006. The selected pin assignment, with ground on the sleeve, is as well standardized in OMTP and has been accepted as a national Chinese standard YDT 1885-2009.

TRRS plugs do not work properly with a TRS stereo jack if the ground contact in the jack connects to the microphone contact on the plug. It is therefore a good practice to implement new TRS headphone jacks using actually a TRRS mechanical jacks and connecting ground to sleeve as well as the second ring contact. This way such jacks will provide better compatibility with different TRRS cell phone headsets.

Although relatively unknown in modern consumer electronics, the professional audio world and the telecommunication industry has used **tiny telephone** (**TT**) connectors in patch bays which are mid-size phone plugs with a 4.4 mm (0.173-inch) diameter shaft. In the telecom world, this is known as a "bantam" plug. Though unable to handle as much power as a 6.35 mm (0.25-inch) jack, and not as reliable, TTs have been used for professional console and outboard patchbays in studios and live sound applications, in which a single patch panel requires hundreds of patch points in a limited space. The TRS versions of TT connectors are capable of handling balanced line signals and have been employed in pro audio installations. Recently, all-in-one digital audio switching matrixes and digital signal processors have reduced the need for physical patching and extensive patch bays.

Both two-conductor and three-conductor versions of the three standard sizes are readily available in male and female inline versions, and panel-mounting female versions. Panel-mounting male versions of these also exist but are rare, as they are vulnerable to mechanical damage and therefore unreliable. Female inline versions are also notoriously unreliable and are avoided by many users.

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″ versions.

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 .210 inch inside diameter jacks for fire safety communication jacks in public buildings, the same size found in vintage 16 mm projector speaker jacks.

A dual 310 patch cable, two-pin jack plug

- A two-pin version, known to the telecom industry as a "310 connector" consists of two TRS 6.35 mm jack plugs at a centre spacing of .625 inches. The socket versions of these can be used with normal jack plugs provided the plug bodies are not too large, but the plug version will only mate with two jack sockets at .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 entertainment system. Plugging a stereo plug into one of the two mono jacks typically results in the audio coming into only one ear. Adaptors are available.
- A short-barrelled version also exists, once used on 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 are still manufactured but are now regarded as a non-standard size.

Mono and stereo compatibility

Old-style male tip-sleeve ("pin" or "jack") connectors. The leftmost 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″ TS connectors.

In the original application in manual telephone exchanges, many different configurations of 1/4″ jack plug 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 1/4″ 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 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 1/4″ 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 3-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.

Uses

A 3.5 mm TRS connector

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

- Headphone and earphone jacks on a wide range of equipment. 1/4″ 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 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 audio plus video, and a TRRS connection for stereo audio plus video. Cables designed for this use are often terminated with RCA connectors on the other end.

- Microphone inputs on tape and cassette recorders, sometimes with remote control switching on the ring.
- 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 volt power available on the ring. Note that traditional, incompatible, use of a stereo plug for a mono microphone is for balanced output)
    - Laptop computers generally have one line level jack for headphones and one mono jack for a microphone at microphone level. You can use an attenuating cable to convert line level or use a signal from an XLR connector, but it is not designed to record from a stereo device such as a radio or music player.
    - LCD monitors with built-in speakers will require a 3.5 mm male-male cable from the sound card.

  Note: Higher end sound cards sometimes sport a breakout panel which supports 1/4″ plug devices as well.

- Devices designed for surround output may use multiple jacks for paired channels (ex. 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″ 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″ jacks are overwhelmingly the most common connectors for:
    - Inputs. A shielded cable with a mono 1/4″ jack plug on each end is commonly called a *guitar cord* or a *patching cord*, the first name reflecting this usage, the second the history of the jack 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″ loudspeaker jacks are rated at 15A maximum which limits them to

applications involving less than 1,800 watts. 1/4″ loudspeaker jacks commonly aren't 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 mono jacks as the standard unbalanced input or output connector, often providing a 1/4″ unbalanced line connector alongside (or in a few cases in the middle of!) and as an alternative to an XLR balanced line connector.
- Modular synthesizers commonly use monophonic cables for creating patches.
- ¼ in connectors are widely used to connect external processing devices to mixing consoles' insert points. TRS or TS connectors might be used in pairs as separate Send and Return jacks or a single TRS jack might be employed for both Send and Return in which case the signals are unbalanced. The single unbalanced combination Send/Return TRS insert jack saves both panel space and component complexity. Note that mixing console insert points can 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 jack as a DC power connector.
- Some photographic studio strobe lights have 1/4″ 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″ mono jack as the sync input; White Lightning uses 1/4″ stereo jacks; Pocket Wizard (radio trigger) and Alien Bees 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 jack plugs 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 a single TRRS jack which serves as headphone, USB, or power supply, depending on the connected plug.

- 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 a single three-conductor connector, where one signal is on the tip conductor and the other is on the ring conductor.
- 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[(?)] DC power.
- The Apple Lisa personal computer used a TRS Jack for its keyboard.

Switch contacts

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

Miniature jack 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 a single 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

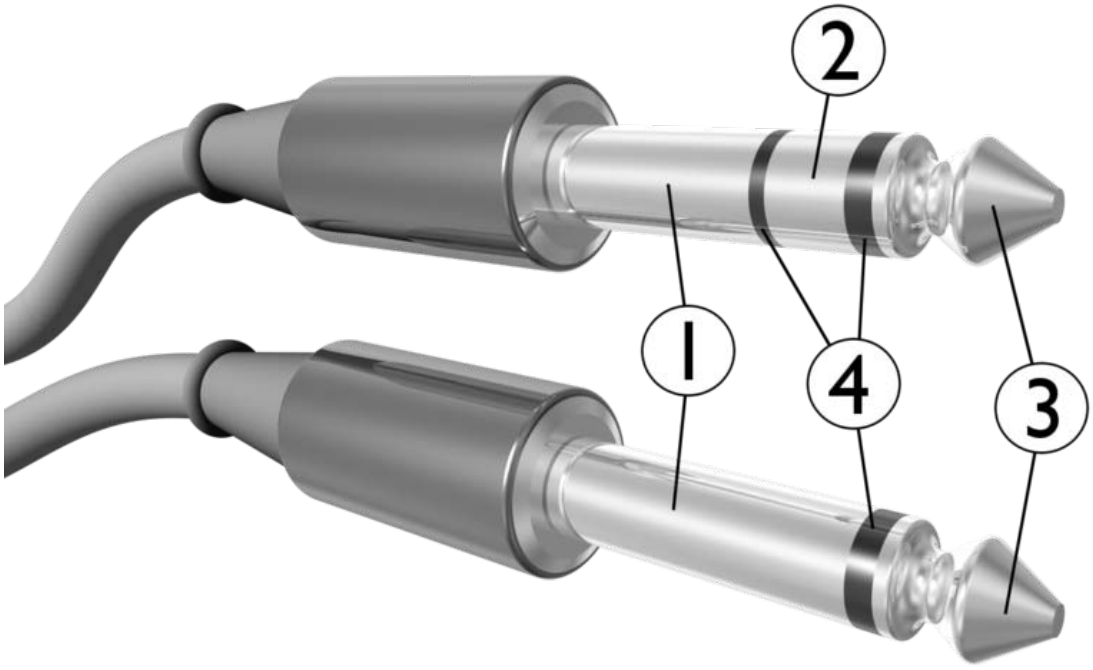
connect the tip and ring together when no plug is inserted. The tip is then made the output, and the ring the input (or vice versa), thus forming a patch point.

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.

Tip/ring/sleeve terminology



1. **Sleeve:** usually ground
2. **Ring:** Right-hand channel for stereo signals, negative polarity for balanced mono signals, power supply for power-requiring 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**

In twisted pair wiring to this day, the non-inverting and/or "live" (or "hot") wire of each pair is known as the **ring**, while the inverting and/or "earthy" (or "neutral") wire is known as the **tip**, inherited from the traditional connection via the TRS connector in telephone systems. If the pair is shielded, or if the pair is accompanied by a dedicated earth wire, this third conductor is known as the **sleeve**. This usage corresponds to the connection to a three-connector jack plug in a manual telephone exchange. This appears to have originated with the use of **TRS** jacks by switchboard operators with the tip and ring wires attached to the corresponding parts of the jack. Originally, the *hot* and *ground* were reversed, but often the metallic desktops of the switch boards were scarred by the discharge from the tips and the system was reversed to the present usage.

The term **tip ring sleeve** is more common in some English-speaking countries than others. Outside of the USA the term *stereo jack plug* is probably more common, even for connectors not used for stereo. The modern profile three-conductor jack plug was originally designed for stereo signal connections, with left channel on the tip, right on the ring and common return on the body or sleeve. The term **TRS** is particularly appropriate to distinguish these three-conductor (stereo) plugs used in other than stereo applications.

	Unbalanced mono in/out	**Unbalanced mono insert**	**Balanced mono in/out**	**Unbalanced stereo**
Tip	Signal	Send or Return signal	Positive/"Hot"	Left channel
Ring	Ground or *No Connection*	Return or Send signal	Negative/"Cold"	Right channel
Sleeve	Ground	Ground	Ground	Ground

Note that 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.
Note that early QSC amplifiers used a tip negative, ring positive input jack wiring scheme.
Whirlwind Line Balancer/Splitters do not use the Sleeve as a conductor on their unbalanced ¼ in TRS input. Tip and Ring are wired to the transformer's two terminals; Sleeve is not connected.

Usage

Audio

When a TRS 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 connectors used for balanced microphone inputs is

that a standard unbalanced signal lead using a mono jack plug 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.

The disadvantage of using TRS jacks for balanced audio connections is that the ground mates last and the socket grounds the plug tip and ring when inserting or pulling out 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. Professional audio equipment uses XLR connectors which mate the ground signal on pin 1 first.

TRS connectors 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 jack plug correctly grounds the input. In the same fashion, use of a "tip return" insert style allows a mono jack 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″ 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 require 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 TRS inserts, the concept is extended by using specially designed TRS jacks that will accept a mono jack plug partly inserted "to the first click" and will then connect the tip to the signal path without breaking it. Most standard TRS jacks 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 (and likely a resistive pad, as well as other circuitry, depending on the design), and thus improve sound quality. 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.

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

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

Computer sound

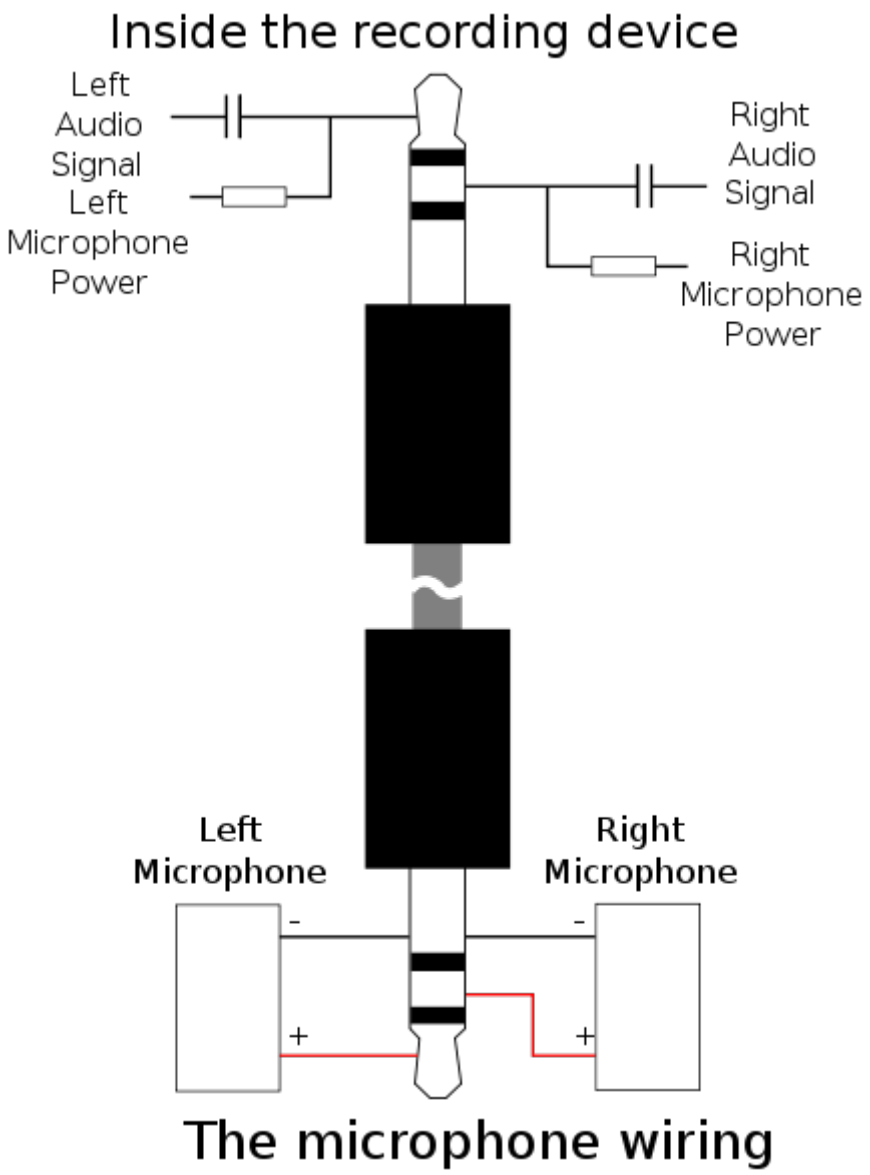
Personal computer sound cards from Creative Labs, Sound Blaster or compatible to these use a 3.5 mm TRS as a mono microphone input, and deliver a 5 V polarising voltage on the ring to power electret microphones from the card manufacturer. Sometimes called *phantom power*, this is not a suitable power source for microphones designed for true phantom power and is better called *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 a preamplifier FET [transistor] built into the electret microphone can.) Compatibility between different manufacturers is unreliable.

Normally, 3.5 mm 3-conductor sockets are used in computer soundcards for stereo output. Thus, for a soundcard with 5.1 output, there will be 3 sockets to accommodate 6 channels—front left & right, surround left & right, and center & subwoofer. But the 6.1 and 7.1 channel soundcards from Creative Labs are equipped with 1 and 2 sockets of 3.5 mm 4-conductor sockets respectively. This is to accommodate rear-center (6.1) or rear left & right (7.1) channels without additional sockets on the sound card. But speaker have normal 3-conductor sockets. In Creative's documentation, the word "pole" is used instead of "conductor".

The Apple PlainTalk microphone jack used on some older Macintosh systems is designed to accept an extended 3.5 mm TRS; 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.

Generally, all of Apple's computers now have combination electric/optical 3.5 mm TRS jacks for both input and output. This allows for conventional stereo input and output with electrical connections, or 5.1 digital input and output with a mini-Toslink cable.

Recording equipment



The microphone wiring

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

Many small video cameras, laptops, Minidisc 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 does not require 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 requires 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 requires 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.

Aircraft headsets

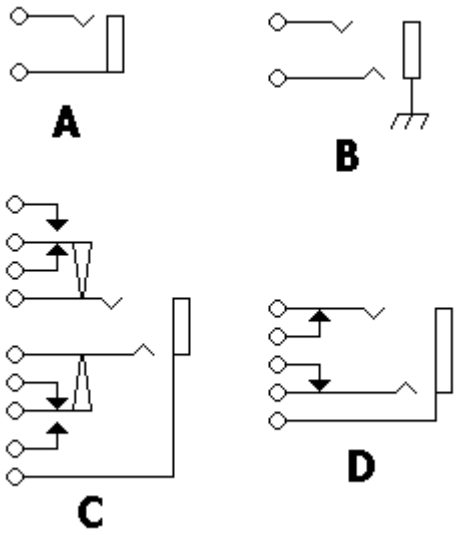
Aviation plug type U-174/U or Nexus TP120, commonly used on military aircraft and civil helicopters.

Commercial and general aviation civil airplane headset plugs are similar, but with a difference. A standard 1/4″ 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. The extra connection in the microphone plug is used by an optional push-to-talk switch.

Military aircraft and civil helicopters have another type known by the designation U-174/U. They are also known as Nexus TP120 telephone plugs. They are similar to a standard 1/4″ (6.3 mm) stereo plug, but with a 7.1 mm (0.281") diameter short shaft with an extra sleeve. This provides four connections in one plug, allowing for a pair of monaural headphones, a microphone, a push-to-talk switch and a common ground conductor.

Some mobile phones such as the Nokia N95, the Apple iPhone and the HP IPAQ 500 Voice Messenger also use a similarly-wired plug for their headset.

Configurations and schematic symbols



These examples are meant to illustrate each possible component of such jacks, but many other configurations using these basic components are available. All examples in the above figure are oriented so the plug 'enters' from the right.

A. A simple two-conductor jack. 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.

B. A three-conductor, or TRS, jack. 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**.

C. 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.

D. 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 most common circuit configurations are the simple mono and stereo jacks (A and B above), however there are a great number of variants manufactured.

Color Codes

These codes were standardized by Microsoft and Intel in 1999 for computers as part of the PC99 standard.

green TRS 3.5 mm	stereo output, front channels or headphones
black TRS 3.5 mm	stereo output, rear channels
grey TRS 3.5 mm	stereo output, side channels
gold TRS 3.5 mm	dual output, center and subwoofer
blue TRS 3.5 mm	stereo input, line level
pink TRS 3.5 mm	mono or stereo microphone input

Chapter 9

XLR Connector

XLR3 cable connectors, female on left and male on right

The **XLR connector** is an electrical connector design. XLR plugs and sockets are used mostly in professional audio and video engineering applications for a variety of purposes including power connections and both analog and digital audio signals.

The connector has been called a *cannon plug* or *cannon connector* in reference to its original manufacturer, James H. Cannon, founder of Cannon Electric in Los Angeles, California (now part of ITT Corporation.) Originally manufactured as the *Cannon X* series, subsequent versions added a latch (*Cannon XL*) and then surrounded the female contacts with a resilient polychloroprene, which resulted in the part number prefix *XLR*. The number of pins varies from three to seven. Many companies now make XLR connectors.

They are superficially similar to the older and smaller DIN connector range, but are not physically compatible with them.

XLR connectors are covered by an international standard for dimensions, IEC 61076-2-103

Patterns of XLR connector

Variety of male and female XLR connectors with different numbers of pins

The most common is the three-pin XLR3, used almost universally as a balanced audio connector for high quality microphones and connections between equipment. XLR3 was also used to transmit MIDI data on some Octave-Plateau synthesizers including the Voyetra-8. Most of the XLR types made by different companies will mate with others of the same number of contacts.

XLR4 (with four pins) is used for ClearCom and Telex intercom headsets and handsets, DC power connections for professional film and video cameras, older versions of AMX analog lighting control and some pyrotechnic equipment. XLR5 is the standard connector for DMX512 digital lighting control and is also used for dual-element microphones and dual-channel intercom headsets. XLR6 is used for dual channel intercom beltpacks. XLR7 is used on several generations of LeMaitre (now Ultratec) fog machines for remote input and control.

Many other types of connectors using the XLR type shell exist, with various pin numbers. Most notable are two now obsolete three-pin patterns manufactured by ITT Cannon. The

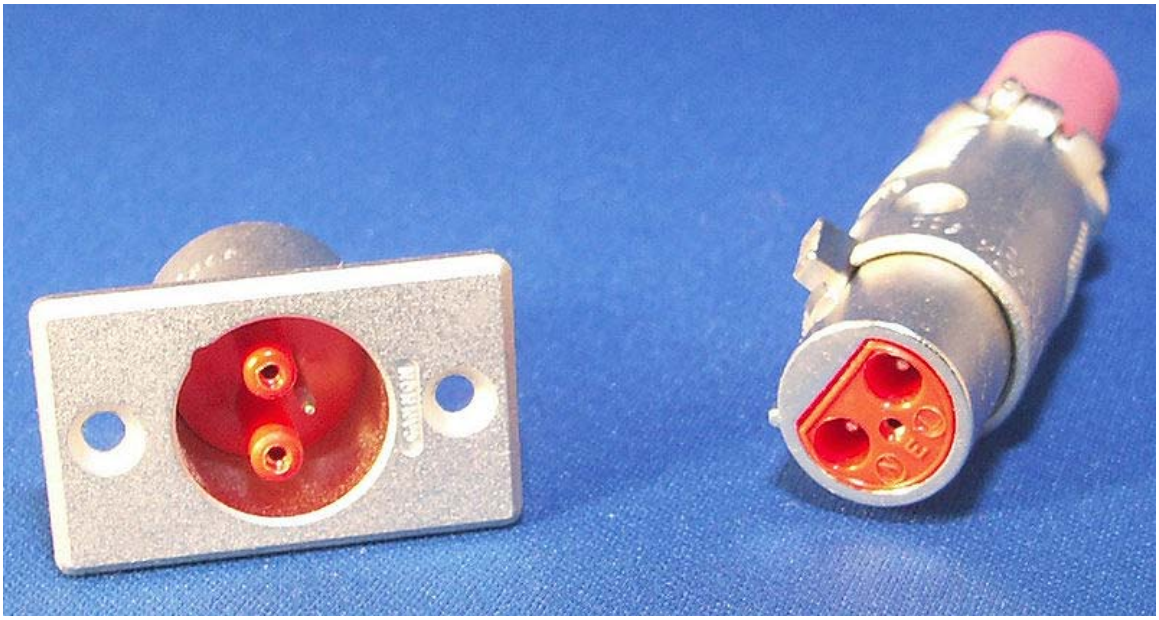
power Cannon (also called the *XLR-LNE* connector) had shrouded pins and red insulation, it was intended as a mains power connector, but has been superseded by the IEC mains connector and increasingly, more recently, the PowerCon connector developed by Neutrik.

The *loudspeaker Cannon* had blue or white insulation (depending on its gender), was intended for connections between audio power amplifiers and loudspeakers. At one time XLR3 connectors were also used extensively on loudspeaker cables, as when first introduced they represented a new standard of ruggedness, and economic alternatives were not readily available. The convention was that a two-conductor loudspeaker cable had XLR3 female connectors on both ends, to distinguish it from a three-conductor shielded signal level cable which has an XLR3 female at one end and an XLR3 male at the other. Either pin 2 or 3 was live, depending on the manufacturer, with pin 1 always the 'earthy' return. This usage is now both obsolete and dangerous to equipment but is still sometimes encountered, especially on older equipment. For example, some loudspeakers have a built-in XLR3M as an *input* connector. This use was superseded in professional audio applications by the Neutrik Speakon connector.

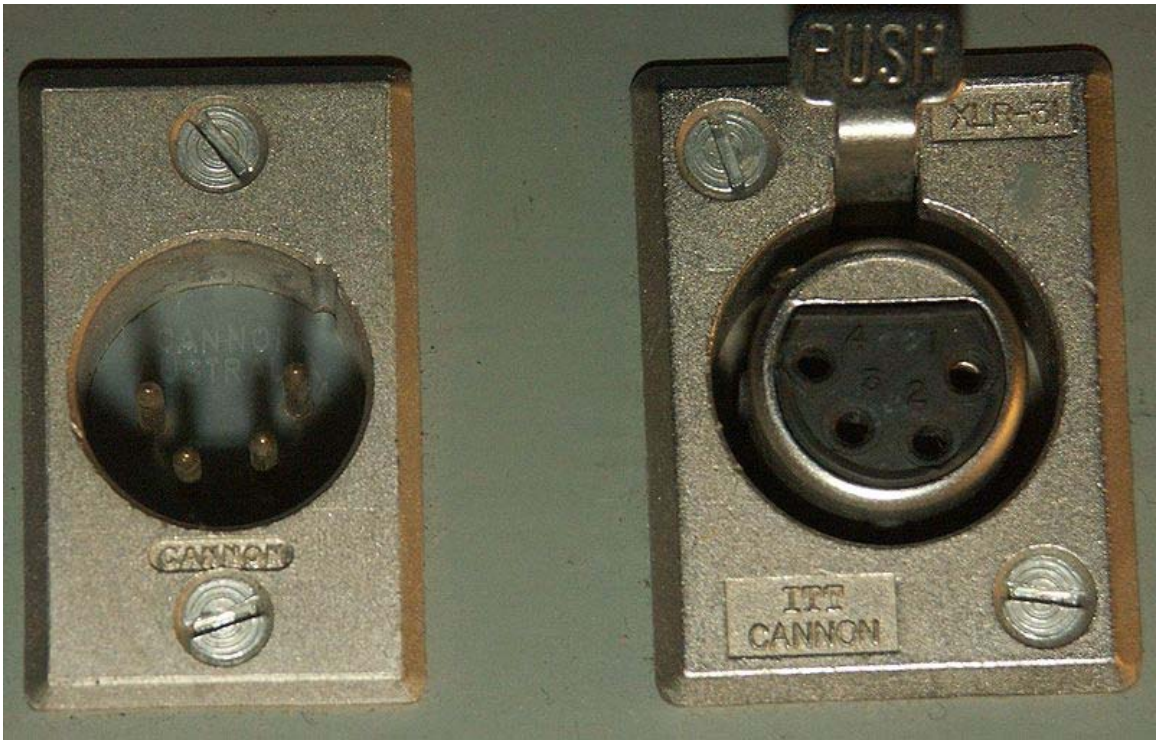
The female XLR connectors are designed to first connect pin 1 (the earth pin), before the other pins make contact, when a male XLR connector is inserted. With the ground connection established before the signal lines are connected, the insertion (and removal) of XLR connectors in live equipment is possible without picking up external signals (as it usually happens with, for example, RCA connectors).

Lighting control for entertainment applications is widely connected using five pin XLRs. Only three pins are used to carry the DMX512 signal, including systems implementing Remote Device Management (RDM). Using XLR5s also prevents users from confusing lighting with common XLR3 audio cables. Unfortunately, five pin XLRs still allow the use of lower-grade (non-110 Ohm) microphone cable for transmission of signals. Some manufacturers of DJ lighting and professional lighting are still using three-pin connectors as their standard. Manufacturers such as Leviton and Lightronics have even established new protocols not compatible with DMX512 that use three pin XLR to control lighting devices (primarily dimmers made by the same manufacturer).

Rechargeable devices exist that use three-pin XLR connectors. These can be found on electric powered mobility wheelchairs and scooters. The connectors carry from 2 to 10 amps at 24 volts.



XLR-LNE three-pin male and female connectors, originally used for mains power connections. Note that the panel connector is shrouded for safety reasons.



Male and female XLR4 panel connectors

Female XLR5 panel connector

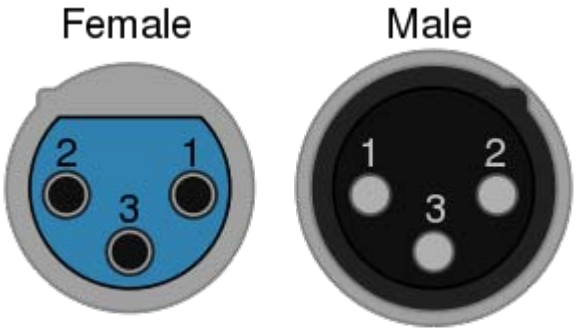
Female XLR6 panel connector

XLR3 connectors

Left to right: Cannon XLR3-12C (line), Switchcraft X3F (line), Neutrik NC3MP panel, Neutrik NC3FP panel

XLR and 0.25 in TRS combo jack.

EIA Standard RS-297-A describes the use of the XLR3 for balanced audio signal level applications:



Pin	Function

1 Chassis ground (cable shield)
2 Positive polarity terminal (*hot*)
3 Return terminal (*cold*)

Some audio equipment manufacturers reverse the use of pin 2 (properly the normal input) and pin 3 (inverting input). This reflects their own previous usage before any standard existed. Pin 1 is always ground, and many connectors connect it internally to the connector shell or case.

Although covered in AES48-2005 and in AES54-3-xxxx, there is still some disagreement on the best way to handle the usage of pin 1 at both ends of a cable, particularly with respect to the cable shield, the connector's shell, signal ground, and a third cable conductor connected to pin 1, which may (or may not) be connected to the shield. The main controversy is whether the shell of the connector should be connected to pin 1 or the shield, or left floating. AES standards mentioned above recommend that shells of cable-mounted connectors should never be connected to pin 1 or the shield, because inadvertent contact of the shell with another grounded surface while in use can create unwanted current paths for fault current, potentially causing hum and other noise. On the other hand, equipment containing active circuitry should always have pin 1 connected to the conductive enclosure of the equipment as close as possible to the point where the signal enters the enclosure. The argument centers around the radio frequency shielding provided by the shell of the connector, which may be reduced if it is left floating. An alternative solution is to connect the shell to pin 1 and the shield through a small value capacitor, providing RF shielding but allowing very little audio-frequency current to flow. This capability can be built into a fixed jack or a cable terminated with XLR connectors.

An XLR3M (male) connector is used for an output and an XLR3F (female) for an input. Thus a microphone will have a built-in XLR3M connector, and signal cables such as microphone cables will each have an XLR3F at one end and an XLR3M at the other. At the stage box end of a multicore cable, the inputs to the mixing desk will be XLR3F connectors, while the returns to the stage will be XLR3M connectors. Similarly, on a mixing desk, the microphone inputs will be XLR3F connectors, and any balanced outputs XLR3M connectors.

Neutrik also offers several models of combination jacks that accept both XLR and 0.25 in TS or TRS plugs.

Phantom power

Some microphones such as condenser microphones require power. An alternative to battery power is phantom power which consists of direct current applied equally through the two signal lines of a balanced audio connector (in modern equipment, usually an XLR connector). The supply voltage is referenced to the ground pin of the connector (pin 1 of an XLR), which normally is connected to the cable shield or a ground wire in the cable or both. When phantom powering was introduced, one of its advantages was that the same

type of balanced, shielded microphone cable that studios were already using for dynamic microphones could be used for condenser microphones as well, in contrast to vacuum-tube microphones, which required special, multi-conductor cables of various kinds.

With phantom power, the supply voltage is effectively invisible to balanced microphones that do not use it: e.g., most dynamic microphones. A balanced signal consists only of the differences in voltage between two signal lines; phantom powering places the same DC voltage on both signal lines of a balanced connection. This is in marked contrast to another, slightly earlier method of powering known as *parallel powering* or *T-powering* (from the German term *Tonaderspeisung*), in which DC was overlaid directly onto the signal in differential mode. Connecting a dynamic microphone (especially a ribbon microphone) to an input that had parallel powering enabled could very well damage the microphone severely, but this is not normally so with phantom powering unless the cables are defective or wired incorrectly.