Handbook of Electrical Power Connectors

(Electrical Components)

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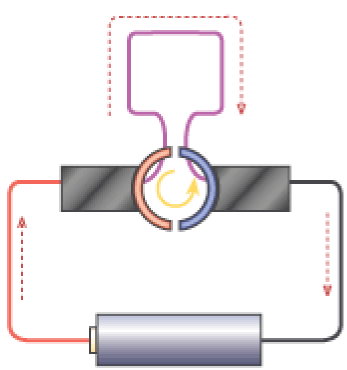
Chapter 1

Commutator (Electric)

A **commutator** is a rotary electrical switch in certain types of electric motors or electrical generators that periodically reverses the current direction between the rotor and the external circuit. In a motor, it applies power to the best location on the rotor, and in a generator, picks off power similarly. As a switch, it has exceptionally long life, considering the number of circuit makes and breaks that occur in normal operation.

A commutator is a common feature of direct current rotating machines. By reversing the current direction in the moving coil of a motor's armature, a steady rotating force (torque) is produced. Similarly, in a generator, reversing of the coil's connection to the external circuit provides unidirectional—direct—current to the external circuit. The first commutator-type direct current machine was built by Hippolyte Pixii in 1832, based on a suggestion by André-Marie Ampère.

Principle of Operation



As the rotor turns, the current in the winding reverses every time the commutator makes half a turn. This reversal of the winding current compensates for the fact that the winding has also rotated half a turn relative to the fixed magnetic field (not shown). The current in the winding causes the fixed magnetic field to exert a rotational force (a torque) on the winding, making it turn. As the rotor's field comes close to aligning itself with that of the stator, the commutator switches the rotor's polarity, so the motor is perpetually trying to settle, so to speak.

Note that all practical commutators have at least three segments, and in some instances (such as the N.Y. City transit system's old rotary AC-to-DC converters), up to several hundred. In these elementary diagrams, there is a dead position where the motor will not start.

For the image to the right, when the brushes make contact across both commutator segments, the commutator is short-circuited and current passes directly from one brush to the other across the commutator, doing no work in the rotor windings, and drawing a destructive fault current from the power source. As well, practical rotors have more turns in their windings. For the image to the left, there is a dead spot when the brushes cross the insulation between the two segments and no current flows. In either case, in a motor, the rotor cannot begin to spin if it is stopped in this position.

Simplest practical commutator

This has three segments, and the rotor has three poles. The left image shows the three rotor poles with their windings. The commutator is near the end of the shaft, as it points up and to the left. It is a metal cylinder (note the yellowish reflection) with three equally spaced cuts parallel to the shaft, and has white plastic discs on both ends. Each segment connects to the nearest junction between two of the three rotor coils.

In the middle illustration, the brushes (in this instance, flat metal springs; carbon brushes are not needed at the low voltages used by such motors as these) are the two straight horizontal pieces; when assembled, the brushes are under tension, slightly away from each other, to stay in contact with the commutator. Power connects to two solder terminals on the outside of the end disc shown in this image. Those terminals are likely to be the same pieces of metal as the brushes themselves.

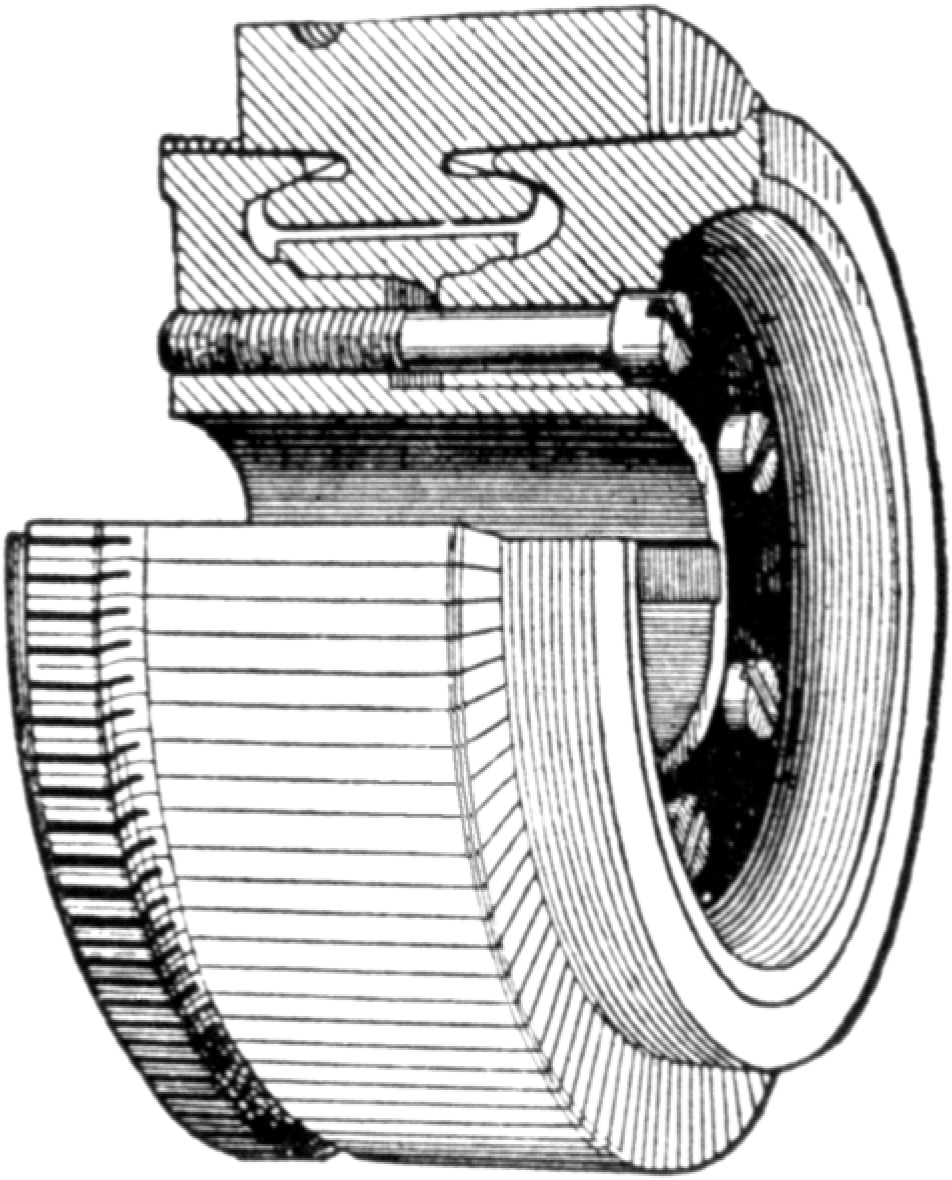
Inside the exterior metal cylinder is a hollow cylindrical permanent magnet with its south pole opposite its north pole. Interaction between the rotor and that magnet's field is what makes the motor spin. This motor's diameter is greater than its length, something uncommon in motors of this sort. In other sorts of motors, it is typical. Considering that it was used to spin the disc in a CD drive, short length was quite important.

This type of motor is widely used in small toys, models, and electromechanical/electronic devices.

Although the rotor can potentially stop in a position where two commutator segments touch one brush, this only de-energizes one of the three rotor arms while the other two are correctly powered. The motor produces sufficient torque with the two powered rotor arms to begin spinning the rotor, and no direct shorting can occur between the commutator brushes.

Although, so far, this explanation has assumed a permanent-magnet field (or a wound field with the electromagnet fed by DC), so-called universal motors in appliances such as vacuum cleaners have wound fields, and operate well on AC. Power goes to both the field and the brushes, so the magnetic fields of both rotor and stator reverse together. These motors also operate on DC, hence the term "universal".

Ring/Segment Construction



Cross-section of a commutator that can be disassembled for repair.

A commutator typically consists of a set of copper segments, fixed around part of the circumference of the rotating part of the machine (the *rotor*), and a set of spring-loaded brushes fixed to the stationary frame of the machine. The external source of current (for a motor) or electrical load (for a generator) is connected to the brushes. For small equipment the commutator segments can be stamped from sheet metal. For very large equipment the segments are made from a copper casting that is then machined into the final shape.

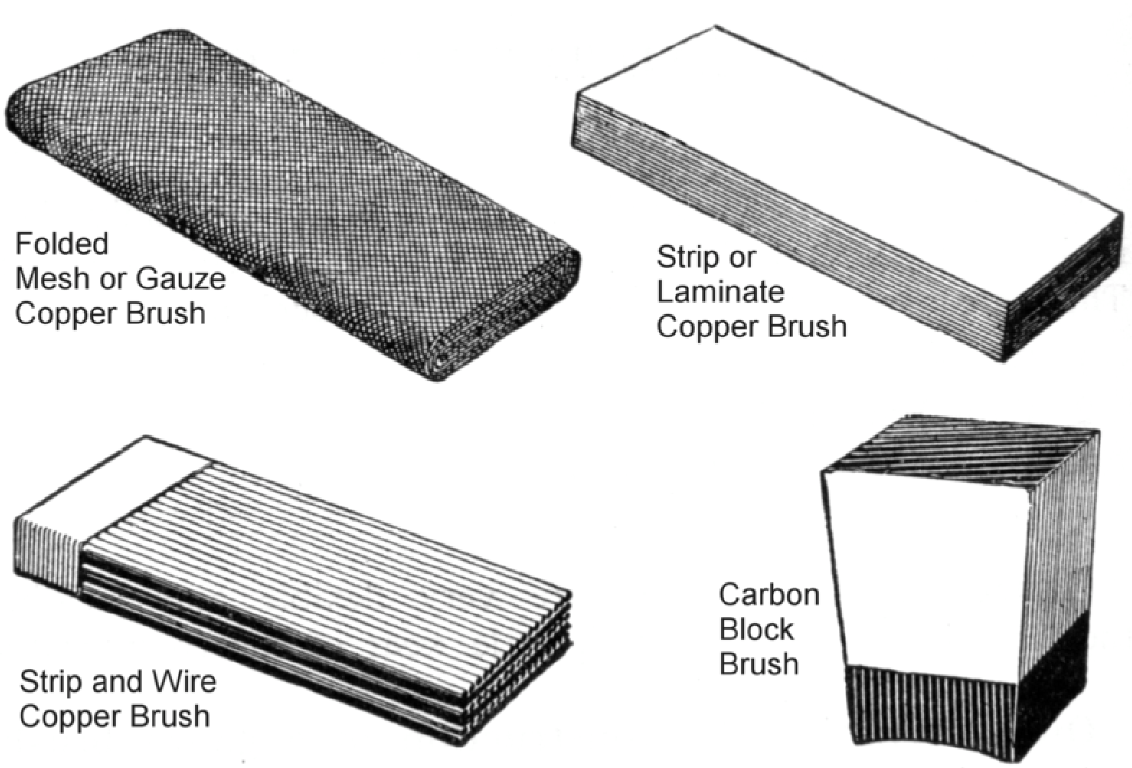
Each conducting segment on the armature of the commutator is insulated from adjacent segments. Initially when the technology was first developed, mica was used as an insulator between commutation segments. Later materials research into polymers brought the development of plastic spacers which are more durable and less prone to cracking, and have a higher and more uniform breakdown voltage than mica.

The segments are held onto the shaft using a dovetail shape on the edges or underside of each segment, using insulating wedges around the perimeter of each commutation segment. Due to the high cost of repairs, for small appliance and tool motors the segments are typically crimped permanently in place and cannot be removed; when the motor fails it is simply discarded and replaced. On very large industrial motors it is economical to be able to replace individual damaged segments, and so the end-wedge can be unscrewed and individual segments removed and replaced.

Commutator segments are connected to the coils of the armature, with the number of coils (and commutator segments) depending on the speed and voltage of the machine. Large motors may have hundreds of segments.

Friction between the segments and the brushes eventually causes wear to both surfaces. Carbon brushes, being made of a softer material, wear faster and may be designed to be replaced easily without dismantling the machine. Older copper brushes caused more wear to the commutator, causing deep grooving and notching of the surface over time. The commutator on small motors (say, less than a kilowatt rating) is not designed to be repaired through the life of the device. On large industrial equipment, the commutator may be re-surfaced with abrasives, or the rotor may be removed from the frame, mounted in a large metal lathe, and the commutator resurfaced by cutting it down to a smaller diameter. The largest of equipment can include a lathe turning attachment directly over the commutator.

Brush Construction



Various types of copper and carbon brushes.

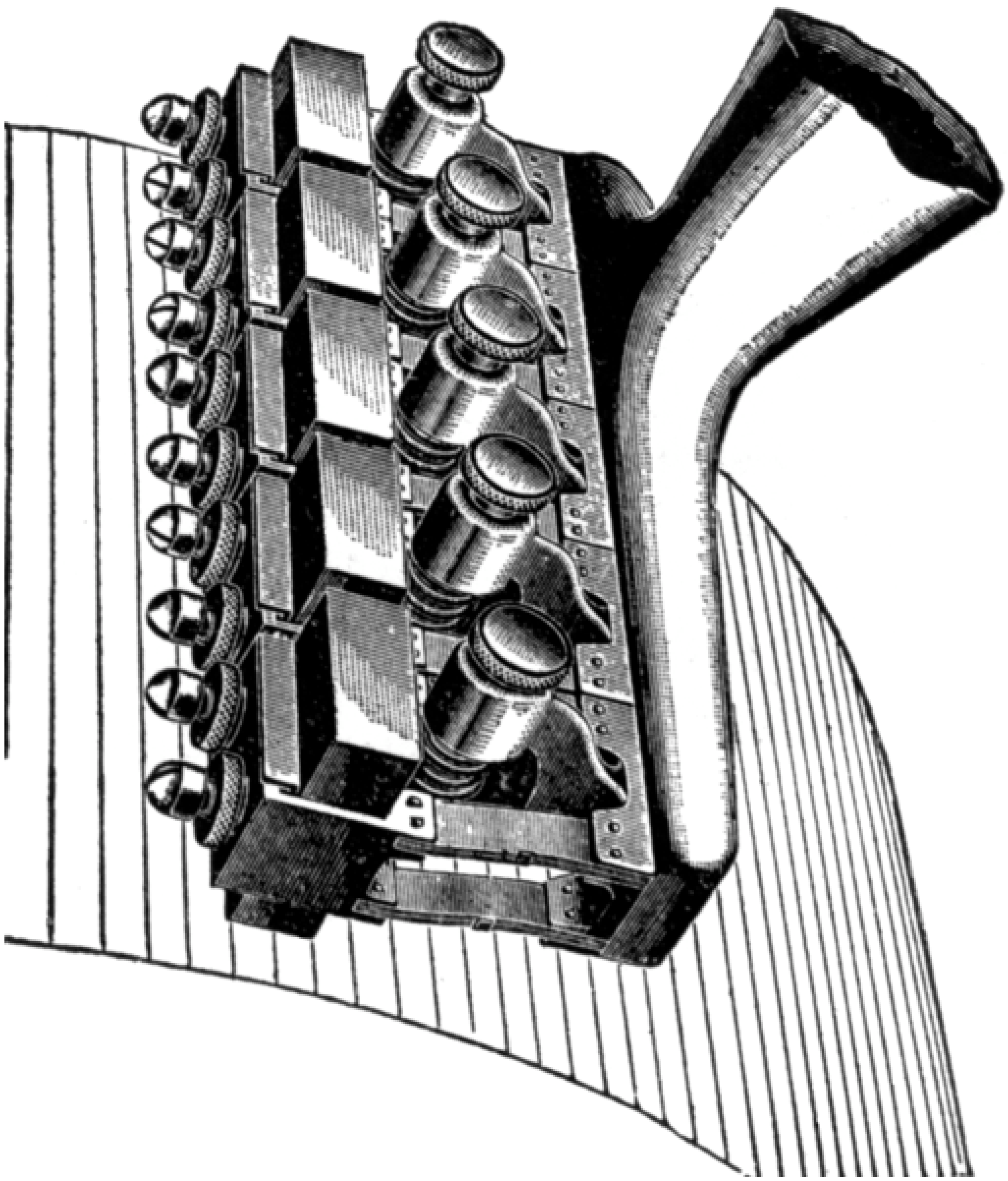
Early in the development of dynamos and motors, copper brushes were used to contact the surface of the commutator. However, these hard metal brushes tended to scratch and groove the smooth commutator segments, eventually requiring resurfacing of the commutator. As the copper brushes wear away, the dust and pieces of the brush could wedge between commutator segments, shorting them and reducing the efficiency of the device. Fine copper wire mesh or gauze provided better surface contact with less segment wear, but gauze brushes were more expensive than strip or wire copper brushes. The copper brush was eventually replaced by the carbon brush.

Carbon brushes tend to wear more evenly than copper brushes, and the soft carbon causes far less damage to the commutator segments. There is less sparking with carbon as compared to copper, and as the carbon wears away, the higher resistance of carbon results in fewer problems from the dust collecting on the commutator segments.

Copper and carbon are each better suited for a particular purpose. Copper brushes perform better with very low voltages and high current, while carbon brushes are better for high voltage and low current. Copper brushes typically carry 150 to 200 amperes per square inch of contact surface, while carbon only carries 40 to 70 amperes per square inch. The higher resistance of carbon also results in a greater voltage drop of 0.8 to 1.0 volts per contact, or 1.6 to 2.0 volts across the commutator.

Modern rotating machines with commutators now use carbon brushes, which may have copper powder mixed in to improve conductivity. Metallic copper brushes would only be found in toy or very small motors, such as the one illustrated above.

Brush Holders



Compound carbon brush holder, with individual clamps and tension adjustments for each block of carbon.

A spring is typically used with the brush, to maintain constant contact with the commutator. As the brush and commutator wear down, the spring steadily pushes the brush downwards towards the commutator. Eventually the brush wears small and thin enough that steady contact is no longer possible or it is no longer securely held in the brush holder, and so the brush must be replaced.

It is common for a flexible power cable to be directly attached to the brush, because current flowing through the support spring causes heating, which may lead to a loss of metal temper and a loss of the spring tension.

When a commutated motor or generator uses more power than a single brush is capable of conducting, an assembly of several brush holders is mounted in parallel across the surface of the very large commutator.

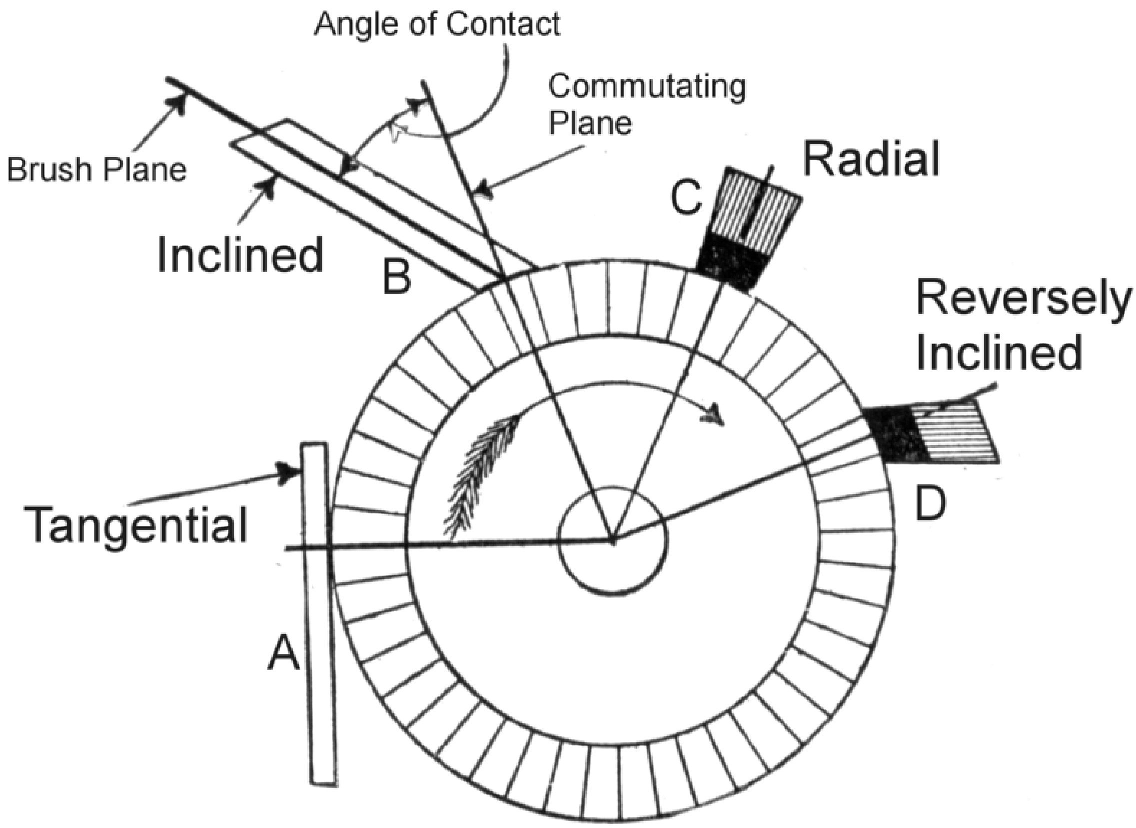
This parallel holder distributes current evenly across all the brushes, and permits a careful operator to remove a bad brush and replace it with a new one, even as the machine continues to spin fully powered and under load.

High power, high current commutated equipment is now uncommon, due to the less complex design of alternating current generators that permits a low current, high voltage spinning field coil to energize high current fixed-position stator coils. This permits the use of very small singular brushes in the alternator design. In this instance, the rotating contacts are continuous rings, called slip rings, and, of course, no switching happens.

Modern devices using carbon brushes usually have a maintenance-free design that requires no adjustment throughout the life of the device, using a fixed-position brush holder slot and a combined brush-spring-cable assembly that fits into the slot. Replacement simply involves pulling out the old brush and inserting a new one.

Older commutator motors sometimes had all brushes mounted on movable frames so that the position of the brushes in relation to the magnetic fields of the stator poles could be adjusted manually.

Brush Contact Angle

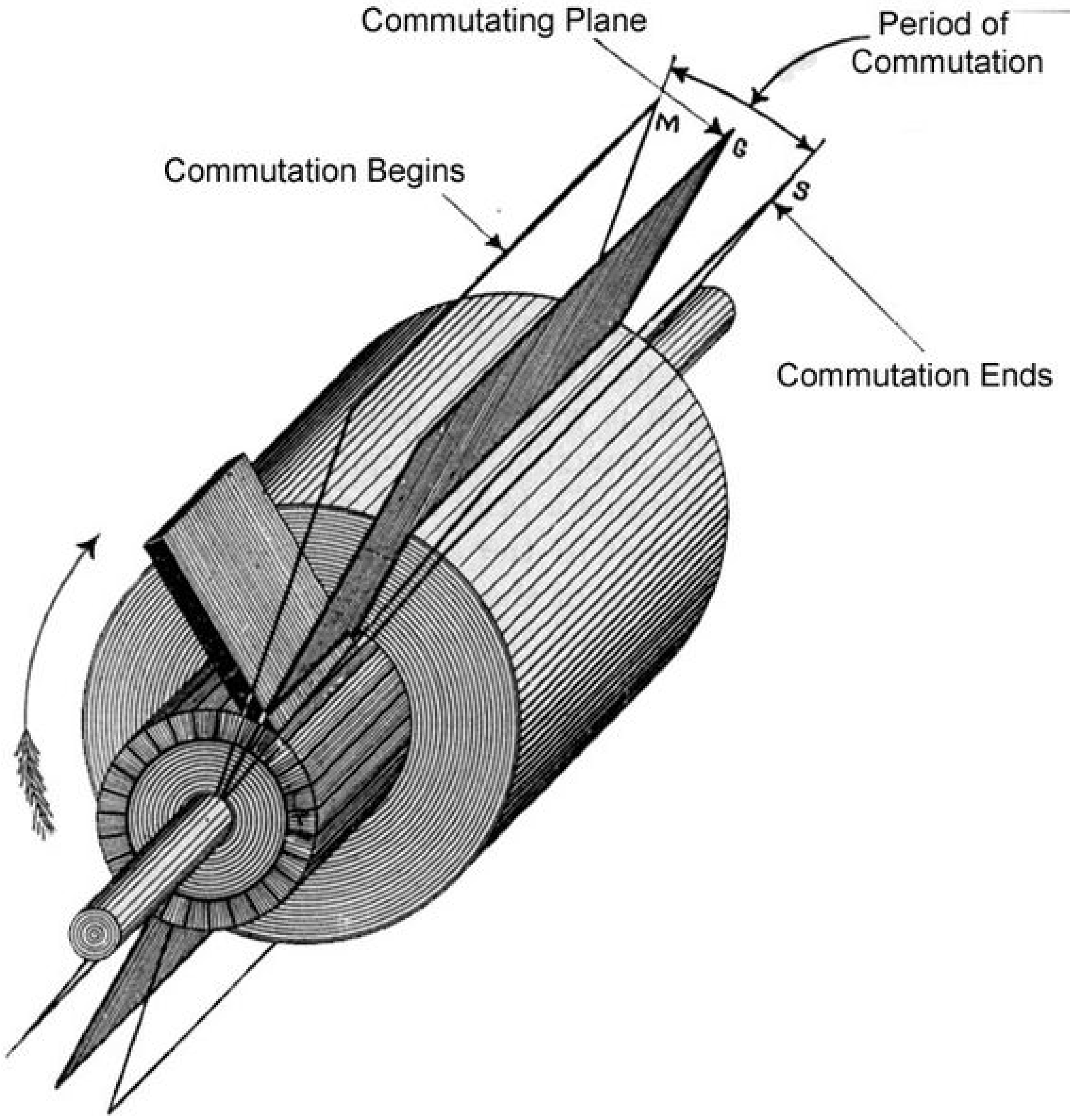


Brush angle definitions

The different brush types make contact with the commutator in different ways. Because copper brushes have the same hardness as the commutator segments, the rotor cannot be spun backwards against the ends of copper brushes without the copper digging into the segments and causing severe damage. Consequently strip/laminate copper brushes only make tangential contact with the commutator, while copper mesh and wire brushes use an inclined contact angle touching their edge across the segments of a commutator that can spin in only one direction.

The softness of carbon brushes permits direct radial end-contact with the commutator without damage to the segments, permitting easy reversal of rotor direction, without the need to reorient the brush holders for operation in the opposite direction. Although never reversed, common appliance motors that use wound rotors, commutators and brushes have radial-contact brushes. In the case of a reaction-type carbon brush holder, carbon brushes may be reversely inclined with the commutator so that the commutator tends to push against the carbon for firm contact.

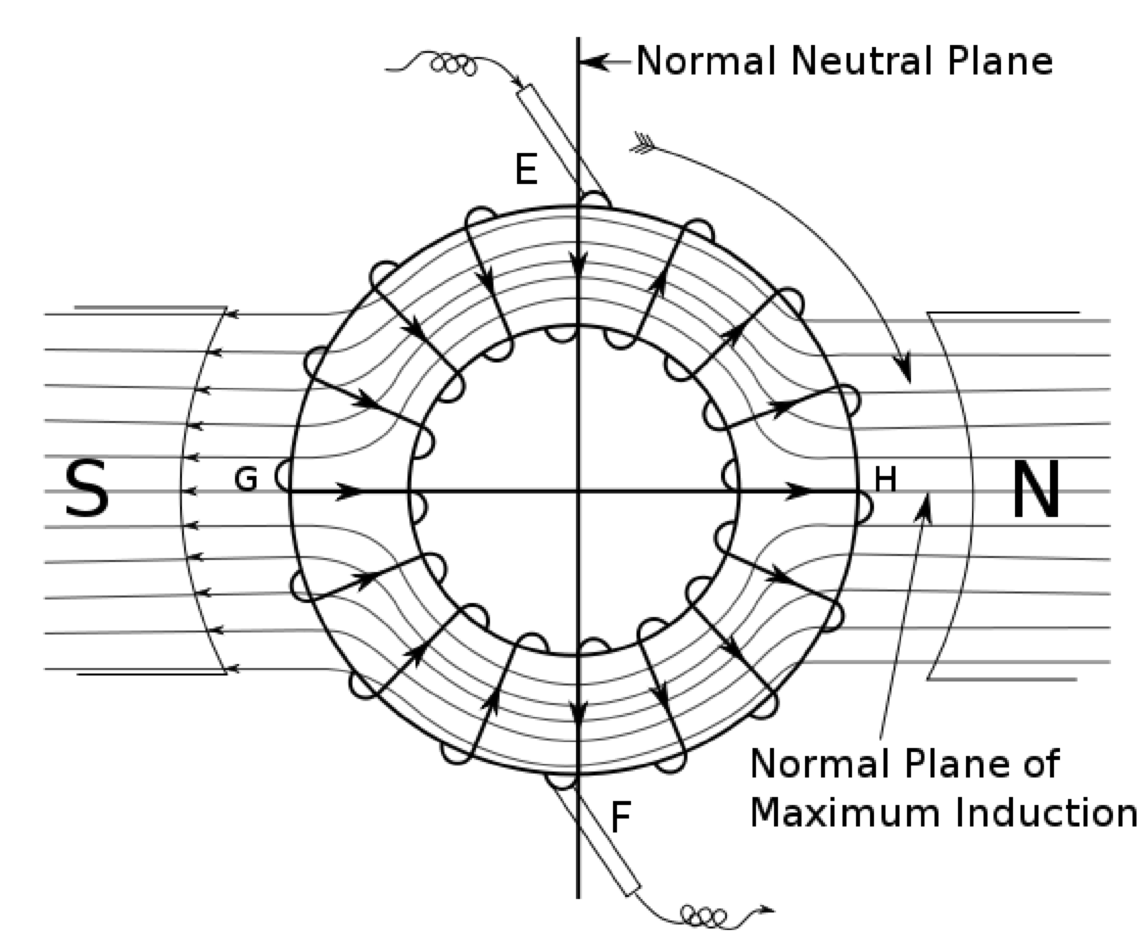
The Commutating Plane



Commutating plane definitions.

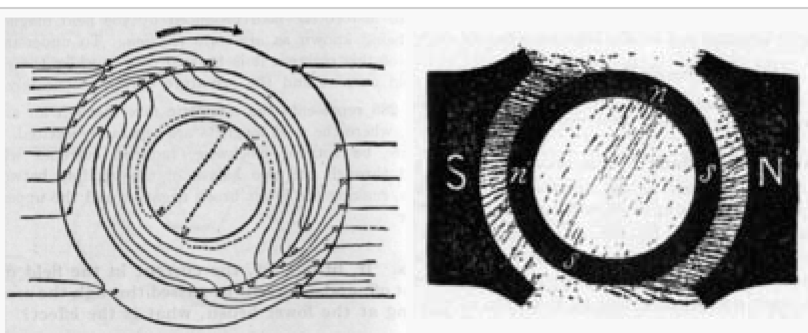
The contact point where a brush touches the commutator is referred to as the *commutating plane*. In order to conduct sufficient current to or from the commutator, the brush contact area is not a thin line but instead a rectangular patch across the segments. Typically the brush is wide enough to span 2.5 commutator segments. This means that two adjacent segments are electrically connected by the brush when it contacts both.

Compensation for stator field distortion



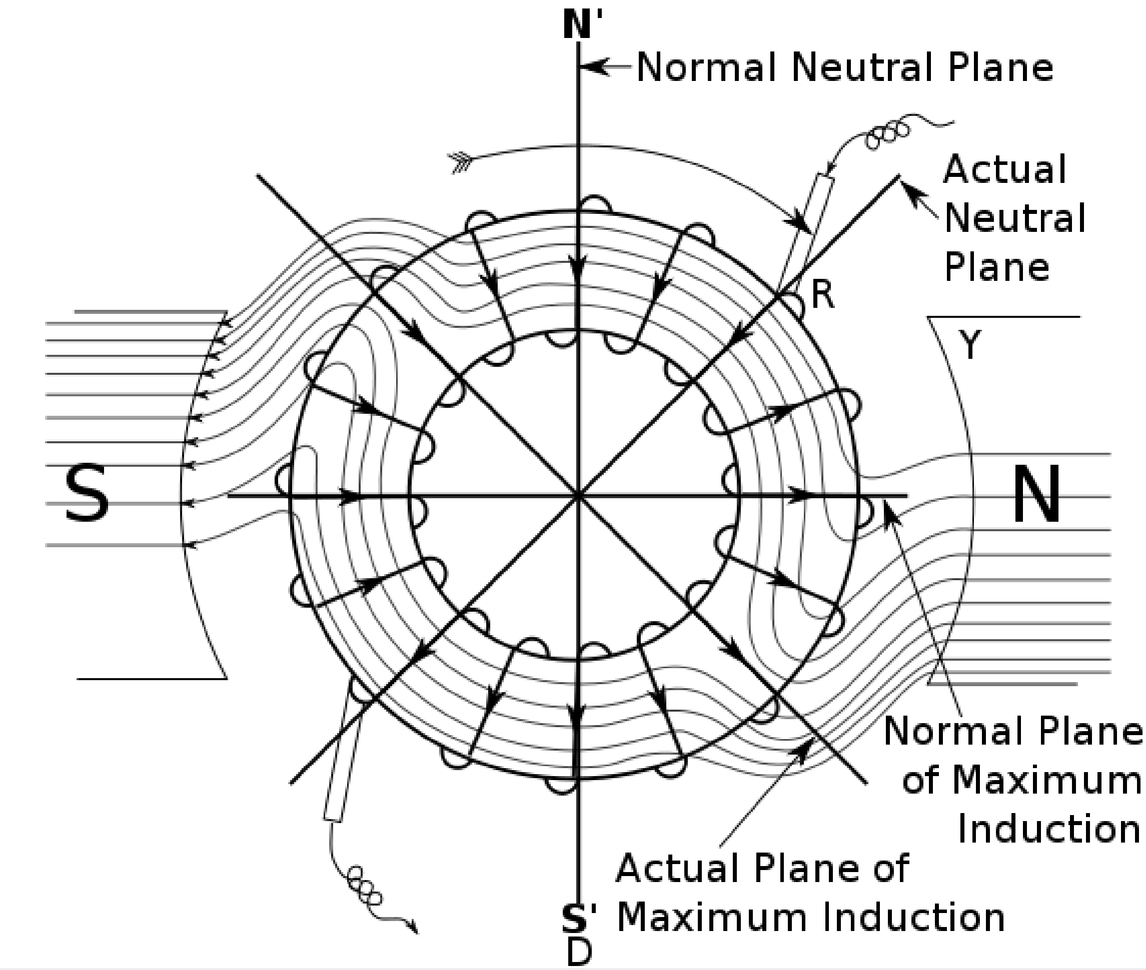
Centered position of the commutating plane if there were no field distortion effects.

Most introductions to motor and generator design start with a simple two-pole device with the brushes arranged at a perfect 90-degree angle from the field. This ideal is useful as a starting point for understanding how the fields interact but it is not how a motor or generator functions in actual practice.



On the left is an exaggerated example of how the field is distorted by the rotor. On the right, iron filings show the distorted field across the rotor.

In a real motor or generator, the field around the rotor is never perfectly uniform. Instead, the rotation of the rotor induces field effects which drag and distort the magnetic lines of the outer non-rotating stator.



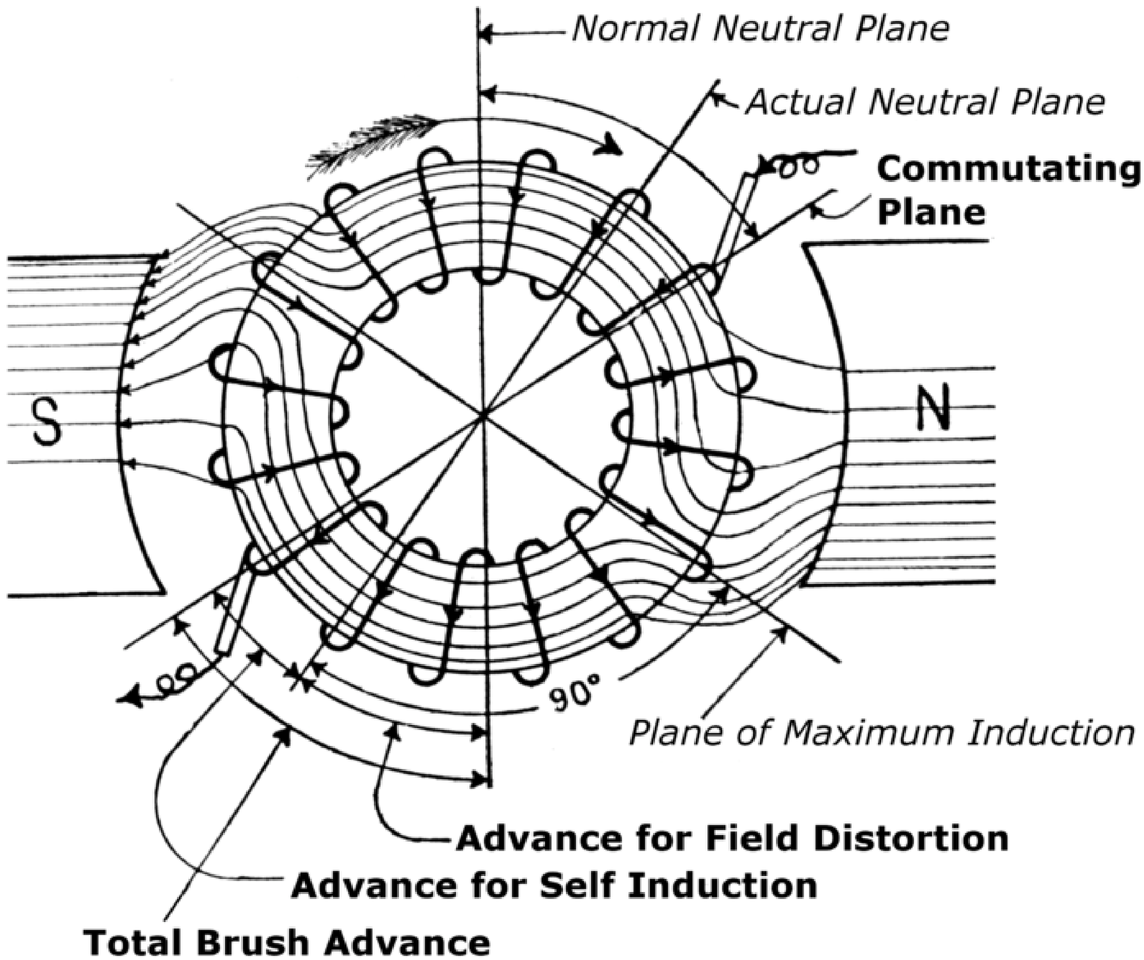
Actual position of the commutating plane to compensate for field distortion.

The faster the rotor spins, the further this degree of field distortion. Because a motor or generator operates most efficiently with the rotor field at right angles to the stator field, it is necessary to either retard or advance the brush position to put the rotor's field into the correct position to be at a right angle to the distorted field.

These field effects are reversed when the direction of spin is reversed. It is therefore difficult to build an efficient reversible commutated dynamo, since for highest field strength it is necessary to move the brushes to the opposite side of the normal neutral plane.

The effect can be considered to be analogous to timing advance in an internal combustion engine. Generally a dynamo that has been designed to run at a certain fixed speed will have its brushes permanently fixed to align the field for highest efficiency at that speed.

Further Compensation for Self-Induction



Brush advance for Self-Induction.

In a coil of wire, the magnetic field of each wire compounds together to form a magnetic field that tends to resist changes in current, as if the current had inertia. This is known as *self-induction*.

In the coils of the rotor, there is a tendency for current to continue to flow for a brief moment after the brush has been reached. This energy is wasted as heat due to the brush spanning across several commutator segments and the current short-circuiting across the segments.

Spurious resistance is an apparent increase in the resistance in the armature winding, which is proportional to the speed of the armature, and is due to the lagging of the current.

In order to minimize sparking at the brushes due to this short-circuiting, the brushes are advanced a few degrees further yet, beyond the advance for field distortions. This moves the rotor winding undergoing commutation slightly forward into the stator field which has magnetic lines in the opposite direction and which oppose the field in the stator. This opposing field helps to reverse the lagging self-inducting current in the stator.

So even for a rotor which is at rest and initially requires no compensation for spinning field distortions, the brushes should still be advanced beyond the perfect 90-degree angle as taught in so many beginners textbooks, in order to compensate for self-induction.

Limitations and alternatives

While commutators are widely applied in direct current machines, up to several thousand kilowatts in rating, they have limitations.

Brushes and copper segments wear. On small machines the brushes may last as long as the product (small power tools, appliances, etc.) but larger machines will require regular replacement of brushes and occasional resurfacing of the commutator. Brush-type motors may not be suitable for long service on aerospace equipment where maintenance is not possible.

The efficiency of direct current machines is limited by the "brush drop" due to the resistance of the sliding contact. This may be several volts, making low-voltage direct-current machines very inefficient. The friction of the brush on the commutator also absorbs some of the energy of the machine.

Lastly, the current density in the brush is limited and the maximum voltage on each segment of the commutator is also limited. Very large direct current machines, say, more than several megawatts rating, cannot be built with commutators. The largest motors and generators, of hundreds of megawatt ratings, are all alternating-current machines.

With the widespread availability of power semiconductors, it is now economical to provide electronic switching of the current in the motor windings. These "brushless direct current" motors eliminate the commutator; these can be likened to AC machines with a built-in DC to AC inverter. In these motors, rotor position determines when the stator windings switch polarity. Operating life is limited only by bearing wear, if other factors are not adverse.

Repulsion induction motors

These are single-phase AC-only motors with higher starting torque than can be obtained with split-phase starting windings, and before high-capacitance (non-polar, relatively high-current electrolytic) starting capacitors became practical. They have a conventional wound stator as with any induction motor, but the wire-wound rotor is much like that with a conventional commutator. Brushes opposite each other are connected to each other (not to an external circuit), and transformer action induces currents into the rotor that develop torque by repulsion.

One variety, notable for having an adjustable speed, runs continuously with brushes in contact, while another uses repulsion only for high starting torque and in some cases lifts the brushes once the motor is running fast enough. In the latter case, all commutator segments are connected together as well, before the motor attains running speed.

Once at speed, the rotor windings become functionally equivalent to the squirrel-cage structure of a conventional induction motor, and the motor runs as such.

Web ref. gives a nice, concise description

Laboratory commutators

Commutators were used as simple forward-off-reverse switches for electrical experiments in physics laboratories. There are two well-known historical types :

Ruhmkorff commutator

This is similar in design to the commutators used in motors and dynamos. It was usually constructed of brass and ivory (later ebonite).

Pohl commutator

This consisted of a block of wood or ebonite with four wells, containing mercury, which were cross-connected by copper wires. The output was taken from a pair of curved copper wires which were moved to dip into one or other pair of mercury wells.

Chapter 2

IEC Connector

IEC connector is the common name for the set of thirteen mains electricity cable mount female connectors (called the *connector* in the specification) and thirteen panel mount male connector (called the *inlet*) defined by International Electrotechnical Commission (IEC) specification **IEC 60320** (formerly **IEC 320**). When used with no other qualifiers, *IEC connector* usually refers specifically to the C13 and C14 connectors. Some types also come in cable mount male and panel female versions to use as outlets but these are less common.

The family includes two and three-conductor connectors of various current capacities and temperature ratings, all designed specifically for the purpose of attaching a mains power cord to a piece of equipment. Allowing an interchangeable mains power cord makes it very easy for equipment manufacturers to sell their equipment anywhere in the world as long as their equipment can operate on both 120/240 V, 50/60 Hz mains power. However, users must still check voltage when moving equipment between regions as not all equipment with these connectors is multi-voltage and some equipment requires manual switching between voltage ranges.

In each case, the male connector is designated by the even number one greater than the odd number assigned to the female connector, so a C1 fits a C2, and a C15A fits a C16A. Most are polarized (though of course being a worldwide standard they will frequently be connected to wall outlets that are unpolarized), the exceptions being the C1, some C7 and all C9 connector. All voltage ratings are 250 V AC maximum. All have maximum temperature ratings of 70 °C unless noted.

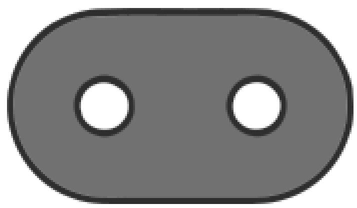
The use of the terms *plug* and *socket* when referring to these connectors is ambiguous. Some use the term plug as a synonym for male and socket as a synonym for female. Others use the term plug for the cable connector and socket for the panel mount connector. For inlet connections where the male connector is on the device and the female connector is on the cable these two definitions are opposite.

Appliance classes

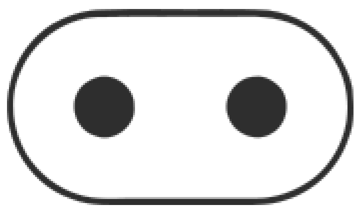
In addition to being grounded or not, these connectors are differentiated according to their IEC protection class.

- Class 0 appliances have no protective-earth connection and feature only a single level of insulation.
- Class I appliances must have their chassis connected to electrical earth.
- Class II double insulated electrical appliances have been designed in such a way that they do not require a safety connection to electrical earth.
- Class III appliances are designed to be supplied from a SELV (Separated or Safety Extra-Low Voltage) power source.

C1 and C2 connectors



C1 cord end connector



C2 inlet

2-conductor 0.2 A, unpolarized. C1 cords and C2 inlets are commonly used for shavers.

C3 and C4 connectors

2-conductor 2.5 A

C5 and C6 connectors

C5 cord end connector

C6 inlet on the Apple iMac G4

The C5 3-conductor 2.5 A cord end connector and the C6 inlet are sometimes colloquially called *cloverleaf* connections or "Mickey Mouse" (because the cross section looks like the silhouette of the Disney character).

This connector is seen on laptop power supplies and portable projectors, and on the Apple desktop computer iMac G4.

C7 and C8 connectors

The C7 (cord end) and C8 (inlet) connectors, with two pins rated at 2.5 A, exist in both polarized and unpolarized versions.

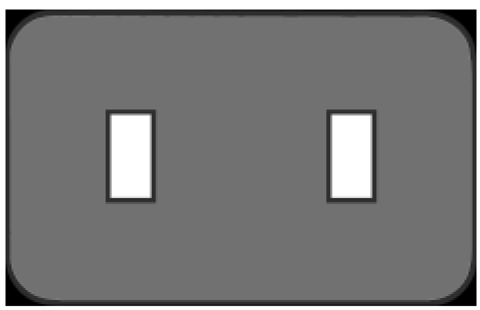
Unpolarized C7 Cord End Connector.

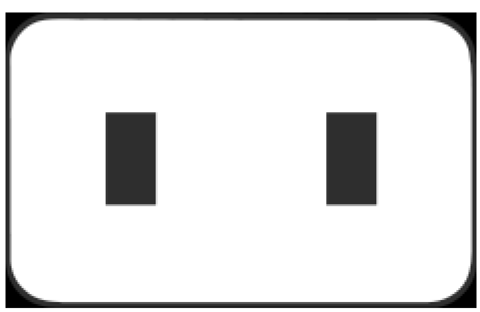
Unpolarized C8 Inlet.

The unpolarized C7 is commonly known as a *figure-8* or *shotgun* connector due to its shape. It is also known as a *euro-connector* in electronic shops. The polarized C7 (C7-PW) is asymmetrical, with one end rounded similarly to the unpolarized version, and the other squared off.

These connectors are often used for small cassette recorders, battery/mains operated radios, some full size AV equipment, laptop computer power supplies, video game consoles, and similar double-insulated appliances. Unpolarized C7 connectors can be inserted into polarized C8-PW sockets; however, doing so might be a safety risk if the device is designed to expect a polarized power connection.

C9 and C10 connectors



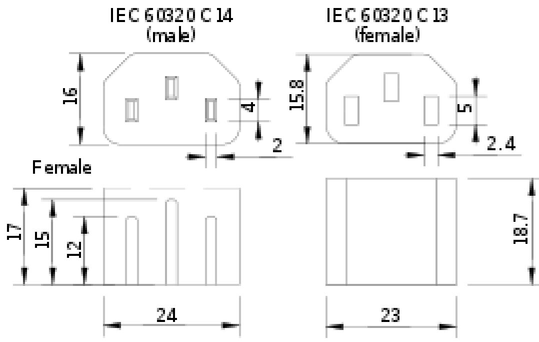


This kind of connector is used by Roland Corporation for a couple of synthesizer and drum computer models (for example: TR-909) and by ReVox for many older models of their HiFi equipment (for example: A76, A77, A78, B77, B225).

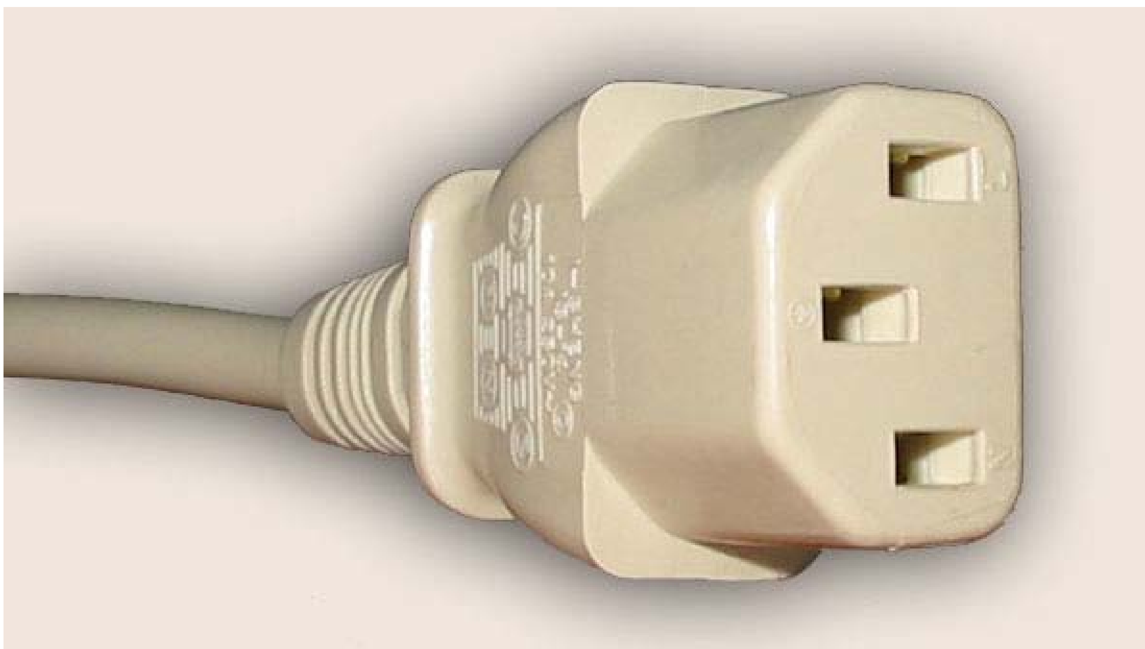
C11 and C12 connectors

2-conductor 10 A

C13 and C14 connectors



Drawing of standard C13 & C14 connectors



C13 cable mounted female connector.

C14 panel mounted male connector (inlet).

3-conductor 15A. Most desktop personal computers use the fifteen-amp panel-mounting C14 inlet to attach the power cord to the power supply, as do many monitors, printers and other peripherals. Many AT form factor computers also provided a panel-mounting C13 outlet controlled by the physical power switch for powering the monitor. With the arrival of ATX the readily accessible permanent power switch was removed and the outlet was either permanently powered or completely removed.

A three-conductor cord with a suitable power plug for the locality in which the appliance is used on one end and a C13 line socket on the other is commonly called an *IEC cord*. IEC cords are used to power many pieces of electronic equipment other than computers, for example instrument amplifiers and professional audio equipment.

Cables with a C14 connector at one end and a C13 connector at the other are commonly available. They have a variety of common uses including connecting power between older PCs and their monitors, extending existing power cords, connecting to C13 socket strips (commonly used with rackmount gear to save space and for international standardization) and connecting computer equipment to the output of a UPS (larger UPSs often have C19 outlets as well.)

There are also a variety of splitter blocks, splitter cables, and similar devices available. These, along with the cables mentioned above, are nearly always un-fused (with the exception of BS1363 to IEC cables which are always fused but sometimes at more than the rating of the IEC connector), and in 230 V countries the cables are often made with only 0.75 mm^2 cable which is rated only to 6 A. Therefore, care must be taken to avoid overloading the cables and connectors when using such products.

C15 and C16 connectors

C15 cable mount female connector

Some electric kettles and similar hot household appliances use a cord with a C15 connector, and a matching C16 inlet on the appliance; their temperature rating is 120 °C rather than the 70 °C of the similar C13/C14 combination. The official designation in Europe for the C15 and C16 connectors is 'hot condition' connectors.

These are almost identical in form to the C13 and C14 combination, except with a ridge opposite the earth in the C16 inlet (preventing a C13 fitting), and a corresponding valley in the C15 connector (which doesn't prevent it fitting a C14 inlet). For example, an electric kettle cord can be used to power a computer, but a computer cord cannot be used to power a kettle.

Many people are not aware of the subtle differences between the C13/C14 and C15/C16 connectors, and so all are loosely referred to as *kettle plug* and *kettle lead* (in the UK) and *jug plug* (in Australia) when referring to these mains cords.

In Britain and Sweden, the C15 and C16 connectors have replaced and made obsolete the appliance plug in most applications.

Two variations:

- C15 3-conductor 10 A (120 °C maximum temperature)
- C15A 3-conductor 10 A (155 °C maximum temperature)

C17 and C18 connectors

C17 cable mount female connector

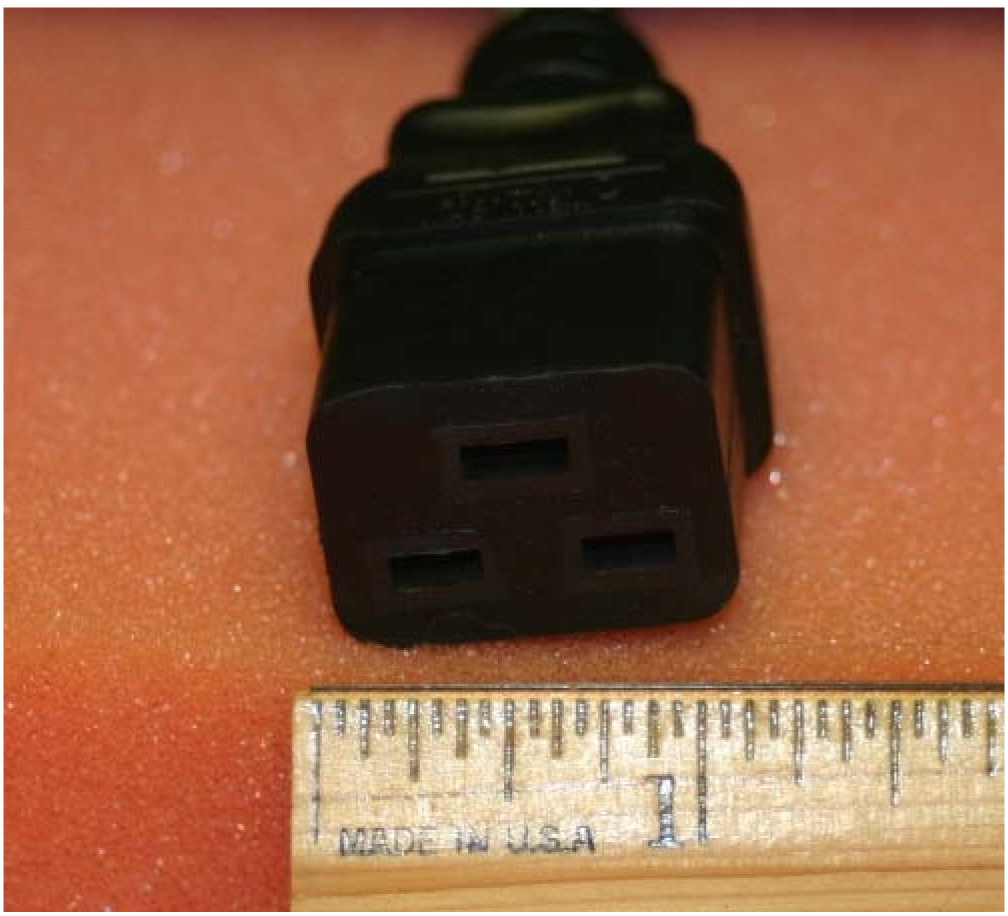
C18 chassis mount male connector

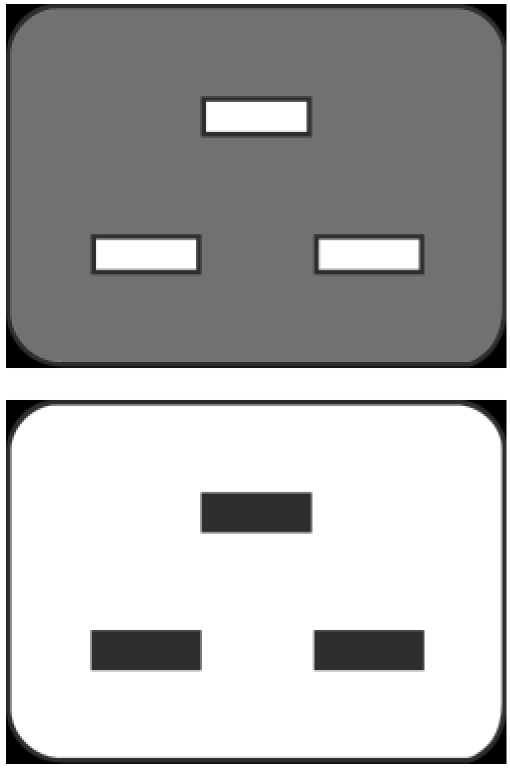
Similar to C13 and C14 connectors. However, the C17 and C18 do not have a third pin for earthing (grounding). A C18 inlet will accept a C13 connector but a C14 inlet will not accept a C17 connector.

IBM's Wheelwriter series of electronic typewriters are one common application. Three wire cords with C13 sockets, which are easier to find, are sometimes used in place of the two wire cords for replacement. In this case, the ground wire will not be connected

Other common applications are the power supplies of Xbox 360 games consoles, replacing the C15 and C16 connectors employed initially, and large CRT televisions manufactured by RCA in the early 1990s.

C19 and C20 connectors





IEC320-C19 16A cable mount female connector

C19 and C20 connectors, with pins rated at 16 A, are used for some IT applications where higher currents are required, for instance, on high-power workstations and servers, UPSs, PDUs and similar equipment. They are similar to C13 and C14 connectors, but rectangular (without chamfered corners) and with slightly larger pins, rotated so they are parallel to the long axis of the connector.

C21 and C22 connectors

3-conductor 16 A (155 °C maximum temperature)

C23 and C24 connectors

2-conductor 16 A

Higher current and IEC 60309 connectors

IEC60309-2 16 A *commando* connector

IEC 60309 plugs are part of a system often regarded as primarily for Industrial usage, to cover electrical interconnection needs in a range of voltages between less than 100 volts to in excess of 1000 volts, often using heavy currents, and in either single or three-phase systems, at several frequencies. Versions for DC use also exist. In United Kingdom they are often refered to as "Commando" plugs after a common make.

There is a range of plugs and sockets of different sizes with differing numbers of pins, depending on the current supplied and number of phases accommodated. The fittings also include limited (IP44) weather-proofing, that is one reason for choosing these fittings when the connections will be used in open-air conditions; a further reason for using these (other than when the heavy-current or three-phase facilities are actually needed), is to deter potential users from connecting Domestic appliances to the sockets, as 'normal' Domestic plug-tops will not fit and no adaptors are commercially available in the UK; reasons for attempting this could be a matter of safety because of the heavier current available, or simply to reserve the sockets for a specific purpose e.g. portable fans on the London Underground railway, or floor cleaning machines in airport terminals.

The plug-tops and sockets are colour-coded, according to the voltage range used e.g. yellow for 100-200 volts, blue for 200-300 volts, and red for 400-500 (to name just the most frequently observed in 'Domestic' situations). The blue coloured fittings are used in housing situations for providing weather-proofed exterior sockets for garden apparatus. The yellow fittings are used domestically to provide a 110 volt connection from a portable power transformer box used to enable heavy-current 110 volt power tools to be used. In camping situations, the large 32-amp blue fittings provide power to static caravans, whilst the smaller blue 16-amp version powers touring caravans and tents. The red version is typically used to run a wine press, using a 415-volt three-phase power supply taken directly from the electricity supplier's nearby sub-station.

The position of the grounding pin/socket relative to the keyway in the housing determines the current type and frequency. The two most common are "4h" and "6h" (from where the ground pin is seen at that clock postion seen from the open end of a female connector and the keyway oriented downwards) for 60Hz and 50Hz, respectively, in conjunction with the yellow,blue and red housings.

If a purpose-made adaptor is built, Domestic appliances fitted with a 13-amp plug containing a fuse appropriate to the appliance connected and its cabling may be connected to the blue 240-volt sockets, preferably via an in-line Residual Current Detector unit. So-called 'universal voltage' appliances (actually covering only the range of 90 to 250 volts) could technically be used with the yellow 110-volt sockets, but unless the appliance comes fitted with an American plug-top, this would necessitate building an adaptor fitted with a 110-volt commando plug-top at one end and a 13-amp 240-volt socket at the other end - and this would potentially be a danger to other persons finding such an adaptor and not understanding its purpose.

Chapter 3

IEC 62196

IEC 62196 is an international standard for set of electrical connectors and charging modes for electric vehicles and is maintained by the International Electrotechnical Commission (IEC).

The standard does not specify physical dimensions for a charging connector mentioning the existence of IEC 60309 "CEEform" connector definitions in Part-2 (IEC 62196-2). The standard is based on IEC 61851 that has a mechanism that not connect the power unless connected to a vehicle that will also immobilise the vehicle stopping from driving away whilst connected.

The Part-1 definitions for the signal pin and its IEC 62196-1 charging mode definitions have been reused in a number of implementations for charging large devices and especially automotive charging stations. Apart from CEEform industrial plugs the modes were picked up for the Yazaki connector in Northern America (standardized in SAE J1772), the CHΛdeMO connector in Japan (using DC charging) and the Mennekes connector in Europe (standardized in VDE-AR-E 2623-2-2) - each designated to be used in a electric vehicle network of charging stations. Other connector types conforming to IEC 62196-1 have been the Framatome plug by EDF, the Scame plug in Italy and the CEEplus plugs in Switzerland.

Public charging stations conforming to IEC 62196 that have a specific socket type (e.g. SAE J1772 or CEEplus) can be used with other plug types by means of adapters - however the current will not be enabled unless a IEC 61851 presence signal pin is connected and the current will be limited to 16 Ampere unless a IEC 62196 charging mode signal is detected that specifies a higher Ampere level.

Charging modes

The Part-1 of IEC 62196 is applicable to plugs, socket-outlets, connectors, inlets and cable assemblies for electric vehicles, intended for use in conductive charging systems (cables with copper or copper-alloy conductors) which incorporate control means, with a rated operating voltage not exceeding:

- 690 V a.c., 50 – 60 Hz, at a rated current not exceeding 250 A;
- 600 V d.c., at a rated current not exceeding 400 A.

The standard leverages the charging modes as defined in IEC61851-1 which includes:

- IEC 61851-1 "Mode 1" - slow charging from a household-type socket-outlet
- IEC 61851-1 "Mode 2" - slow charging from a household-type socket-outlet with an in-cable protection device
- IEC 61851-1 "Mode 3" - slow or fast charging using a specific EV socket-outlet with control and protection function installed
- IEC 61851-1 "Mode 4" - fast charging using an external charger

The IEC 61851-1 standard documents the pilot signal flagging the charging requirements by using pulse width modulation. The pilot signal is integrated in the plugs of IEC 62196 electric vehicle charging equipment being a requirement for higher currents.

Mode 1

Mode 1 charging relates to the connection of the EV to the a.c. supply network (mains) utilizing standardized socket-outlets not exceeding 16 A and not exceeding 250 V a.c. single-phase or 480 V a.c. three-phase, at the supply side, and utilizing the power and protective earth conductors.

Mode 1 connectors do not require any control pins from IEC 61851-1. In many countries there are additional restrictions on household mains being less than 16 A - it is left to the system user to respect the actual charging limits.

In some countries like the USA, mode 1 charging is prohibited by national codes. The main reason is that the required earthing is not present in all domestic installations so that Mode 2 was defined as an interim solution.

Mode 2

Mode 2 charging relates to the connection of the EV to the a.c. supply network (mains) not exceeding 32 A and not exceeding 250 V a.c. single-phase or 480 V a.c. three-phase utilizing standardized single-phase or three-phase socket-outlets, and utilizing the power and protective earth conductors together with a control pilot function and system of personnel protection against electric shock (RCD) between the EV and the plug or as a part of the in-cable control box. The inline control box shall be located within 0,3 m of the plug or the EVSE or in the plug.

Mode 2 connectors require a control pin from IEC 61851-1 but which is only required on the side of the electric vehicle. The supply network side of the cable does not need a control pin and the control function is governed by the control box in the cable. These provisions allow for charging stations with low complexity while extending the permissible range or charging currents compared to Mode 1 charging. A possible setup uses a IEC 60309 connector ready for 32 A - controlled by the diameter of the plug that would not fit in a 16 A socket - with the control pin flagging the charging mode to the electric vehicle. A 1000 Ω resistor is used between pilot and earthing allowing to break the circuit if the current on the pilot-earth loop is lost.

Mode 3

Mode 3 charging relates connection of the EV to the a.c. supply network (mains) utilizing dedicated electric vehicle supply equipment (EVSE) where the control pilot function extends to control equipment in the EVSE, permanently connected to the a.c. supply network (mains).

Mode 3 connectors according to IEC 61851-1 require a range of control and signal pins for both sides of the cable. The charging station socket is dead if no vehicle is present - the pilot pin in the plug on the charger side controls the circuit breaker. For compatibility the 32 A plugs of IEC 61851-1 Mode 2 connectors (1000 Ω pilot-earth) may be used while fast charging with higher currents up to 250 A require specialized cables flagging the IEC 61851-1 charging mode. The communication wire between car electronics and charging station allows for an integration into smart grid scenarios.

Mode 4

Mode 4 charging relates to the connection of the EV to the a.c. supply network (mains) utilizing an offboard charger where the control pilot function extends to equipment permanently connected to the a.c. supply.

The IEC 62196 accessories encompass the vehicle inlet/connector (all modes) and the plug/socket-outlet (Mode 3).

The scenario for Mode 4 charging is a setup where the supply network a.c. power is converted in the charging station to d.c. and the plug type ensures that only a matching electric vehicle can be connected. Using d.c. fast charging allows for considerable higher currents up to 400 A according to IEC 61851-1 Mode 4. Mode 4 connectors according to IEC 61851-1 require a range of control and signal pins to ensure operation for fast charging comparable to Mode 3. The Mode 4 charging station equipment are however much more expensive than Mode 3 EVSE.

Plug types

The IEC 62196-1 refers to plugs as specified in IEC 60309 for industrial and multiphase power plugs and sockets.

A number of industry groups have made advancements to add details on specific plugs beyond the existing range IEC 60309 "CEEform" connectors. The CEEform industry connectors are used in many areas while the following plug types from the IEC 62196 annex have been taylored to the usage as automotive chargers. The IEC 62196-2 contains categorizations on plug types to be used in the charging process. There is an ongoing standardization process to choose plug types for public charging stations of electric vehicle networks. The Formula E-Team in the Netherlands notes that the next IEC 62196-2 edition will probably refer to three designs for Mode-3 plugs including the Yazaki/SAE connector, the VDE/Mennekes connector and the Scame/EVPlug connector.

The plug type standardization in Europe is part of a process including smart grid elements for charging stations as well as battery recharge electronics in the cars. The DKE / VDE has an influence on the IEC and CENELEC standardization with existing range of working groups. In June 2010 the ETSI and CEN-CENELEC were mandated by the European Commission to develop a European Standard on charging points for electric vehicles. The Commission expects that the standard will be ready by mid-2011 including recommendations on the plug types from the IEC 62196-2 range. The IEC 62196-2 circulation started on 17. December 2010 and voting closes on 20. May 2011.

The list of IEC 62196-2 plug types includes:

- IEC 62196-2 "Type 1" - *single phase vehicle coupler* - reflecting the SAE J1772/2009 automotive plug specifications
- IEC 62196-2 "Type 2" - *single and three phase vehicle coupler* - reflecting the VDE-AR-E 2623-2-2 plug specifications
- IEC 62196-2 "Type 3" - *single and three phase vehicle coupler with shutters* - reflecting the EV Plug Alliance proposal

Type 1 - SAE J1772-2009

SAE J1772-2009 plug and receptacle

In 2001 SAE International had proposed a standard for conductive coupler which had been approved by the California Air Resources Board for charging stations of electric vehicles. The SAE J1772-2001 plug had a rectangular shape that was based on a design by Avcon. In 2009 a revision of the SAE J1772 standard was published that included a new design by Yazaki featuring a round housing. The SAE J1772-2009 coupler specifications have been included to IEC 62196-2 standard as an implementation of the Type 1 connector for charging with single-phase AC. The connector has five pins for the two AC wires, ground and two signal pins compatible with IEC 61851-2001 / SAE J1772-2001 for proximity detection and control pilot function.

Note that only the plug type specification of the SAE J1772-2009 haven been taken over but not the relation to Level 1, 2, and 3 charging modes inherited from the proposition of the California Air Resources Board. The Level 1 charging mode at 120 V is specific to Northern America and Japan as most regions around the world use 220-240V and IEC 62196 does not include a special option for lower voltages. The Level 3 for DC charging is not applicable to either IEC 62196-2 or SAE J1772-2009.

While the original SAE J1772-2009 standard describes ratings from 120V 12A/16A to 240V 32A/80A the IEC 62196 Type 1 specification covers only 250V ratings at 32A/80A. The 80A version of IEC 62196 Type 1 is considered US only however.

Type 2 - VDE-AR-E 2623-2-2

Mennekes/VDE automotive connector & vehicle inlet

The connector manufacturer Mennekes had developed a series of 60309-based connectors that were enhanced with additional signal pins - these "CEEplus" connectors have been used for charging of electric vehicles since the late 1990s. With the resolution of the IEC 61851-1:2001 control pilot function (aligned with the SAE J1772:2001 proposal) the CEEplus connectors were replacing the earlier Marechal couplers (MAEVA / 4 pin / 32A) as the standard for electric vehicle charging. When Volkswagen promoted its plans for electric mobility Alois Mennekes contacted Martin Winterkorn in 2008 to learn about the requirements of the charging equipment connectors. Based on requirement of the industry led by utility RWE and car maker Daimler a new connector was derived by Mennekes that would later be accepted as the standard connector by other car makers and utilities for their field tests in Europe. The proposal is based on the observation that standard IEC 60309 plugs are rather bulky (diameter 68 mm / 16A to 83 mm / 125 A) for higher current. To ensure easy handling by consumers the plugs were made smaller (diameter 55 mm) and flattened on one side (physical protection against polarity reversal).

Since the IEC standardization track is a lengthy process, the German DKE/VDE (Deutsche Kommission Elektrotechnik / *German Commission for Electronics* of the Association for Electrical, Electronic and Information Technologies) took over the task to standardize the handling details of the automotive charging system and its designated connector published in November 2009 in **VDE-AR-E 2623-2-2** The connector type has been included in the next Part-2 (IEC 62196-2) connector reference as "Type 2". The standardization process of the VDE plug continues with an extension for high current d.c. loading that will be proposed for inclusion by 2013.

Unlike the IEC 60309 plugs, the Mennekes/VDE automotive solution (German **VDE-Normstecker für Ladestationen** / *VDE standard plug for charging stations*) has a single size and layout for currents from 16A single-phase up to 63A three-phase (3.7 kW to 43.5 kW) but it does not cover the full range of Mode 3 levels (see below) of the IEC 62196 specification. Since the VDE automotive connector was described first in the DKE/VDE proposal for the IEC 62196-2 standard (IEC 23H/223/CD), it was also called the IEC-62196-2/2.0 automotive connector before it got its own standardization title. The VDE will formally withdraw the national standard as soon as the international IEC standard is resolved.

There has been criticisms of the price of the VDE connector however by the car manufacturer Peugeot comparing it to the IEC 60309 plugs that are readily available. Unlike field tests in Germany, a number of field tests in France and the UK have taken over the campground sockets (blue IEC 60309-2 plug, single-phase, 230V, 16 A) that are already installed in many outdoor locations across Europe or weatherproofed versions of their normal domestic sockets. Also the Scame plugin is promoted by a French-Italian alliance mentioning its comparable low price.

The ACEA has decided to use the Type 2 connector for deployment in European Union. For the first phase the ACEA recommends public charging stations to offer Type 2 (Mode 3) or CEEform (Mode 2) sockets while home charging may additionally use a standard home socket (Mode 2). In the second phase (expected to be 2017 and later) a uniform connector shall be used only, whereas the ultimate choice for Type 2 or Type 3 is left open. The rationale of the ACEA recommendation points to using Type 2 Mode 3 connectors however. Based on the ACEA position Amsterdam Electric has put up the first Type 2 Mode 3 public charging station for use with the Nissan Leaf test drive.

Beginning at the end of 2010 the utilities Nuon and RWE have started to deploy a network of charging poles in Central Europe (Netherlands, Belgium, Germany, Switzerland, Austria, Poland, Hungary, Slovenia, Croatia) using the *Type 2 Mode 3* socket type based on the widely available 400V three-phase domestic power grid.

Type 3 - EV Plug Alliance

The EV Plug Alliance was formed on March, 28 2010 by electrical companies in France (Schneider Electric, Legrand) and Italy (Scame). Within the IEC 62196 framework they propose an automotive plug derived from the earlier SCAME plugs (the Libera series) that are already in use for light electric vehicles. Gimélec joined the Alliance on May 10 and a number of more companies joined on May 31: Gewiss, Marechal Electric, Radiall, Vimar, Weidmüller France & Yazaki Europe. The new connector is able to provide 3-

phase charging up to 32 Ampere as being examined in the Formula E-Team tests. Schneider Electric emphasises that the "EV Plug" uses shutters over the socket side pins which is required in 12 European countries and that none of the other proposed EV charger plugs is featuring. Limiting the plug to 32 A allows for cheaper plugs and installation costs. The EV Plug Alliance points out that the future IEC 62196 specification will have an annex categorizing electric vehicle charger plugs into three types (Yazaki's proposal is type 1, Mennekes' proposal is type 2, Scame's proposal is type 3) and that instead of having a single plug type at both ends of a charger cable one should choose the best type for each side — the Scame / EV Plug would be the best option for the charger side / wall box leaving the choice for the car side open. On 22 September 2010 the companies Citelum, DBT, FCI, Leoni, Nexans, Sagemcom, Tyco Electronics joined the Alliance. As of early July 2010 the Alliance has completed the test of products from several partners and the plug and socket-outlet system are made available on the market.

While the first ACEA position paper (June 2010) has ruled out the Type 1 connector (based on the requirement of three-phase charging which is abundant in Europe and China but not in Japan and the USA) it has left open the question whether a Type 2 or Type 3 connector should be used for the uniform plug type in Europe. The rationale points to the fact that Mode 3 requires the socket to be dead when no vehicle is connected so that there can be no hazard that the shutter could protect from. The shutter protection of Type 3 connectors do only have advantages in Mode 2 allowing for a simpler charging station. On the other hand a public charging station exposes the charging socket and plugs to a harsh environment where the shutter could easily have a malfunction which is not noticeable to the electric vehicle driver. Instead the ACEA expects that Type 2 Mode 3 connectors also to be used for home charging in the second phase after 2017 while still allowing Mode 2 charging with established plug types that are already available in home environments. The impact of some jurisdictions requiring shutters is still being debated.

IEC 62196-3 - DC Charging

The 2010/2011 voting ballot of IEC 62196-2 does not contain a proposal for DC charging / Mode 4. This is scheduled for the next part of the standards series named **IEC 62196-3** with expectations for the proposal to be published in a time frame ranging from June 2012 to beginning of 2013 and the IEC expecting the functional release in December 2013. The IEC working group for TC 23/SC 23H/PT 62196-3 (max. 1000Vdc / 400A plugs) has been approved for new work. Specifications on DC charging have already begun on the national level.

The CHAdeMO specification describes high-voltage (up to 500VDC) high-current (125 Amps) automotive fast charging via a JARI Level-3 DC fast charge connector. This connector is the current defacto standard in Japan. The SAE 1772 Task Force works on a proposal for DC loading to be published in December 2011 The extension of the VDE plug ("Type 2") will be submitted directly to the IEC 62196-2 until 2013. Both China and the SAE consider using the *Type 2 Mode 4* connector for DC charging as well (the Japanese TEPCO plug housing is considerably larger than Type 2).

The VDE has supplied the National Development Plan for Electric Mobility in Germany with the expectation that charging stations for electric vehicles will be deployed in three stages - 22kW (400V 32A) Mode 2 stations are introduced in 2010-2013, the 44kW (400V 63A) Mode 3 stations to be introduced in 2014-2017 and the next generation batteries will require at least 60kW (400Vdc 150A) by 2020 allowing to charge the standard 20kWh battery pack to 80% in less than 10 minutes. Similarly the SAE 1772 DC L2 plan is sketched for charging up to 200A / 90kW.

Chapter 4

IEC 60309

Two IEC-60309-style plugs inserted into wall-mounted sockets

IEC 60309 (formerly **IEC 309**) is an international standard from the International Electrotechnical Commission for "plugs, socket-outlets and couplers for industrial purposes". The highest voltage allowed by the standard is 690 V DC or AC; the highest current, 250 A; and the highest frequency, 500 Hz. The temperature range is −25 °C to 40 °C.

IEC 60309-1 specifies general functional and safety requirements for any form of industrial high-current power connector. IEC 60309-2 specifies a range of mains power connectors with circular housings, and different numbers and arrangements of pins for different applications. IEC 60309-3 dealt with connectors for use in explosive gas environments, but was withdrawn in 1998. IEC 60309-4 concerns switched socket-outlets and connector interlocks. In the United Kingdom, this standard was first adopted as BS 4343:1968 and has since been replaced by its European equivalent EN 60309:1999, catalogued in the BSI system as BS EN 60309:1999. In the U.K. these plugs are often referred to as Commando, CEE industrial, CEEform or simply CEE plugs.

Colour Identification

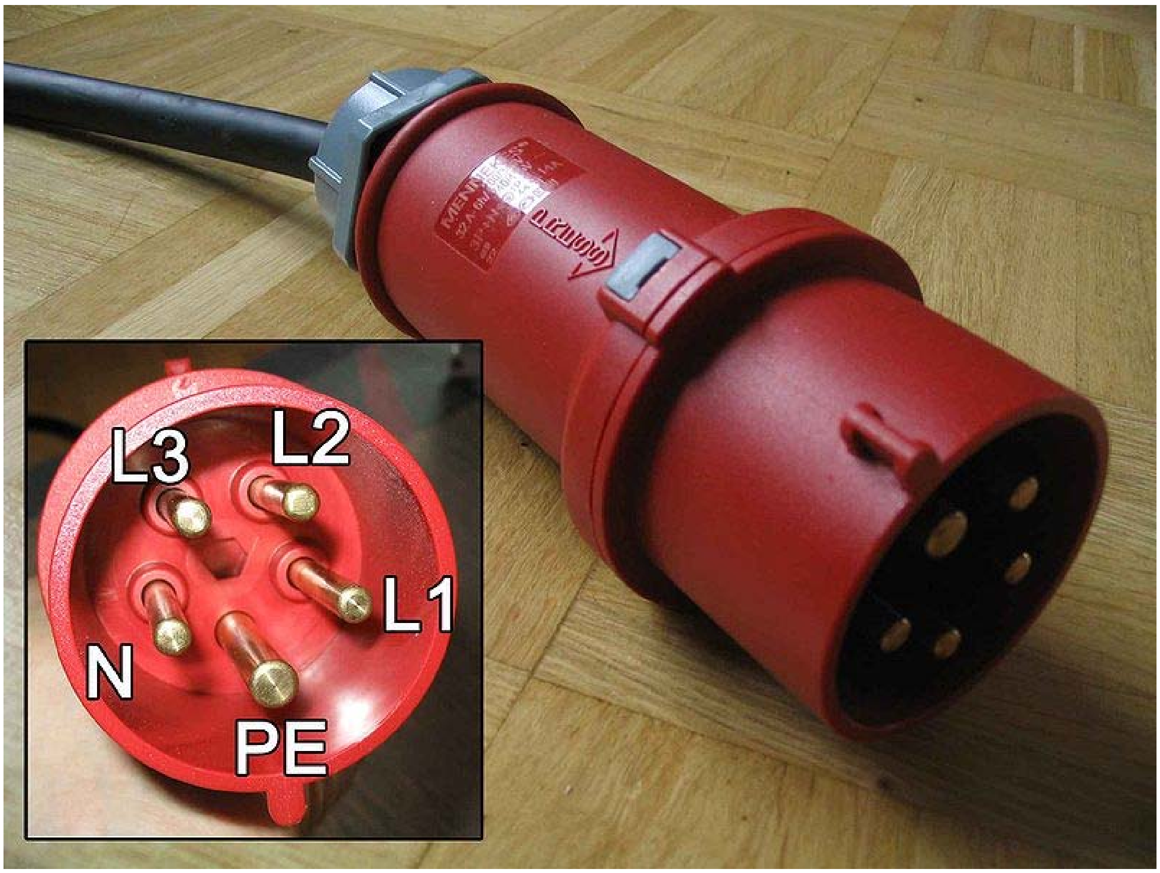
Cables with 3P+N+E connectors

IEC 60309 plugs and sockets are identified by colour. The national mains power around the world are almost always based on a frequency of 50 Hz or 60 Hz, so the colour coding refers to the voltage. Effectively the most widespread colour codes are yellow 110 V, blue 230 V and red 400 V. The black 500 V colour code can often be found on ships.

For higher frequencies beyond 60 Hz (up to 500 Hz) green connectors are used. For any other voltage and frequency a grey housing is used. This makes for the following colour coding:

Voltage Range	Frequency Range	Colour Code
020–025 V	0050/60 Hz	Purple
040–050 V	0050/60 Hz	White
100–130 V	0050/60 Hz	Yellow
200–250 V	0050/60 Hz	Blue
380–480 V	0050/60 Hz	Red
500–690 V	0050/60 Hz	Black
-	>60–500 Hz	Green
None of the above		

Keying



32 A 400 V 3P+N+E 6h (180°) plug

Mated 16 A plug and wall-mounted socket

IEC 60309-2 connectors are produced in many variants, designed so that a plug of one type can only be inserted into a socket of the same type. Different current ratings (such as 16 A, 32 A, 63 A and 125 A) are distinguished by different diameters of the circular housing.

Different voltage and frequency combinations are distinguished by the location of the ground pin (or a plastic projection called the *minor keyway*, for connectors with no ground pin), as shown in the following table. The ground pin can be in one of twelve locations spaced at 30° intervals around the circle on which all the pins lie. The various positions are referenced from the view of the open side of a socket; the 6 o'clock (180°) position is at the same angle as the *major keyway*, and is oriented downwards. The major keyway is a projection on the plug casing that aligns with a notch on the socket. The ground pin has a larger diameter than the other pins, preventing the wrong type of plug being inserted in a socket.

Ground pin location	**Pin configuration (P: power; N, neutral; E, earth or ground;)**		
	P+N+E, 2P+E	**3P+E**	**3P+N+E**
60° / 2h	>50 V 300–500 Hz green housing	>50 V 300–500 Hz green housing	>50 V 300–500 Hz green housing
90° / 3h	50–250 V DC	380 V 50 Hz 440 V 60 Hz	220/380 V 50 Hz 250/440 V 60 Hz
120° / 4h	100–130 V AC yellow housing	100–130 V AC yellow housing	57–75/100–130 V AC yellow housing
150° / 5h	277 V 60 Hz	600–690 V AC black housing	347–400/600–690 V AC black housing
180° / 6h	**200–250 V AC blue housing**	380–415 V AC red housing	**200–240/346–415 V AC red housing**
210° / 7h	480–500 V AC black housing	480–500 V AC black housing	277–288/480–500 V AC black housing
240° / 8h	250 V DC		
270° / 9h	380–415 V AC red housing	200–250 V AC blue housing	120–144/208–250 V AC blue housing
300° / 10h		>50 V, 100–300 Hz green housing	
330° / 11h		440–460 V 60 Hz red housing	250–265/440—460 V 60 Hz, red housing

- A six-phase plus earth (6P+E) version also exists.

Common plugs

The most common plug types are CEE yellow 2P+E, CEE blue 2P+E, CEE yellow 3P+E, CEE blue 3P+E and CEE red 3P+N+E. The colour of the casing refers to the regional electric power distribution at either 110/120 Volt = yellow, 230/240 Volt = blue or 400 Volt = red.

400 V phase swap plug

3P+N+E, 6h

The red 3P+N+E, 6h (180°) plug is the most common connector as it allows to connect to the widespread 400 V three phase power network that reaches many domestic places. The most common ratings are 16 A, 32 A and 63 A – only in some cases the higher specifications of 125 A and 200 A is used. Construction sites in central Europe have most of their cabling setup with this *three phase socket* type as the single phase to neutral voltage is 230 Volt usable for other devices.

The five pins are positioned in a circle with the ground connector E to be thicker and longer than the network pins. When looking at the socket the three hot pins L1, L2, L3 are supposed to make for a clockwise turn; i.e., to have their high in the order L1 first, then L2, and L3 last. As some domestic wiring does not support this assumption (which could make some motors turn backwards) many machines on construction sites feature a phase swap plug that allows to swap two pins.

Three-phase induction motors (delta connected) do not need the neutral wire to function so that there is also a four pin variant of the IEC 60309 plugs for three phase power. For their usual occurrence, it is often called farmer three phase (German "Bauerndrehstrom"). Although not actually allowed by the standard, in some wiring setups a five pin socket is attached to a four wire cable so that the neutral pin, N, is not connected. In that case 230

Volt between phase and neutral is not available but 400 Volt equipment with its usual five pin plug can be connected without an adapter.

P+N+E, 6h

16 A 230 V P+N+E 6h plug

The blue P+N+E, 6h (180°) plug is a single phase connector that is especially common in camping vehicles and sockets to be found in caravan parks and yacht marinas throughout Europe including the British isles. The *Caravan Mains Socket* has almost universally replaced other 230 V domestic plugs since they are inherently safe to standard IP44. When sockets are mounted looking downwards then the connector system reaches IP53 that is safe to use in outdoor settings under all weather conditions.

P+N+E, 4h

The yellow P+N+E, 4h (120°) plug is a single phase connector that is in widespread use on the British Isles. This socket type was used with the MK Commando which lead to all IEC 60309 sockets to be called *Commando sockets* later on.

3P+N+E, 9h

16 A 240 V 3P+E+N 9h plug and socket

The blue 3P+N+E, 9h (270°) plug is a three phase connector available in areas with both 110 V and 240 V supply systems (mains). It is prevalent in the outdoor event lighting and audio power industry as an outdoor-safe replacement for NEMA-connectors. In the United States it is not usually used for three phase power but for the high leg delta wiring of split-phase electric power (unknown in Europe). This allows one to choose single-phase AC power at either 110/120 Volt between phase and neutral or 220/240 V between phase and phase. Since these two modes do not need three phases there is a non-standard yellow four-pin connector available designed for a single-phase 110/120 or 220/240 V load.

Chapter 5

EmPower (Aircraft Power Adapter) & Brush (Electric)

EmPower (Aircraft Power Adapter)

EmPower is a 15 volt DC connector type found on many commercial airlines designed to provide power to travelers' electronic devices. The system is limited to 75 watts. The use of a special connector is to prevent laptops charging at altitude and ensure that only approved adapters can be used.

Empower Plug

Some airlines offer it only in business class or only in certain types of aircraft or flights. Travelers can buy EmPower adapters, frequently from duty-free shops at airports, that allow them to run laptops and other electronic equipment without using battery power.

Supporting airlines include:

- Almost all Air Canada flights
- Some Air France flights
- Some Air India flights
- Some British Airways flights
- Some Continental Airlines flights, used only on 767 aircraft.
- Some Delta Air Lines flights
- Some US Airways flights
- Some United Airlines flights
- Some Virgin Atlantic flights
- Almost all Cathay Pacific flights
- Others (The Seatguru web site contains more detailed information on which flights support EmPower)

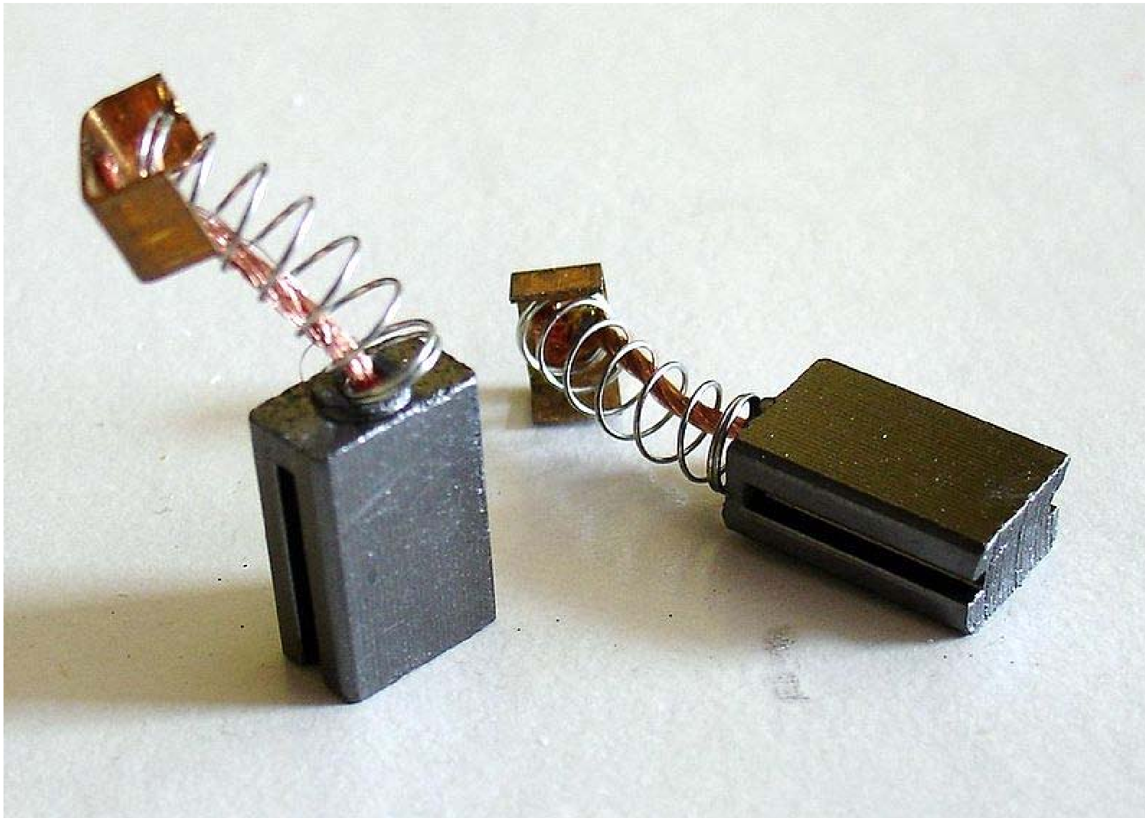
American Airlines uses cigarette lighter sockets instead of EmPower jacks. Adapters exist to convert EmPower plugs to cigarette lighter sockets and most EmPower power adapters come with these.

EmPower is a trademark registered initially by Primex Technologies (VA) and assigned to Astronics advanced electronic systems, Inc in Redmond, Washington, USA. Subsequently, the trademark has been expanded to include not just the proprietary DC 15 V connector but also the AC 110 V 60 Hz in-seat power (and video entertainment) systems.

Many laptops will not function properly at 75 W. The new AC EmPower system provides more power than the DC system. The conversion of aircraft AC 400 Hz or wild frequency power to standard AC 60 Hz is to prevent addition stresses in laptop chargers already stressed by reduced cooling at altitude. Note that laptops on this system will still charge batteries. Modern laptop batteries, however include a temperature sensor that should compensate for the reduced cooling at altitude. This new system accepts various national power plugs and most laptop chargers will function properly at AC 110 V 60 Hz even if sold in AC 230 V 50 Hz markets.

Apple offers an EmPower Magsafe power adapter for their MacBook, MacBook Pro, and MacBook Air lines of notebooks, and also includes a cigarette lighter socket adapter. However, this system only runs the computer and will not charge the computer's battery, and Apple indicates that users should not plug this device into a car's cigarette lighter outlet.

Brush (Electric)



A pair of carbon brushes

A **brush** is a device which conducts current between stationary wires and moving parts, most commonly in a rotating shaft. Typical applications include electric motors, alternators and electric generators.

Etymology

For an electric motor or generator to function, the coils of the rotor must be connected to complete an electrical circuit. To accomplish this, (copper or brass) 'slip rings' are affixed to the shaft, and springs press braided copper wire 'brushes' onto the rings which conduct the current. Such brushes provided poor commutation as they moved from one commutator segment to the next. The cure was the introduction of 'high resistance brushes' made from graphite (sometimes with added copper). Although the resistance was of the order of tens of milliohms, they were high resistance enough to provide a gradual shift of current from one commutator segment to the next. The term 'brush' has remained in use to this day. As the brushes are slowly abraded, they may have to be replaced, if this is possible.

If the copper rings are split into parts with "interlaced" connections, the arrangement is called a commutator.

Metal fiber brushes are currently being developed again. These brushes may have advantages over current carbon brushes, but have not yet seen wide implementation.

Types of carbon brushes

There are distinguished basically 3 types of carbon brushes:

1. brushes for automotive applications: DC current, voltage 12-48 V
2. brushes for household applications: AC current, voltage 110 / 220 V
3. brushes for industrial motors: both AC and DC current, various voltages

Manufacturing process

Mixing Components

Exact composition of the brush depends on the application. Graphite/Carbon powder is commonly used. Copper is used for better conductance (rare for AC applications and not on automotive fuel pumps which run on carbon commutators). Binders are mixed in so the powder holds its shape when compacted. (mostly phenol- or other resins, pitch). Other additives include metal powders, and solid lubricants like MoS_2, WS_2. Much know-how and research is needed in order to define a brush grade mixture for each application or motor.

Compacting the mixture

The brush compound is compacted in a tool consisting of upper and lower punch and die, on mechanical or hydraulic presses. In this step, depending on later processing, the copper-wire (called shunt wire) can be inserted automatically through a hole in the upper punch and fixed into the pressed brush block by the powder pressed around. After this process, the brush is still very fragile and in professional jargon called a 'green brush'.

Firing of green brushes

Heat treatment of the 'green brushes' under artificial atmosphere (usually $H_2 + N_2$). Temperatures up to 1200° C. This process is called sintering or baking. During sintering, the binders either burn off or carbonize and form a crystalline structure between the carbon, copper and other additives. Baking is followed by graphatisation (heat treatment). The heat treatment is transformed by a temperature curve exactly defined for each material mixture. Besides the mixture composition, the used temperature curve is the second big 'secret' of each brush manufacturer. After the heat treatment, the brush structure is modified in a way which makes copying of the brush nearly impossible for competing companies.

Secondary operations

Sintering causes the brushes to shrink and to bend. They must be ground to net shape. Some companies use additional treatments in order to enlarge durability of brush (and therefore application), for example impregnation on the running surface by special oils, resins and grease.

Manufacturing of carbon brushes requires a very high knowledge of materials and experience in mixture compositions. Very small changes in brush contents by just a few percent of components by weight can significantly change the properties of brushes on their applications. There are just a handful of brush developing companies in the world, which are mostly specialized on certain types of brushes.

Carbon brushes are one of the least costly parts in an electro motor. On the other hand, they usually are the key part which delivers the durability ("life-time") and performance to the motor they are used in. Their production requires very high attention to quality control and production process control throughout all steps of the production process.

Liquid metal brushes

From time to time the use of liquid metals to make contacts is researched. Drawbacks of this approach are the need to contain the liquid metal as it is usually toxic or corrosive, and power losses from induction and turbulence.

Chapter 6

SAE J1772

SAE J1772 is a North American standard for electrical connectors for electric vehicles maintained by the Society of Automotive Engineers and has the formal title "SAE Surface Vehicle Recommended Practice J1772, SAE Electric Vehicle Conductive Charge Coupler”. It covers the general physical, electrical, communication protocol, and performance requirements for the electric vehicle conductive charge system and coupler. The intent is to define a common electric vehicle conductive charging system architecture including operational requirements and the functional and dimensional requirements for the vehicle inlet and mating connector.

History

The main stimulus for the development of SAE J1772 came from the California Air Resources Board. Formerly electric vehicles like the General Motors EV1 had used inductive charger couplers. These were ruled out in favor of conductive coupling to supply electricity for recharging with the California Air Resources Board to settle on the SAE J1772-2001 standard as the charging interface for electric vehicles in California in June 2001. Avcon manufactured a rectangular connector compliant with the

SAE J1772 REV NOV 2001 specification that was capable of delivering up to 6.6 kW of electrical power.

The CARB regulation of 2001 mandated the usage of SAE J1772-2001 beginning with the 2006 model year. Later requirements asked for higher currents to be used than the Avcon connector could provide. This process led to the proposal of a new round connector design by Yazaki which allows for an increased power delivery of up to 16.8 kW delivered via single phase 120–240 V AC at up to 80 amperes. In 2008 the CARB published a draft amendment to section 1962.2 Title 13 that mandated the usage of the oncoming SAE J1772 standard beginning with the 2010 model year.

The Yazaki plug that was built to the new SAE J1772 plug standard successfully completed certification at UL. It is only certified to 30A although the standard is written to 80A. The standard specification was subsequently voted upon by the SAE committee in July 2009. On January 14, 2010 the SAE J1772 REV 2009 was adopted by the SAE Motor Vehicle Council. The companies participating in or supporting the revised -2009 standard include GM, Chrysler, Ford, Toyota, Honda, Nissan, and Tesla.

The SAE J1772-2009 connector specification has been added to the international IEC 62196-2 standard ("Part 2: Dimensional compatibility and interchangeability requirements for a.c. pin and contact-tube accessories") with voting on the final specification to close in May 2011. The SAE J1772 connector is considered a "Type 1" implementation providing a single phase coupler.

As of February 2010, the SAE J1772 committee is continuing the standardization process with designing a level 3 connector with additional DC and ground pins.

Properties

Connector

The connector is designed for single phase electrical systems with 120 V or 240 V such as those used in North America and Japan.

The round 43 mm diameter connector has five pins, with 3 different pin sizes.

- AC Line 1 and AC Line 2 - have same size power pins
- Ground Pin
- Proximity Detection and Control Pilot - have same size pin

Proximity Detection - Prevents movement of the car while connected to the charger.

Control Pilot - Communication line used to coordinate charging level between and car and the charger as well as other information.

The connector uses a 1kHz square wave at +/- 12 volts generated by the EVSE on the pilot pin to detect the presence of the vehicle, communicate the maximum allowable charging current, and control charging. The connector is designed to withstand up to 10,000 connection/disconnection cycles and exposure to all kinds of elements. Approximating one connection/disconnection cycle daily, the average connector's lifespan should be just over 27 years.

Charging

In the initial standard, two charging levels are defined.

	Voltage	Phase	Peak current
AC Level 1	120 V	Single phase	16 A
AC Level 2	240 V	Split phase	32 A (2001) 80 A (2009)

Work continues on specifications for higher-voltage, DC Fast Charge charging, which has been referred to as level 3 charging.

As of February 2010, the SAE J1772 committee is designing a DC connector based on the SAE J1772 AC connector with additional DC and ground pins, to then evaluate against other designs including the JARI/TEPCO connector used by the CHAdeMO DC fast charge protocol. There are indications SAE is also investigating a third level of AC charging.

Safety

The J1772 standard includes several levels of shock protection, ensuring the safety of charging even in wet conditions. Physically, the connection pins are isolated on the interior of the connector when mated, ensuring no physical access to those pins. When not mated, J1772 connectors have no voltage at the pins, and charging power does not flow until commanded by the vehicle.

The pins are of the first-make, last-break variety. So that if the plug is in the charging port of the vehicle and charging, and it is removed, the Control Pilot and Proximity Detection pins will break first so that the Power Pin relay in the Charging Station will be shut off and no current will flow.

Signaling

- Supply equipment signals presence of AC input power
- Vehicle detects plug via proximity circuit (thus the vehicle can prevent driving away while connected)
- Control pilot functions begin
    - Supply equipment detects plug-in electric vehicle

    - Supply equipment indicates to PEV readiness to supply energy
    - PEV ventilation requirements are determined
    - Supply equipment current capacity provided to PEV
- PEV commands energy flow
- PEV and supply equipment continuously monitor continuity of safety ground
- Charge continues as determined by PEV
- Charge may be interrupted by disconnecting the plug from the vehicle

Compatible vehicle models

- Nissan Leaf
- Chevrolet Volt
- Coda Automotive sedan
- Toyota Prius Plug-in Hybrid
- Mitsubishi i MiEV
- Honda Fit EV
- Ford Focus BEV

Compatible charging stations

The Chevrolet Volt and Nissan Leaf both come with 120V portable charging leads that couple a 120V mains plug to the car's J1772 receptacle. For 240V charging, the U.S. National Electrical Code require a coupler to be permanently wired to an AC outlet in most cases; such a coupler is commonly called a charging station. Products compatible with SAE J1772-2009 include:

- AeroVironment home charging station for the Nissan Leaf
- ClipperCreek CS-40
- Coulomb Technologies CT2100 family of charging stations
- EATON Pow-R-Station Family of Electric Vehicle Charging Stations
- ECOtality Blink home wall-mount and commercial stand-alone charging stations
- GE Wattstation available in 2011
- GoSmart Technologies ChargeSPOT line of charging stations
- GRIDbot "UP" family of networked charging stations, designed for shared access and fleet charging
- Leviton evr-green home charging stations at a range of power levels, with separate pre-wire kit that allows one to plug in to a NEMA 6 240V receptacle
- SemaConnect ChargePro Charging Stations

Competing standards

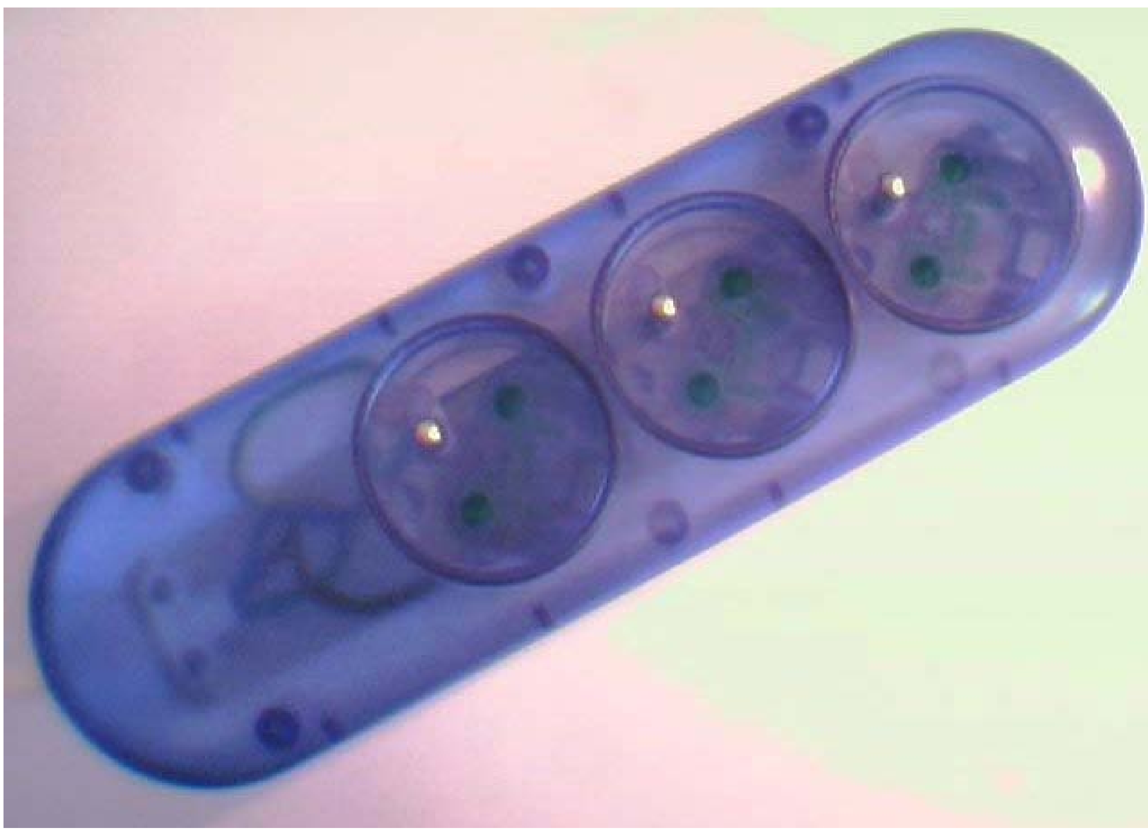
The proposal of the Mennekes connector initiated by RWE and Daimler has been added as a "Type 2" implementation to IEC 62196 providing a single and three phase coupler. The connector was specified in the VDE-AR-E 2623-2-2 standard - this connector specifies up to 63A three-phase (at 400V in Central Europe) which makes for a maximum of $63A*400V*\sqrt{3} = 43.6$ kW. Additionally the IEC 62196-2 standard specifies a "Type

3" connector providing a single and three phase coupler with shutters which takes up the proposal of the EV Plug Alliance (Scame, Schneider, Legrand). All plug types - including Type 1 (SAE), Type 2 (VDE) and Type 3 (EVPlug) - share the same specifications for the pilot pin taken from the IEC 61851-1 standard.

Tokyo Electric Power Company has developed a specification solely for level 3 high-voltage DC automotive fast charging using a different connector (JARI Level 3 DC), and formed the CHΛdeMO (stands for Charge and Move) association with Japanese automakers Mitsubishi, Nissan and Subaru to promote it.

Chapter 7

Power Strip



French/Belgian power strip

A **power strip** (also known as an **extension lead**, **power board** and by many other variations) is a strip of electrical sockets that attaches to the end of a flexible cable and allows multiple devices to be plugged in. As such it can be considered a type of trailing socket though that term is more often used for single and double cable mounted sockets. The term is also used to refer to the complete assembly with the power strip on one end and a plug on the other. Power strips are often used when many electrical devices are in proximity, especially with audio/video and computer systems. Power strips have a maximum power specified to them, such as 3500 W.

Control

Illuminated power switch on a power strip

Power strips can include a switch to turn all devices on and off. Some have outlets individually switched. Some strips can detect one device being turned on or off (say the PC itself in a computer setup) and turn everything else on or off. Remote control strips also exist to allow a group of devices to be switched remotely.

Indication

Many power strips have a neon or LED indicator light to show that power is on. Better-quality surge-protected strips often have additional lights to indicate the status of the surge protection system.

Overload protection

Overload protection is different from surge protection. Some power strips only have overload protection, which does not protect from electricity spikes (surges); it only means that the device will trip itself when too many devices are plugged into it, or when the devices plugged in require more power than the strip is rated to supply. For example, the standard rating for overload protected powerboards is 2400W in Australia, and exceeding that power will make the board trip.

An overload protected board cannot cause damage to trip distribution boards that are plugged into them, that damage can only be done by surge protected board by the way the MOV's inside them are manufactured. Both boards have a reset switch. Overload protection boards generally do not have a power light.

Energy-saving features and standby power

Some power strips have energy-saving features, which switch off the strip if appliances go into standby mode. Using a sensor circuit, they detect if the level of current flowing through the socket is in standby mode (less than 30 watts), and then they will turn off that socket. This reduces the consumption of standby power used by computer peripherals and other equipment when not in use, saving money and energy. Some more-sophisticated power strips have a master and slave socket arrangement, and when the "master" socket detects standby mode in the attached appliance's current it turns off the whole strip.

However, there can be problems in detecting standby power in appliances that use more power in standby mode (e.g. plasma televisions) and are thus not turned off in the desired way. When using a master–slave power strip, one way to avoid such problems is to plug an appliance with a lower standby wattage (like a DVD player) into the master socket, using it as the master control instead.

Also it is recommended that appliances that need a controlled shutdown sequence (e.g. many ink-jet printers) *not* be plugged into such a strip as it can damage them. It is better use the appliance's own power switch to initiate a proper shutdown sequence.

Within Europe, power strips with energy-saving features are within the scope of the Low Voltage Directive 2006/95/EC and the EMC Directive 2004/108/EC and require CE Marking.

Socket arrangement

Italian power strip with two different types of socket

In some countries where multiple socket types are in use, a single power strip can have two or more kinds of socket.

Socket arrangement varies considerably, but for access reasons there are rarely more than two rows.

If sockets on a power strip are grouped closely together, a cable with a large "wall wart" transformer at its end may cover up multiple sockets. Various designs address this problem, some by simply increasing the spacing between outlets. Other designs include receptacles which rotate in their housing, or multiple short receptacle cords feeding from a central hub. A simple DIY method for adapting problematic power strips arrangements to large "wall warts" is to use a three-way socket adapter to extend the socket above its neighbors, providing the required clearance.

Surge protection and filtering

German/Dutch surge protected power strip

Many power strips have built in surge protectors and/or EMI/RFI filters: these are sometimes described as **surge suppressors** or **electrical line conditioners**. Some also provide surge suppression for phone lines, TV cable coax, or network cable. Unprotected power strips are often mistakenly called "surge suppressors" or "surge protectors" even though they may have *no ability to suppress surges*.

Surge suppression is usually provided by one or more metal-oxide varistors (MOVs), which are inexpensive two-terminal semiconductors. They act as very high speed switches, momentarily limiting the peak voltage across their terminals. By design, MOV surge limiters are selected to trigger at a voltage somewhat above the local mains supply voltage, so that they do not clip normal voltage peaks, but clip abnormal higher voltages. In the US, this is (nominally) 120 VAC. It should be borne in mind that this voltage specification is RMS, not peak, and also that it is only a nominal value.

In most of the developed world, mains electrical circuits are (supposed to be) grounded (earthed), so there will be a live wire, a neutral wire, and a ground wire. Power strips often come with only one MOV mounted between the live and neutral wires. More complete (and desirable) power strips will have three MOVs, mounted between each possible pair of wires. Since MOVs degrade somewhat each time they are triggered, power strips using them have a limited, and unpredictable, protective life.

More elaborate power strips may use inductor-capacitor networks to achieve a similar effect of protecting equipment from high voltage spikes on the mains circuit. These more expensive arrangements are less prone to silent degradation than MOVs.

Within the EU power strips with surge suppression circuits can demonstrate compliance with the (LVD) Low Voltage Directive 2006/95/EC Official Journal of the European Union at by complying with the requirements of EN 61643-11:2002+A1. The standard covers both the performance of the surge suppression circuit and the safety. Likewise power strips with telecoms surge suppression circuits can demonstrate compliance with the LVD by complying with the requirements of EN 61643-21:2001.

Daisy chaining and surge protection

Connecting Power Strips in a daisy chain does not necessarily increase the protection they provide . Connecting them in this manner connects their surge protection trips in parallel, spreading any potential surge across each surge protector. However, due to manufacturing tolerances of the MOVs, the surge will not be spread evenly and will typically go through the one that trips first. A single surge protector with a higher surge rating is more effective and has a longer lifetime.

Safety

Multiple power strips and AC adapters

Overloading can be a problem with any sort of power distribution adaptor. This is especially likely if multiple appliances with heating elements, such as electric room heaters or benchtop cooking appliances like electric frying pans are plugged into a power strip or similar device.

In the U.S. and some other countries, power strips generally have a circuit breaker integrated to prevent overload. In the UK power strips are required to be protected by the fuse in the BS 1363 plug. Some also feature a 13A BS1362 fuse in the socket end. Whilst this is not much use if they are being fed with a 13A plug it can be very helpful for providing safe protection to adaptor leads from a higher current plug type.

Power strips are generally considered a safer alternative to "double adaptors", "two-way plugs", "three-way plugs" or "cube taps" which plug directly into the socket with no lead for multiple appliances. These low-cost adaptors are generally not fused (although more modern adaptors in the UK and Ireland are). Therefore in many cases the only protection against overload is the circuit fuse which may well have a rating higher than the adaptor. The weight of the plugs pulling on the adapter (and often pulling it part way out of the socket) can also be an issue if adaptors are stacked or if they are used with brick-style power supplies. Such adaptors, while still available, have largely fallen out of use in some countries (two and three-way adaptors are common in the UK and Ireland).

When plugging a device into a power strip, a build up of carbon can cause sparking to occur. This generally doesn't pose much of a risk, but it can bother some people.

US requirements

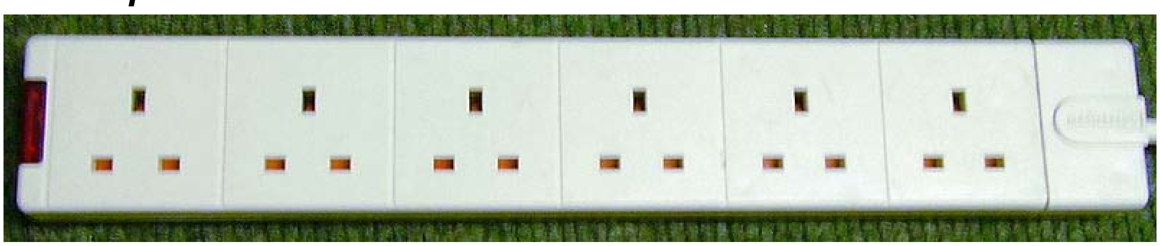
US power strip with switch

- Underwriters Laboratories standard 1363 contains requirements for *relocatable power taps*. Included in the scope section of the standard is the statement:

  1.1 These requirements cover cord-connected, relocatable power taps rated 250 V AC or less and 20 A AC or less. A relocatable power tap is intended only for indoor use as a temporary extension of a grounding alternating-current branch circuit for general use.

- National Electrical Code recognizes power strip as Multioutlet Assembly in Article 220.

UK Requirements



British power strip with neon indicator

In Europe plugs and sockets without additional control or surge protection circuits are outside the scope of the Low Voltage Directive 2006/95/EC and controlled by National regulations, and therefore must not be CE marked. In the UK the legal requirements for plugs and sockets are listed in Statutory Instrument 1994 No. 1768, The Plugs and Sockets etc. (Safety) Regulations 1994.

The regulation requires all socket outlet units to comply with the requirements of BS 1363-2 Specification for 13A switched and unswitched socket-outlets and with the requirements of BS 5733 Specification for General requirements for electrical accessories. Sockets and socket outlets do not require independent approval under the regulations. Any plug fitted to the socket outlet unit must comply with the requirements of BS 1363-1 Specification for rewirable and non-rewirable 13A fused plugs. Plugs must also be independently approved and marked in accordance with the requirements of the regulation.

If a socket outlet unit contains additional control circuits or surge protection circuits they will fall within the scope of the Low Voltage Directive 2006/95/EC and must be CE marked. Socket outlet unit with control circuits also fall within the scope of the EMC Directive 2004/108/EC.

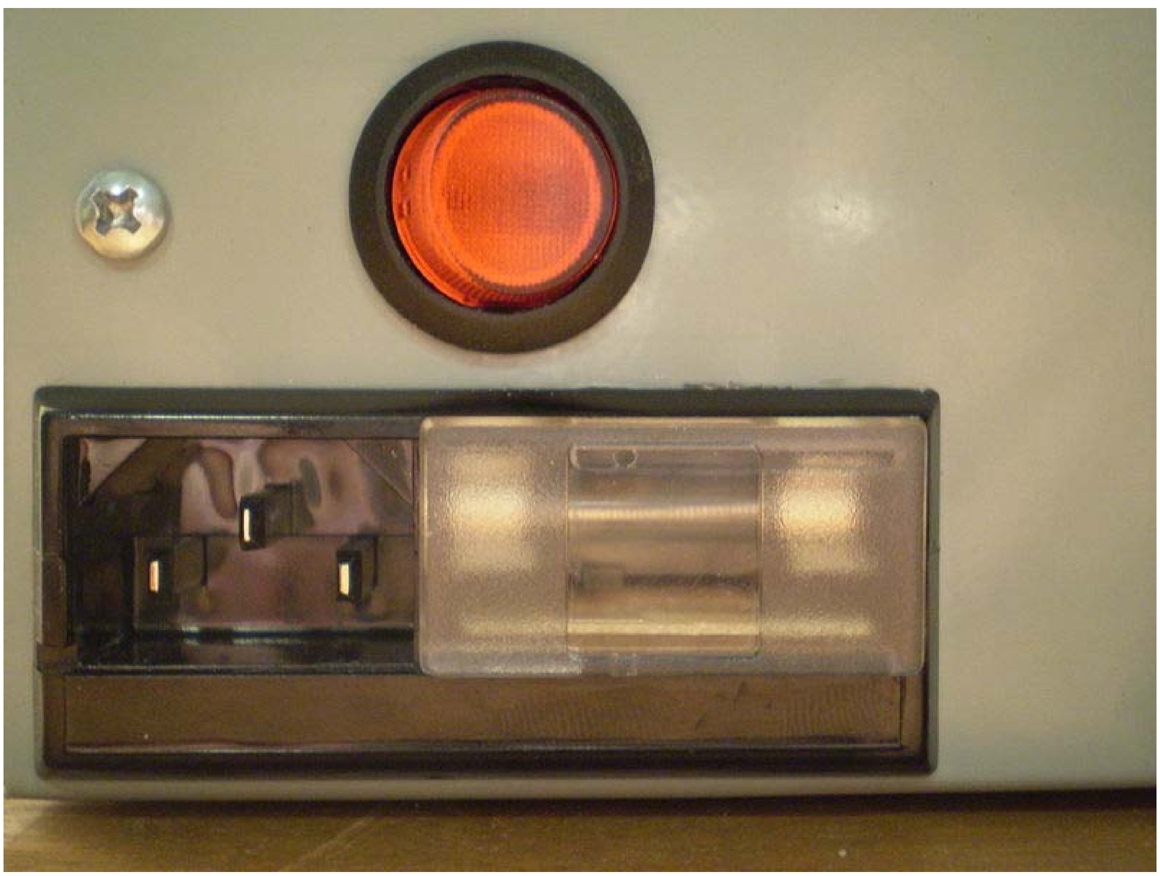
History

In 1972, the electrical "power-board" was invented by Australian electrical engineer Peter Talbot working under Frank Bannigan, Managing Director of Australian company Kambrook. The product was hugely successful, however, it was not patented and market share was eventually lost to other manufacturers.

Chapter 8

Power Entry Module, Powerlock and Slip Ring

Power Entry Module



A simple power entry module, consisting of an IEC C14 inlet connector and fuse holder. The fuse is protected by a sliding plastic cover.

A **power entry module** is an electromechanical component used in electrical appliances and electronic equipment, replacing a power inlet connector and one or more other components. They can be helpful in saving space and cutting manufacturing costs.

Power entry modules (sometimes abbreviated to PEMs, see are used to save labor in manufacturing electrical and electronic equipment powered by an external source, such as the AC powerline. They are also quite compact, taking up a small amount of space on the equipment's chassis, or printed circuit board.

AC power entry modules usually include IEC 60320 AC appliance inlets and accept power cord connectors designed to the same standard due to their wide acceptance. (These household devices and portable equipment are covered by IEC 60950.) Other components commonly found in power entry modules include line switches, fuse holders, circuit breakers, EMI/RFI line filters (designed to IEC 60939) and shields and IEC 60320 power outlets. As many as four or more components can be integrated into a power entry module.

They are designed to save labor, and frequently allow connections to the equipment circuitry using quick connect tab terminals. The AC inlet connector allows use of a separate, detachable AC line cord that has the type of wall plug favored by the locality. IEC 60320 AC inlet connectors can handle either 120 or 250 volts.

Since most power entry modules connect to the AC powerline, they are subject to safety standards set by Underwriters Laboratories (UL), the Canadian Standards Association (CSA), Verband der Elektrotechnik, Elektronik und Informationstechnik (VDE), and many other safety standards agencies such as BSI. Power entry module manufacturers take on the responsibility of producing power entry module products in such a way that they meet the standards of one or more of these safety standard agencies, so equipment manufacturers using them needn't worry about safety issues. They also pay testing labs to test their products against the safety standards, so the products can carry the agency's approval mark. AC Power entry modules often have dielectric strengths of 2000 volts or more, and can handle currents of up to 10 to 20 amperes at 250 volts maximum. Exceeding these ratings can cause unsafe operation and must be avoided.

Medical devices can and do take advantage of power entry modules. Power entry modules are available with EMI/RFI filters with very low leakage current ratings, even those suitable for direct patient contact in accordance with UL 544 and IEC 60601-1. Shock-safe fuseholders have also been integrated into power entry modules. These devices require a tool to remove the fuse for replacement.

DC power entry modules have been less common, but are finding popularity with equipment manufacturers, especially those that supply equipment in both AC- and DC-powered versions. The DC-powered versions of such equipment are frequently used in telecom central office applications.

Newer units are also available rated water resistant at IP65 with seal protection at the panel opening, around the fuse holders when provided, and between the inlet housing and connector pins.

Powerlock

Powerlock, also referred to as: **power-loc** and **power-lok**, is a single pole electrical connector used by the entertainment industry for high current applications, similar to but considered safer than camlock connectors. Originally developed by Litton Veam in the mid-1990s the Powerlock connector introduced safety features that protected the user against electric shock and making potential fatal connection errors. Such features included finger proof electrical contacts, colour coded insulators, mechanical keys and locking devices.

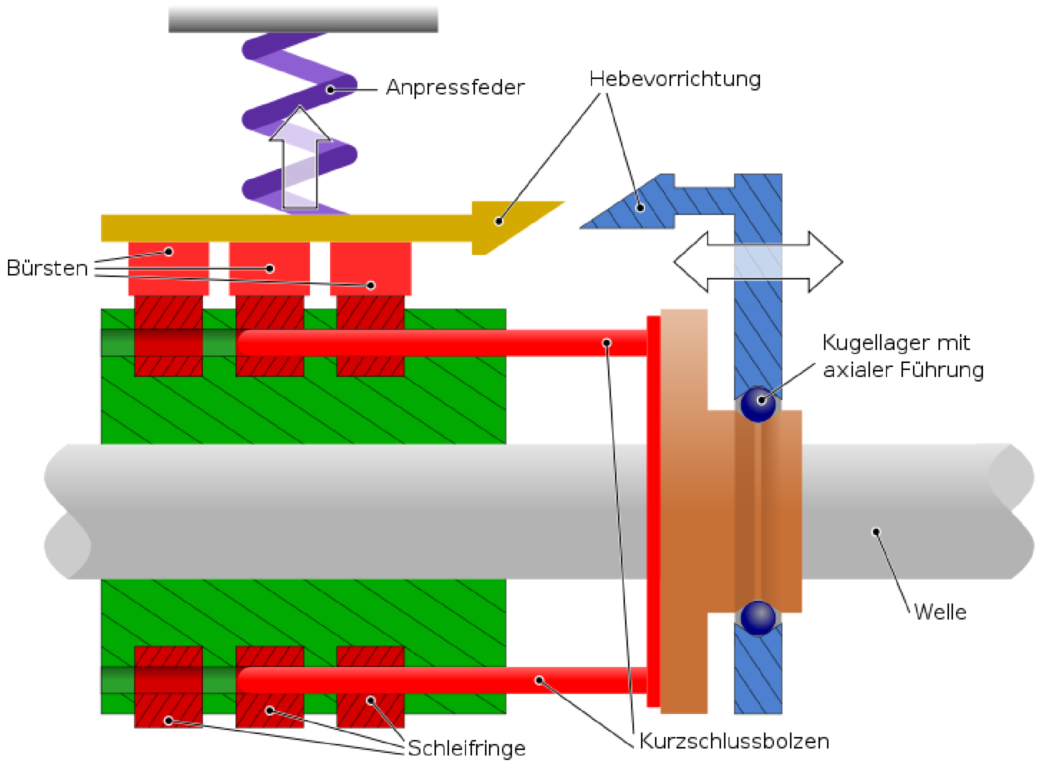
The original Powerlock is available in 400A and 600A versions. All versions can be used for single phase and, much more commonly, three phase applications. Three phase connections require five separate cables.

The Powerlock style connector can also be used with Sequential Mating Units. These units allow for safe and controlled connection of the single core power cables. These units control the sequence of connection to ensure Earth and Neutral connections are made before phase connections can be made.Thereby ensuring high levels of safety through eliminating connection errors and ensuring safety circuits are always connected.

Applications

Powerlock connectors are typically used to connect to generators. Powerlock inputs are available on many large dimmers and on large power distribution units.

Slip Ring



Sketch of an electric motor with slip rings

A **slip ring** (in electrical engineering terms) is a method of making an electrical connection through a rotating assembly. Slip rings, also called **rotary electrical interfaces**, **rotating electrical connectors**, **collectors**, **swivels**, or **electrical rotary joints**, are commonly found in electric motors, electrical generators for AC systems and alternators and in packaging machinery, cable reels, and wind turbines. One of the two rings is connected to one end of the field winding and other one to the other end of the field winding.

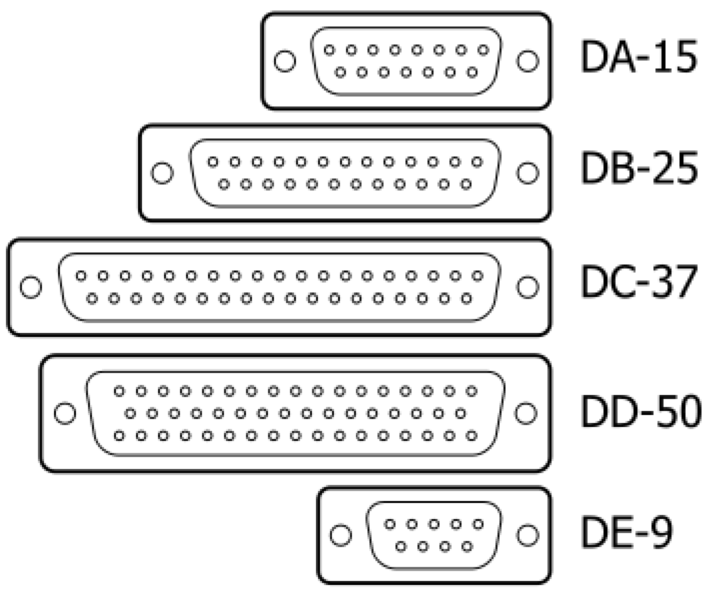
A slip ring is a rotary coupling used to transfer electric current from a stationary unit to a rotating unit. This is accomplished by either (1) holding the center core stationary while the brushes and housing rotate around it, or (2) holding the brushes and housing stationary while the center core is allowed to rotate..

This system is similar to the brushes and commutator, found in many types of DC motors. While commutators are segmented, slip rings are continuous, and the terms are not interchangable. Slip rings can also be used where electrical power or signals need to be transferred to a rotating device, such as an aerodrome beacon, rotating tank, power shovel, radio telescope or heliostat. Rotary transformers are often used instead of slip rings in high speed or low friction environments.

Mercury-wetted slip rings, noted for their low resistance and stable connection use a different principle which replaces the sliding brush contact with a pool of liquid metal molecularly bonded to the contacts. During rotation the liquid metal maintains the electrical connection between the stationary and rotating contacts. However, the use of mercury poses safety concerns, as it is a toxic substance. If a slip ring application involves food manufacturing or processing, pharmaceutical equipment, or any other use where contamination could be a serious threat, the choice should be precious metal contacts. Leakage of the mercury and the resultant contamination could be extremely serious.

Chapter 9

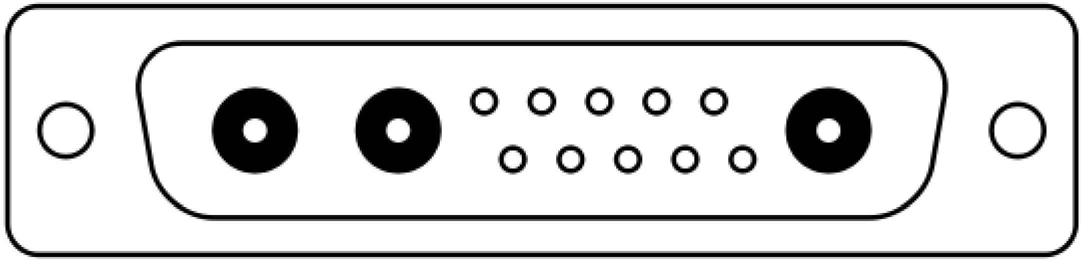
D-Subminiature



DA, DB, DC, DD, and DE sized connectors

The **D-subminiature** or **D-sub** is a common type of electrical connector used particularly in computers. At the time of introduction they were some of the smaller connectors used on computer systems.

Description and nomenclature



The DB13W3 Connector with 3 coaxial connections and ten ordinary pins

Male 13W3 Plug

DE-15F, used for VGA, SVGA and XGA ports

A D-sub contains two or more parallel rows of pins or sockets usually surrounded by a D-shaped metal shield that provides mechanical support, some screening against electromagnetic interference, and ensures correct orientation. The part containing pin contacts is called the *male connector* or *plug*, while that containing socket contacts is called the *female connector* or *socket*. The socket's shield fits tightly inside the plug's shield. The shields are connected to the overall screens of the cables (when screened cables are used). This creates an electrically continuous screen covering the whole cable and connector system.

D-subminiature connectors were invented by ITT Cannon, part of ITT Corporation, in 1952. Cannon's part-numbering system uses a D as the prefix for the whole series, followed by a letter denoting the shell size (A=15 pin, B=25 pin, C=37 pin, D=50 pin, E=9 pin), followed by the actual number of pins, followed by the gender (P=plug, S=socket). For example, DB25 denotes a D-sub with a 25 position shell size and a 25 position contact configuration. The contacts in these connectors are spaced approximately 0.109 inches (2.77 mm) apart with the rows spaced 0.112 inches (2.84 mm) apart. (To be precise, the horizontal contact spacing is $326/3000 = 108\frac{2}{3}/1000 = 0.108\overline{6}$ inch per row, with the second row offset by half that amount.)

Cannon also produced "hybrid" D-subs with larger positions in place of some of the normal pin positions that could be used for either high-current, high-voltage, or co-axial inserts. The DB13W3 variant was commonly used for high-performance video connections; this variant provided 10 regular (#20) pins plus three coaxial contacts for the red, green, and blue video signals. Hybrid D-subs are currently being manufactured in a broad range of configurations by other companies, including Amphenol, Conec, Teledyne Reynolds, Assmann Electronics, Norcomp, Cinch, 3M, and Tyco. Variations include current ratings up to 40A, operating voltages as high as 13,500V, and waterproof variants that are certified to IP67 standards.

In the photograph below, the connector on the left is a 9-pin male (DE-9M) connector plug, and the one on the right is a 25-pin female (DB-25F) socket. The hexagonal pillars at either end of each connector have a threaded stud (not visible) that passes through flanges on the connector, fastening it to the metal panel. They also have a threaded hole that receives the jackscrews on the cable shell, to hold the plug and socket together.

Because PCs first used DB25 connectors for their serial and parallel ports, when the PC serial port began to use 9-pin connectors, they were often called "DB9" instead of DE9, due to the lack of understanding that the "B" represented a shell size. It is now common to see DE9 connectors sold as "DB9" connectors. *DB-9* is nearly always intended to be a 9 pin connector with an *E* size shell.

The non-standard 23-pin D-sub connectors for external floppy drives and video output on most of the Amiga computers are usually referred to as DB23, even though their shell size is two pins smaller than ordinary DB sockets.

There are now D-sub connectors which have the original shell sizes, but more pins, and the names follow the same pattern. For example, the DE15, usually found in VGA cables, has 15 pins, in three rows, in an E size shell. The pins are spaced 0.090 inch horizontally and 0.078 inch vertically.) The full list of connectors with this pin spacing is: DE15, DA26, DB44, DC62, and DD78. Alternatively, following the same confusion mentioned above in which all D-sub connectors are called "DB", these connectors are often called DB15HD, DB26HD, DB44HD, DB62HD, and DB78HD, where the "HD" stands for "high density". They all have 3 rows of pins, except the DD78, which has 4.

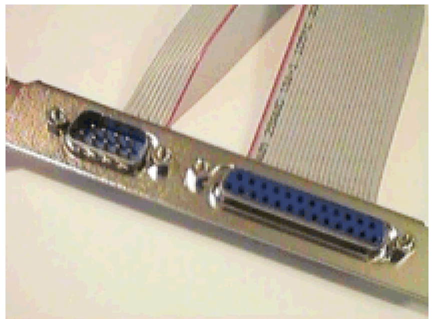
A series of D-sub connectors with even denser pins is called "double density", and consists of DE19, DA31, DB52, DC79, and DD100. They have 4 rows of pins.

There is yet another similar family of connectors that is easy to confuse with the D-sub family, but is not part of it. These connectors have names like "HD50" and "HD68", and have a D-shaped shell but the shell is about half the width of a DB25. They are common in SCSI attachments.

The suffixes M and F (male and female) are sometimes used instead of the original P and S (plug and socket).

The original D-subminiature connectors are now defined by an international standard, DIN 41652. The United States military also specifies D-subminiature connectors using the MIL-DTL-24308 standard.

Typical applications



D-sub connectors.
Left: DE9M   Right: DB25F.

Communications ports

The widest application of D-subs is for RS-232 serial communications, though the standard did not make this connector mandatory. RS-232 devices originally used the DB25 25-pin D-sub, but for many applications the less common signals were omitted, allowing a DE9 9-pin D-sub to be used. The standard indicates a male connector for terminal equipment and a female connector for modems, but many variations exist. IBM PC compatible computers tend to have male connectors at the device, while modems have female connectors. Early Apple Macintosh models used DE9 connectors for RS-422 serial interfaces (which can operate as RS-232). Later Macintosh models used 8 pin miniature DIN connectors instead.

On PCs, 25-pin and (beginning with the IBM-PC/AT) 9-pin plugs are used for the RS-232 serial ports; and 25-pin sockets are used for the parallel printer ports (instead of the Centronics socket found on the printer itself).

25-pin sockets on Macintosh computers are typically SCSI connectors (again in contrast to the Centronics C50 connector typically found on the peripheral), while older Sun hardware uses DD50 connectors for FastSCSI equipment.

Many uninterruptible power supply units have a DE9F connector on them, in order to signal to the attached computer via an RS-232 interface. Often these do not send data serially to the computer but instead use the handshaking control lines to indicate low battery, power failure or other conditions. Such usage is not standardized between manufacturers and may require special cables to be supplied.

Network ports

The RS-422 capability of Macintosh serial ports was used for AppleTalk/LocalTalk networking. (This is also true of Apple IIgs—though it never used D-sub connectors for this.)

DE9 connectors are also used for some token ring and other computer networks. The DA15S was also used for the AUI connectors included on Ethernet cards in the 1980s and 1990s, albeit with a sliding latch to lock the connectors together instead of the usual hex studs with threaded holes. (The sliding latch was intended to be quicker to engage and disengage and to work in places where jack-screws could not be used for reasons of component shape.

Computer video output

A female 9-pin connector on an IBM compatible personal computer may be a video display output: monochrome, CGA, or EGA. Even though these all use the same connector, the displays cannot all be interchanged and monitors or video interfaces may even be damaged if connected to an incompatible device using the same connector. Later analog video (VGA and later) adapters replaced these connectors by DE15 15-pin high-density sockets, which have three rows of five contacts each in the space that was previously occupied by two rows of contacts, five in the top row and four in the bottom row. Other common names for DE15 connectors are HD15, where HD stands for High Density, and (less accurately) DB15 and DB15HD.

Many Apple Macintosh models (beginning with the Macintosh II) used DA15 sockets for analogue RGB video out. Just prior to this, the Apple IIgs used the same connector for the same purpose, but in a non-compatible way. A digital (and thus also incompatible) RGB adapter for the Apple IIe also used a DA15F. And the Apple IIc used a DA15F for an auxiliary video port which was not RGB, but provided the necessary signals to derive RGB.

Game controller ports

Starting in the late 1970s the Atari 2600 game console used DE9 connectors without the pair of fastening screws (male on the system, female on the controller) for its game controller connectors. In the years following, various video game consoles and home computers adopted the connector for their own game ports, though they were not all interoperable. The common wirings supported digital connections for up, down, left, right, and one or two buttons. Some systems supported connecting a pair of analog potentiometers, or paddles, and on some computers a computer mouse or a light pen was also supported via the game port. These devices were much like joysticks in that they were not typically interchangeable between different systems.

Systems utilizing the DE9 connector for their game port included the Atari 8-bit and ST lines; the Commodore VIC-20, 64, 128, and Amiga; the Amstrad CPC (which employed daisy-chaining when connecting two Amstrad-specific joysticks); the MSX, Sharp X68000, and FM-Towns, predominantly used in Japan; the Sega Master System and Sega Genesis; and the Panasonic 3DO. The Sinclair ZX Spectrum lacked a built in joystick connector of any kind but aftermarket interfaces provided the ability to connect DE9 joysticks.

Many Apple II computers also used DE9 connectors for joysticks, but they had a female port on the computer and a male on the controller, used analog rather than digital sticks, and the pin-out was completely unlike that used on the aforementioned systems. DE9 connectors were not used for game ports on the Apple Macintosh, Apple III, IBM PC systems, or most newer game consoles.

DA15S connectors are used for PC joystick connectors, where each DA15 connector supports two joysticks each with two analog axes and two buttons. In other words, one DA15S "game adapter" connector has 4 analog potentiometer inputs and 4 digital switch inputs. This interface is strictly input-only, though it does provide +5V DC power. Some joysticks with more than two axes and/or more than two buttons use the signals designated for both joysticks. Conversely, Y-adapter cables are available that allow two separate joysticks to be connected to a single DA15 game adapter port; if a joystick connected to one of these Y-adapters has more than two axes or buttons, only the first two of each will work.

The IBM DA15 PC game connector has been modified to add a (usually MPU-401 compatible) MIDI interface, and this is often implemented in the game connectors on third-party sound cards, particularly the Sound Blaster line from Creative Labs. The "standard" straight game adapter connector (introduced by IBM) has three ground pins and four +5V power pins, and the MIDI adaptation replaces one of the grounds and one of the +5V pins, both on the bottom row of pins, with MIDI In and MIDI Out signal pins. (There is no MIDI Thru provided.) Creative Labs introduced this adaptation.

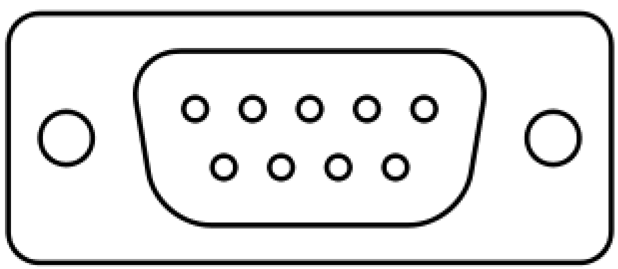
Other

A male PCB-mounting DD50 D-sub connector

The complete range of D-sub connectors also includes 15-pin DA15s (one row of 7 and one of 8); 37-pin DC37s (one row of 18 and one of 19); and 50-pin DD50s (two rows of 17 and one of 16), the last two being used in industrial products.

The early Macintosh, and late Apple II computers used an obscure 19 pin D-sub for connecting to external floppy disk drives. And the Commodore Amiga used an equally unusual 23-pin version for both its video output and for connecting an external floppy disk drive.

A male DE-9 connector.



TASCAM used DB25 connectors for their multi-track recording audio equipment (TDIF), and Logitek Audio later did the same for its broadcast consoles, though with different pinouts. A few patch panels have been made which have the DB25 connectors on the back with phone jacks (or even TRS jacks) on the front, however these are normally wired for TASCAM, which is more common outside of broadcasting.

In broadcast and professional video, "parallel digital" is a digital video interface that utilizes DB25 connectors, per the SMPTE 274M specification adopted in the late 1990s. The more common SMPTE 259M "serial digital interface" (SDI) utilizes BNC connectors for digital video signal transfer.

Types and variants

D-sub connectors exist in at least five types, differentiated by the method used to attach wires to the contacts. These are *solder-cup* or *solder-bucket*, *insulation displacement*, *crimp*, *PCB pins*, and *wire wrap*.

- Solder-bucket contacts have a cavity into which the stripped wire is inserted and hand-soldered (a somewhat tricky process especially to do alone as the wire can easily pop out of the bucket whilst soldering unless held there).
- Insulation displacement contacts (IDC) allow a ribbon cable to be forced onto sharp tines on the back of the contacts; this action pierces the insulation of all the wires simultaneously. This is a very quick means of assembly whether done by hand or automatically but requires use of flat ribbon cable which can be awkward to handle and makes it difficult to make cables with different connections at each end.
- Crimp contacts are assembled by inserting a stripped wire end into a cavity in the rear of the contact, then crushing the cavity using a *crimp tool* causing it to grip the wire tightly at many points. The crimped contact is then inserted into the connector where it locks into place. Individual crimped pins can be removed later with a tool inserted into the rear of the connector. This "rear release" feature is valuable when pins are damaged or modifications must be made to the circuits.
- PCB pins as the name suggests are intended to be soldered directly to a printed circuit board and not to a wire. These connectors are frequently mounted at a right-angle to the PCB allowing a cable to be plugged into the edge of the PCB assembly. Blocks containing multiple stacked D connectors (and sometimes other connectors too) are nearly always seen on ATX (or variants thereof) PC motherboards but aren't generally seen elsewhere.
- Wire wrap connections are made by wrapping solid wire around a square post with a wire wrap tool. This type of connection is usually used in prototyping.

A smaller type of connector derived from the D-subminiature, and about half the linear size, is called the microminiature D, or micro-D, which is a trademark of ITT Cannon. This connector is used in industrial instrumentation products. A few manufacturers make nano-D connectors, which are about half the size again.

Usage

The 25 pin D-sub connector is occasionally used in the recording studio industry for multi-channel analog audio and AES Digital audio.

The D-sub connector family is now in decline for general usage in the computer industry, due to size and cost. For portable devices such as PDAs, MP3 players or mobile phones, the D-sub connector is usually too large to fit. In the laptop computer sector, where weight and size are crucial, many models no longer include D-subs. Even small form factor desktop PCs may find D-sub connectors too large for their value.

Because of the relatively complex shapes and assembly, especially the shaped metal D shield, and screws and nuts for physical securing, D-sub connectors are now quite expensive compared to other, mostly simpler, common connectors. In the retail PC world where margins are very thin, these connectors are a natural target for removal.

The physical design is not friendly to consumer plug-and-play applications. Thin metal pins, especially in higher-density connectors, are easily bent or broken, especially when frequently plugged in "blind" behind equipment. The need to tighten screws for a secure connection is cumbersome. Although ESD and EMI resistant D-sub connectors exist, the fundamental design was never intended to protect from electrostatic discharge or electromagnetic interference or facilitate very high frequency interconnections.

For video purposes, the DE15HD connector is in the process of being replaced by DVI and HDMI connectors. A notable exception to this replacement is on the many analog CRT monitors still in use - the analog version of the DVI connector is similar in price and more complex than the D-sub, so adoption in this field is slow.

For the majority of other consumer applications, D-sub serial and parallel connectors have been replaced by the physically much simpler and cheaper IEEE 1394 (FireWire), SATA, USB or Ethernet connectors.

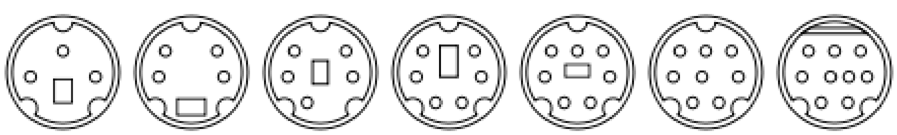
Chapter 10

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.

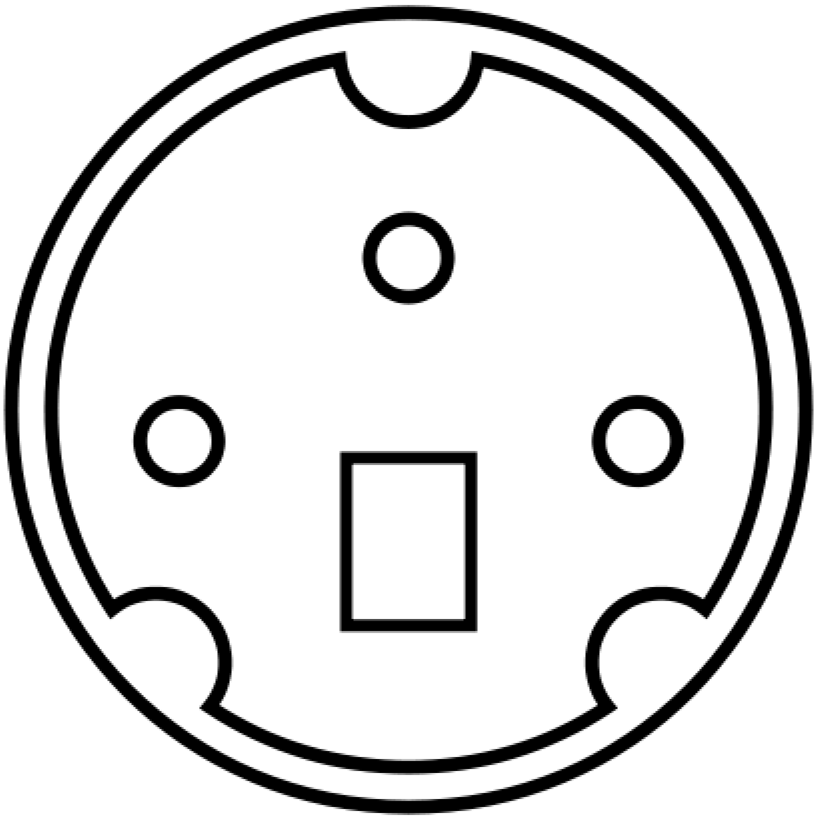


(The plug or male connectors shown, as visible when unplugged looking into the connector.)

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.

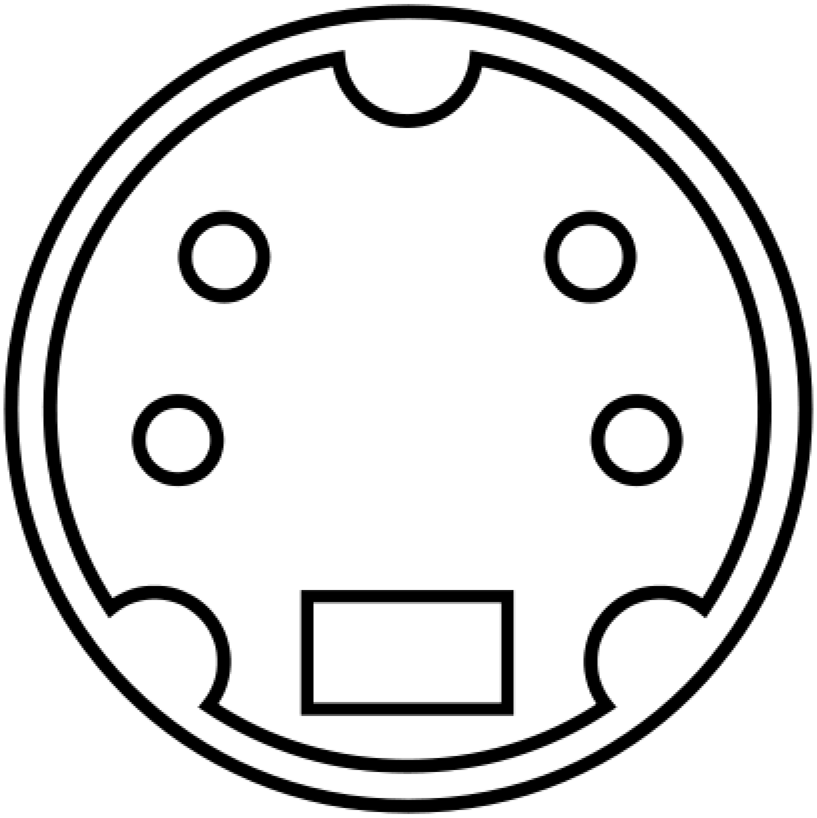
3-pin



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

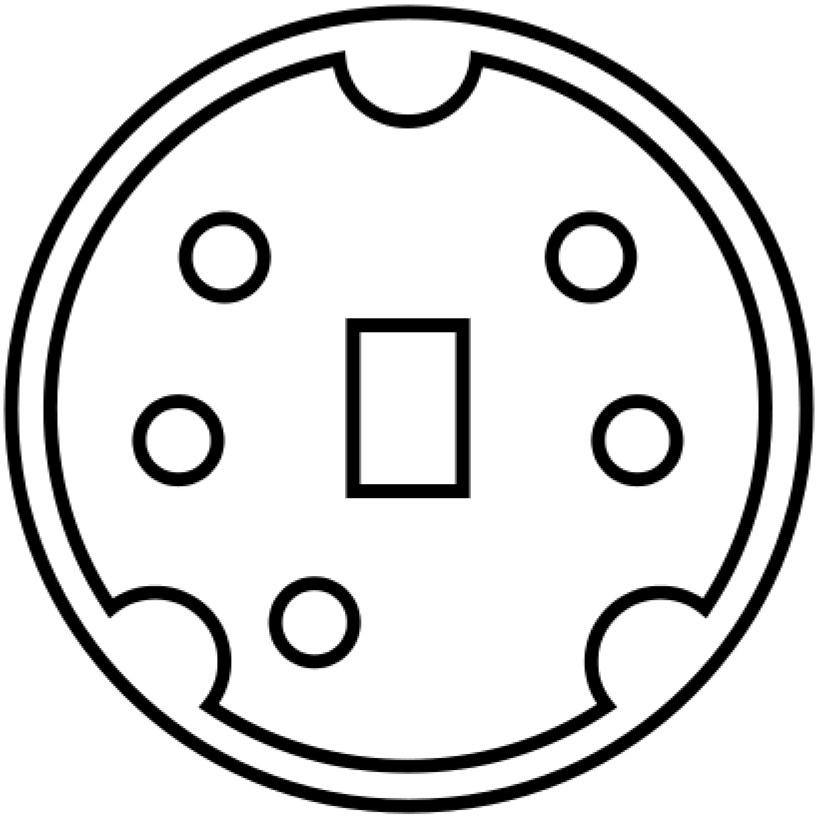
4-pin

4 pin mini-DIN for S-Video



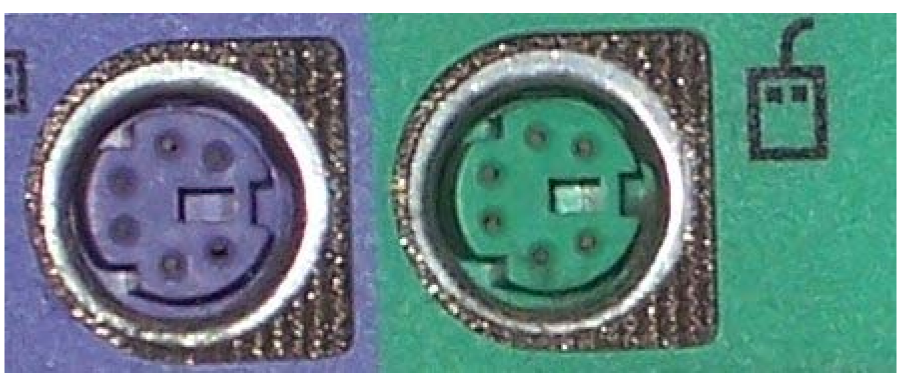
- Apple Desktop Bus (Pinout diagram)
- S-Video (Pinout diagram)
- Thomson SpeedTouch 605 Console Serial Port / DSL Router (pinout diagram)
- Low voltage power supplies like the Seagate Pushbutton External Drive Power Supply

5-pin

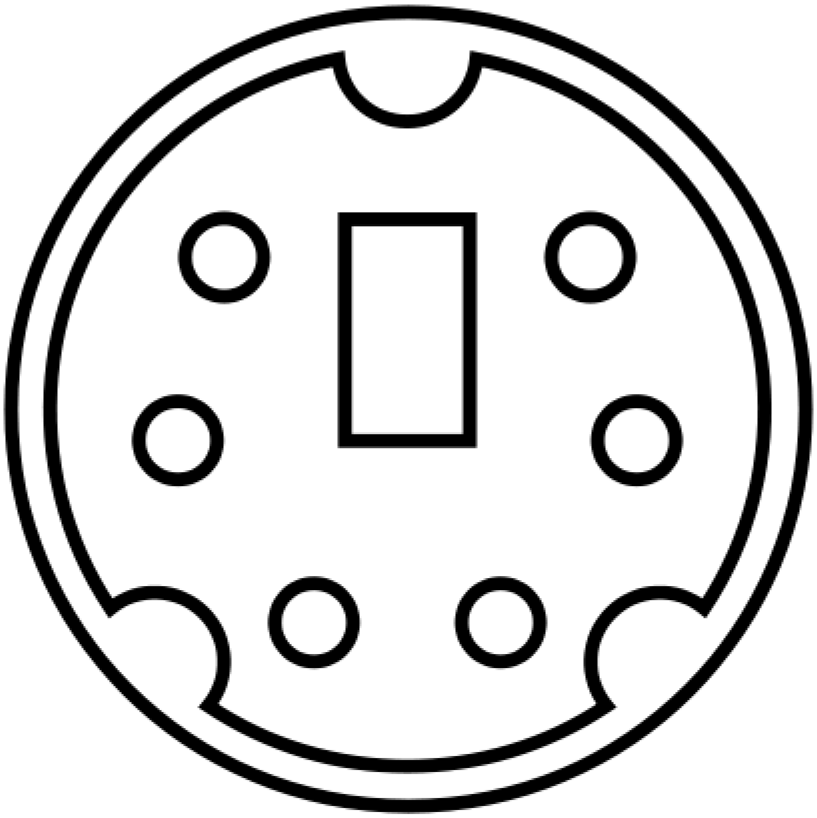


- Low-voltage power supply input connector on various pieces of equipment
- SONY LANC camcorder control interface (Pinout diagram)
- 5-pin MIDI input and output connectors used by the Creative Technology Sound Blaster X-Fi Front I/O Panel and the Creative LivedriveII (pinout diagram)
- Altec Lansing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

6-pin



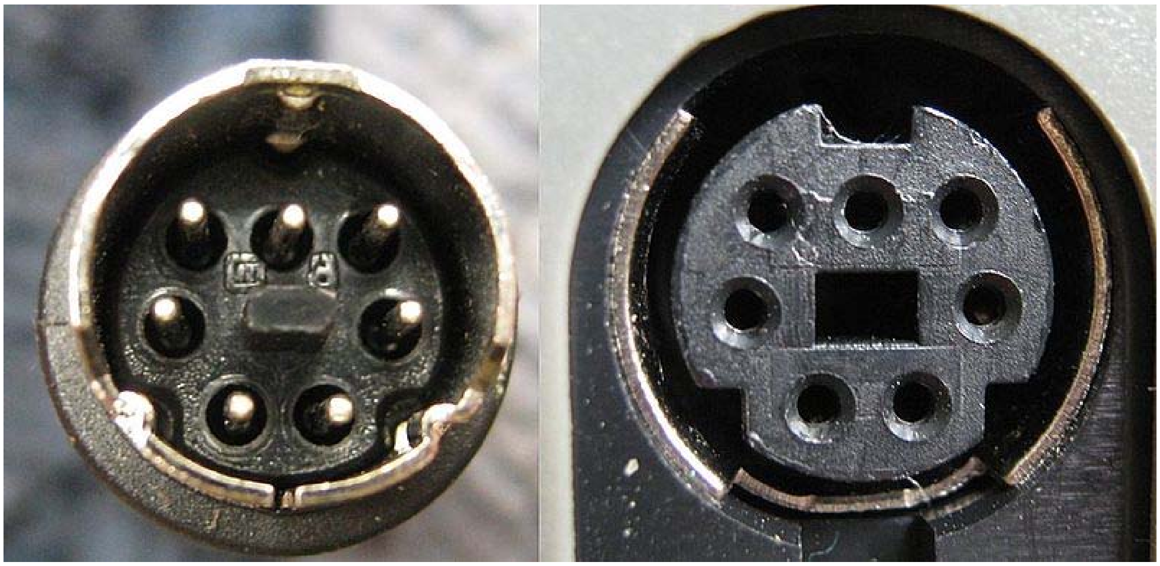
The color-coded PS/2 connection ports (purple for keyboards and green for mice)



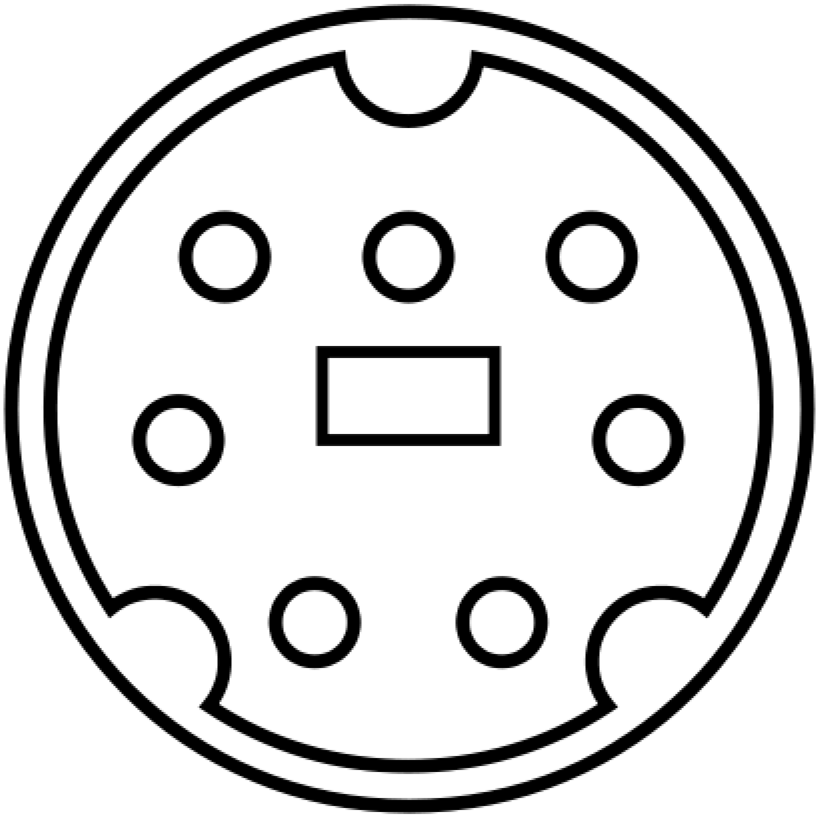
- IBM PC compatible PS/2 keyboard/mouse connector
- Amateur radio TNC modem-radio interface
- Power supply DC output for some electronic devices
- Acorn Archimedes keyboard
- Blitz DVD screen for cars
- Klipsch 2.1 channel audio system (2 speakers/1 subwoofer)
- Leadtek and VisionTek GeForce2 Ti cards 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

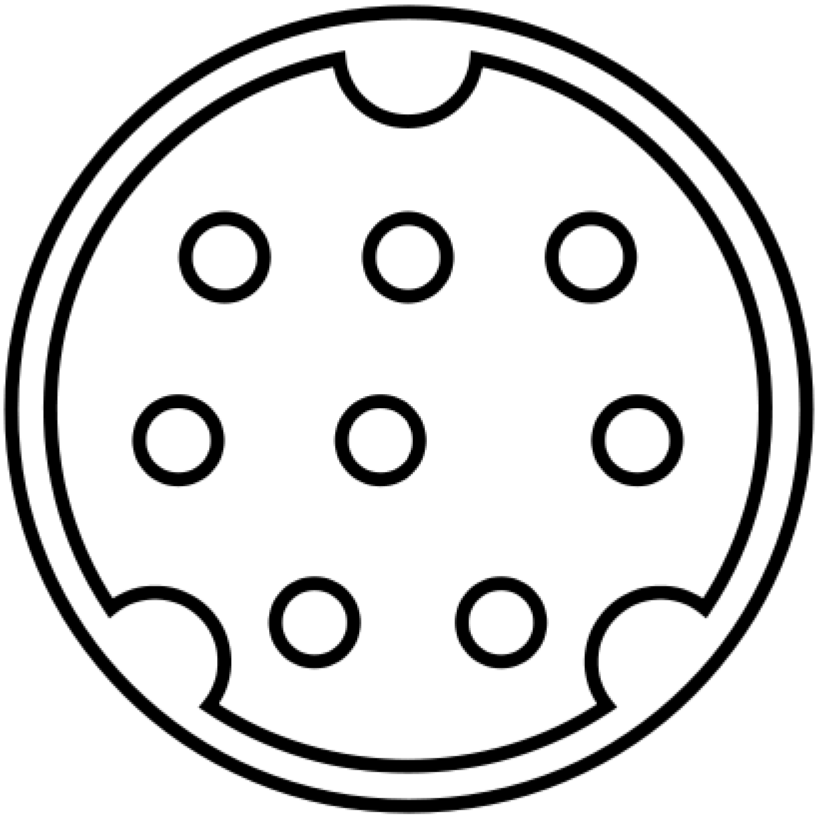


Example of the standard 7 pin mini-DIN connectors. These are from a Commodore 1531 datasette and its adapter.



- 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

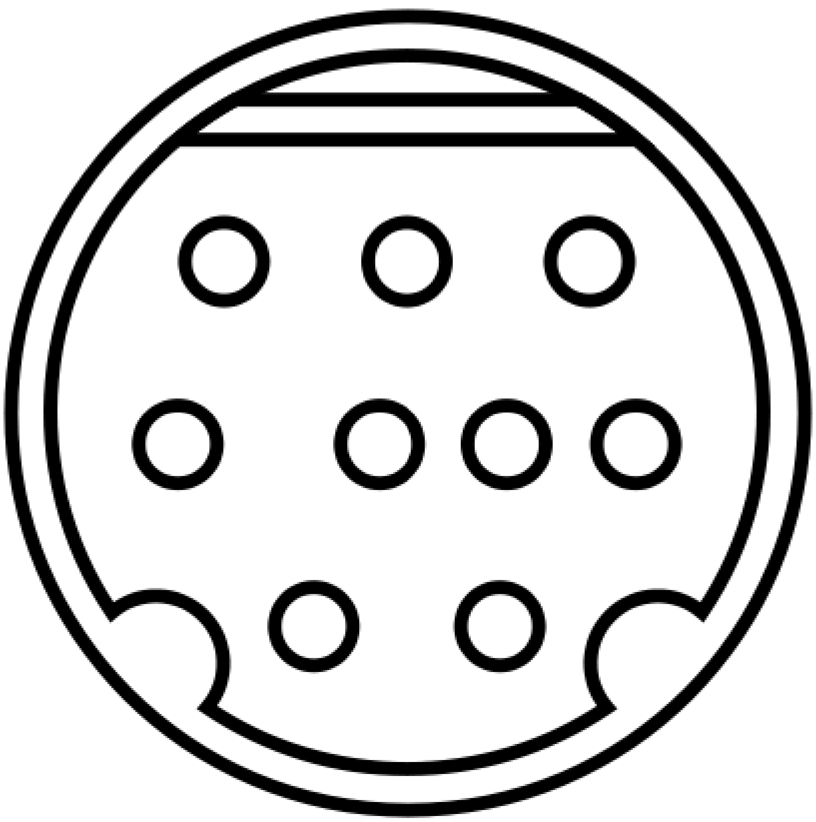
8-pin



- 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

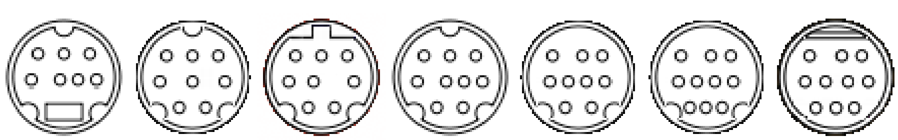
These devices may or may not be mini-DIN 9:

- 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

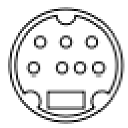
Several non-standard sockets are designed to mate with standard mini-DIN plugs. These connectors provide extra conductors, and are used to save space by combining functions in one connector that would otherwise require two standard connectors.

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.

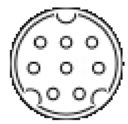
The use of the extra three pins varies from manufacturer to manufacturer, but commonly includes a composite video output which is available using the manufacturer's proprietary adapter. Alternatively a YPbPr signal may be provided. Later Dell laptops provide an SPDIF audio signal. Some proprietary adapters 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

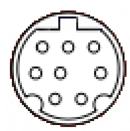
- Aspenhome iPod Dock
- Hauppauge WinTV
- Samsung X20 notebook

8-pin



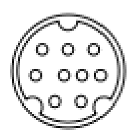
- Amstrad CPC6128 Plus Monitor
- SGI Personal IRIS 4D/30, 4D/35, Indigo, Indy, and Indigo2 Serial Port

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.)

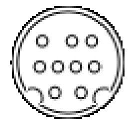
- 9-pin Apple GeoPort connector

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.

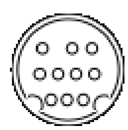
9-pin (b)



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

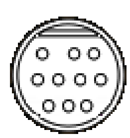
- Hypercom T7 Eftpos terminal
- Nvidia GeForce S-Video 9 pin to YPbPr (YCbCr)
- Sigma EM8300 Video Card
- Cambridge Soundworks DTT2500 Digital
- Speed-link Medusa Amplifier
- Creative Inspire T7700 Speakers - Wired control unit connector.
- Creative X-fi elite pro unit - Cable to connect to the speakers 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 11

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.

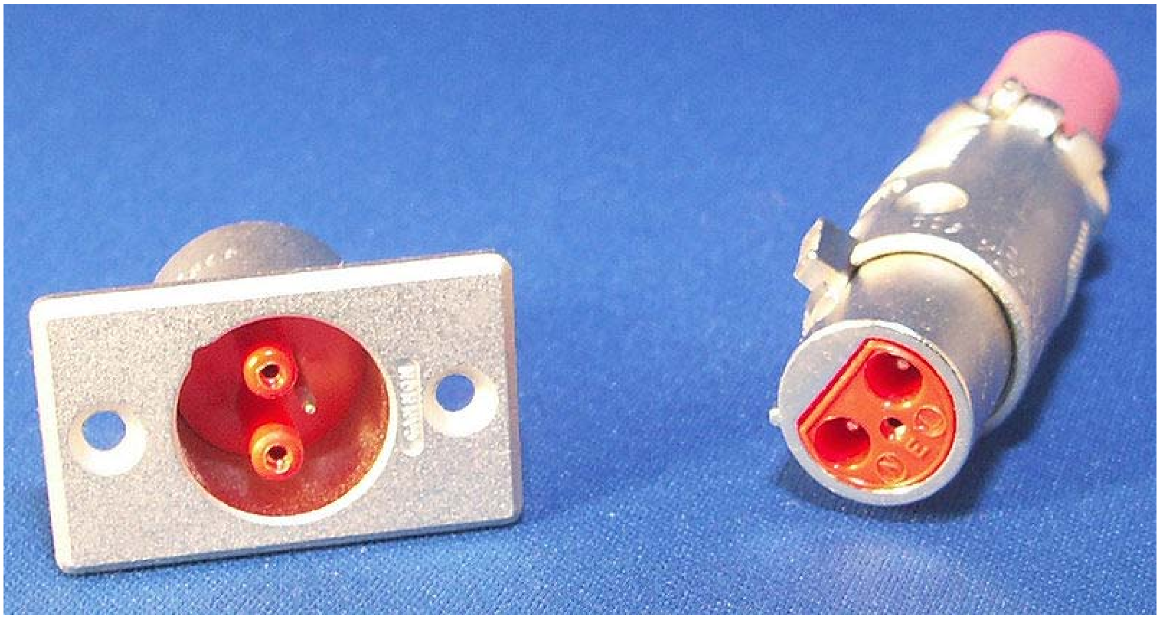
Many other types of connectors using the XLR type shell exist, with various pin numbers. Most notable are two now obsolete three-pin patterns manufactured by ITT Cannon. The *power Cannon* (also called the *XLR-LNE* connector) had shrouded pins and red insulation, it was intended as a mains power connector, 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.

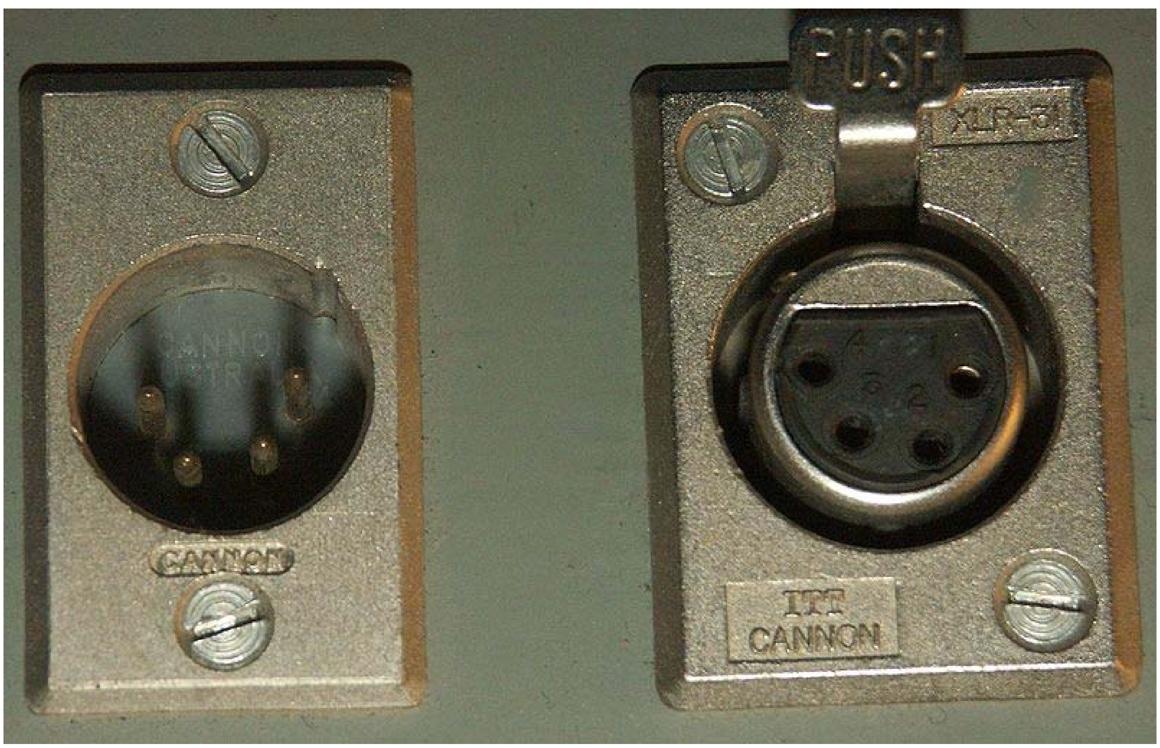
The female XLR connectors are designed to first connect pin 1 (the earth pin), before the other pins make contact, when a male XLR connector is inserted. With the ground connection established before the signal lines are connected, the insertion (and removal) of XLR connectors in live equipment is possible 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

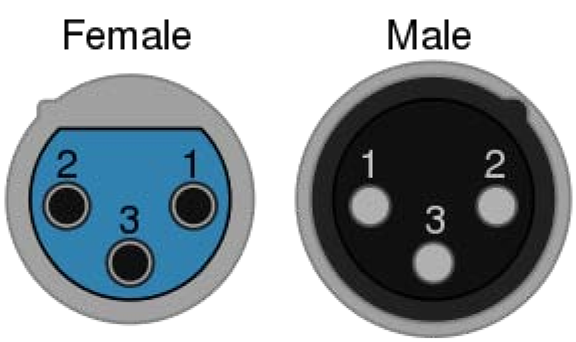
Female XLR6 panel connector

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.

Chapter 12

Insert (Effects Processing) & Ground Lift

Insert

In audio processing and sound reinforcement, an **insert** is an access point built into the mixing console, allowing the user to add external line level devices into the signal flow between the microphone preamplifier and the mix bus.

Common usages include gating, compressing, equalizing and for reverb effects that are specific to that channel or group. Inserts can be used as an alternate way to route signals such as for multitrack recording output or line level direct input.

Insert Jacks

Inserts can be balanced or unbalanced. Typically, higher-end mixers will have balanced inserts and entry level mixers will have unbalanced inserts. Balanced inserts appear as a *pair* of jacks, one serving as the Send (out from the mixer) and the other serving as the Return (back to the mixer.) Balanced insert jacks can be XLR, TRS or Bantam TT.

Unbalanced inserts can also be a pair of jacks such as RCA or 1/4" TS (Tip Sleeve.) Again, one jack serves as Send and the other serves as Return.

Most modern entry level and medium format mixers use a single TRS jack for both Send and Return. This dual-purpose insert jack only has three conductors, and balanced lines need at least two conductors. Because two lines share the same three-conductor insert jack, its architecture is necessarily unbalanced, with the two circuits sharing a common ground. Of the mixers using this kind of dual-purpose insert jack, most are designed with Tip Send, Ring Return, though many can still be found with Ring Send, Tip Return. A very few mixers have *both* architectures present on the same mixer; Tip Send for input channels and Tip Return for mix groups.

Insert jacks are often normalized so that signal is passed through the jack if nothing is inserted but is interrupted when the jack is holding a plug. Inserts with two separate jacks will have normalizing such that the Return jack interrupts signal but the Send jack doesn't. The Send jack can always be counted on to send signal out to external devices. A refinement of the normalization of jacks is the presence on the mixer of an insert ON/OFF button which allows the user to patch into or around the inserted devices at will without having to physically disconnect the insert cables.

Unbalanced TRS inserts are normalized as well. The presence of a plug in the jack breaks normal internal signal flow, sending signal out to external devices and returning this signal to the channel. TRS jacks can be specially wired with Tip and Ring connected together at the insert end, and both conductors going to Tip at the distant end. This allows for tapping the insert point for its signal without interrupting signal flow inside the mixer. A less reliable method to achieve the same end is to insert a TS or TRS plug halfway into the insert until there is a springy "click" feeling, at which point the plug is contacting the signal within the insert jack, but isn't breaking the normalized contact. The "half-click" method works fine until the insert cable is jarred or wiggled, causing noise or a loss of signal within the channel.

Because of the combination of balanced external devices and unbalanced insert jacks, the process of inserting involves finding out which devices have which kinds of output configurations. Full electronic balancing needs a different cabling style than transformer balancing, which in turn needs a different cabling style than impedance balancing. Mistakes in the interconnection may make the inserted signal drop in level by 6 dB or add hum and buzz or even overheat a balanced output circuit on the external device, decreasing its usable life.

Insert jacks themselves can be the source of intermittent signal problems. Internal jack contacts may get too loose over time and they may oxidize, impeding electrical conduction. Regular use of the jack helps keep oxidization down. The manufacturer using high quality jacks and good assembly practices helps reduce failures over time.

Another problem with TRS, TS and TT jacks that come in Send/Return pairs is that the Send jack and plug look just like the Return jack and plug. Cross-patching mistakes are possible, resulting in no signal passing through the insert.

Mixer Implementation

Inserts on analog mixers appear in various locations in the signal flow, depending on the vision of the designer. Most inserts tap the signal after the microphone preamplifier and after the HPF (if present.) Others tap the signal after the channel EQ and before the fader. A few tap the signal after the fader and before the mix buses. Many consoles offer a choice between two, three or four of the possible insert points by a combination of internal jumpers or links that a skilled technician can modify.

Digital consoles are often designed to allow the user to move the virtual insert point before or after the channel EQ and some allow the insert point to be placed after the fader and before the mix buses. These are "soft" changes; the options depend largely upon the design of the mixer's user interface and the breadth of processing power devoted to the insert function.

Inserted devices can be connected in series to create a string of inserted devices. For instance, one could connect a gate, a compressor and an equalizer in series through the same channel's insert.

Some digital mixers allow multiple effects to be inserted virtually, still others allow multiple third party plugins to be used as virtual inserts.

Inserts might be found on monoaural mixer inputs, monoaural and stereo subgroups, auxiliary inputs, main outputs and matrix outputs. They're rarely found on stereo line level inputs. EQs are commonly inserted on monitor mixer output mixes so that the monitor engineer can use his own wedge and the PFL/Solo bus to hear what the artist's wedge sounds like without having to climb on stage to check.

Signal Levels

Electrically, inserts are found at a variety of signal levels. Some are -10 dB consumer line level, others are nominally -6 dB or -2 dB or 0 dB or +4 dB. Most balanced inserts are at +4 dB nominal level. Digital mixers might specify their inserts as -20 dBFS which is similar in level to +4 dBu nominal on an analog mixer, depending on the maximum headroom of the analog design. For optimum gain staging and the least amount of system hiss, inserted devices should be chosen with regard to the signal level they can handle and the signal level the mixer can handle. Best gain staging is achieved when both insert and inserted device match in level.

Ground Lift

In sound recording and reproduction, **ground lift** or **earth lift** is a technique used to reduce or eliminate ground-related noise when connecting signal lines between two or more pieces of equipment. It interrupts the ground line at some point. It is particularly effective at eliminating ground loops, but it may also increase or decrease noise from other sources.

These XLR connectors used for audio have the cable shield and connector shell connected to one pin.

If all pieces of equipment are tied to a common ground reference, no current flows in the ground conductors and cable shields and no noise is introduced into signal circuits. In applications such as sound reinforcement for a concert, however, it is difficult to ensure all equipment shares a common ground reference.

Ground lift switch

Professional audio equipment intended for use with balanced lines may have a ground lift switch for the cable shield. The ground lift switch eliminates unwanted hum and buzz by interrupting the ground loops between equipment, preventing the flow of current along the cable shield between two devices. The switch disconnects pin 1 on the XLR jack, which is connected to the braid or foil shield in the cable and acts as the ground point of the circuit.

Ground lifts do not conform to Audio Engineering Society standard AES48.

Other ways of isolating the cable shield

Specially wired signal adaptors may leave the shield connection disconnected, or connected to safety ground through an RF bypass capacitor. Isolation transformers may be used to convert from balanced lines to single-ended inputs, and also to isolate the cable shield from the equipment safety ground.

Safety

Removal of the safety ground connection on equipment can expose users to an increased danger of electric shock and may contradict wiring regulations. The safety ground is disconnected by an adaptor (cheater plug) in a power lead in which the ground conductor is deliberately disconnected, or by cutting a ground pin in the power plug. If a fault develops in any line-operated equipment, cable shields and equipment enclosures may become energized, creating an electric shock hazard. For example, the metal shell of a stage microphone or the strings of a guitar may become energized, creating a hazard to performers. Wireless microphones and guitar pickups eliminate this hazard.

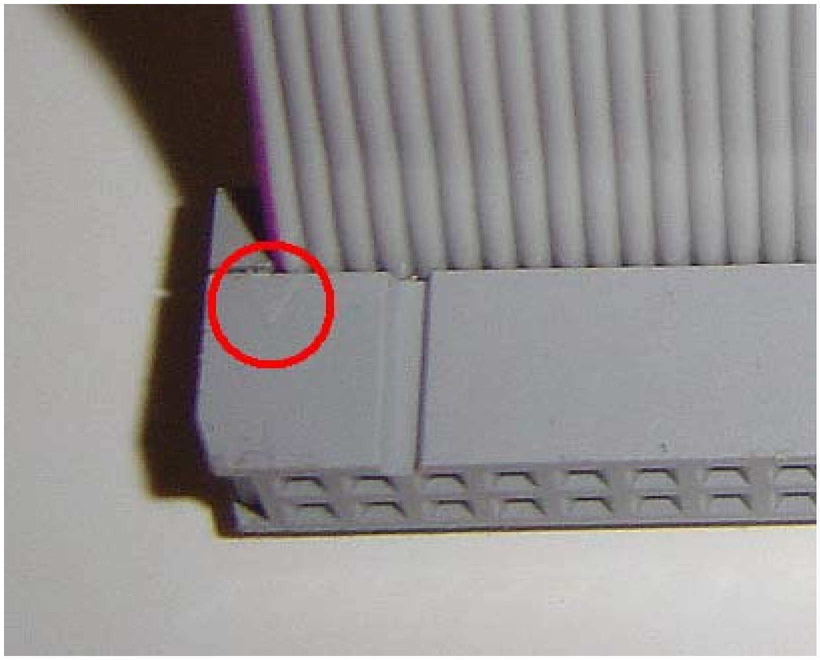
Chapter 13

Insulation-Displacement Connector & Gender Changer

Insulation-Displacement Connector

Insulation-displacement connectors (also called **IDC**s or **insulation-piercing connectors**) are designed to be connected to the conductor(s) of an insulated wire or cable by a connection process which forces a selectively sharpened blade or blades through the insulation, bypassing the need to strip the wire of insulation before connecting. Such connections are usually seen in low-current applications such as telecoms, networking and signal connections between parts of an electronic or computer system. When properly made, the connector blade cold-welds to the wire, making a highly reliable gas-tight connection.

Modern IDC technology developed after and was influenced by research on wire-wrap and crimp connector technology originally pioneered by Western Electric, Bell Telephone Labs, and others . Although originally designed to connect only solid (single-stranded) conductors, IDC technology was eventually extended to multiple-stranded wire as well.



The 'V' mark (ringed) shows the position of pin 1

Ribbon cable

Ribbon cable (also called **multi-wire planar cable**) is designed to be used with multi-contact IDC connectors in such a way that many IDC connections can be made at once, saving time in applications where many connections are needed. These connectors are not designed to be reusable, but can often be re-used if care is taken when removing the cable.

Pin 1 is typically indicated on the body of the connector by a red or raised 'V' mark. The corresponding wire in a ribbon cable is usually indicated by red coloration, a raised molded ridge, or markings printed onto the cable insulation.

Telephone and network plugs

In some types of telephone and network plug, including the BS 6312 and the registered jack family, generally separate wires in a sheath are used. In these applications, the outer sheath is stripped then the wires are inserted into the connector and a special crimp tool is used to force the contacts into the wires. Traditionally these connectors have been used with flat cable which makes it easy to ensure the right wires go into the right slots. However modular connectors used with Category 5 twisted pair cable require careful arranging of the wires by hand before inserting them into the connector.

Punchdown blocks

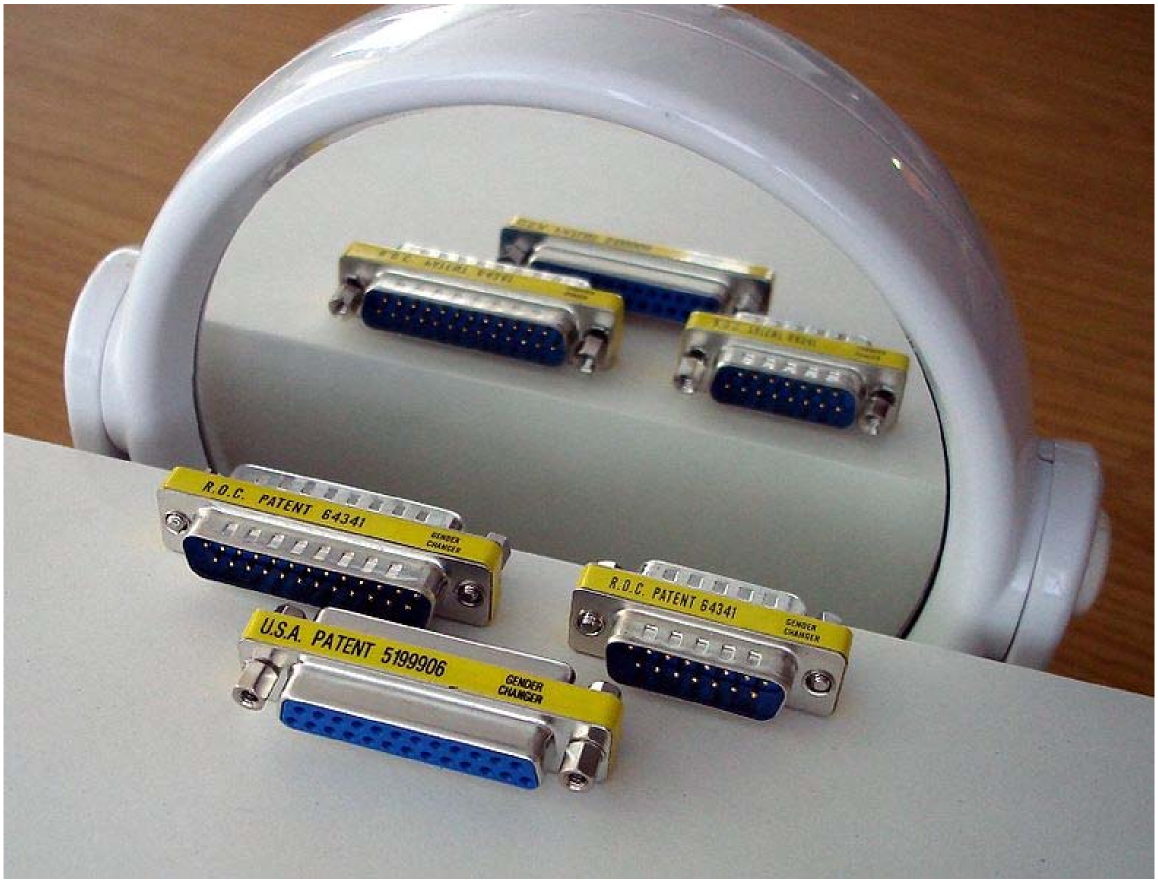
Punchdown blocks are intended to connect individual wires punched down into each position in the block with a special punchdown tool. Punchdown type terminations are also generally seen in telephone and network wall sockets, in patch panels and distribution frames, and in telephone equipment such as PBXs.

Common layouts

Connectors are categorized by pin spacing in mm (pitch), number of pins, and number of rows. Connectors commonly used in computers include:

- 3.5 in IDE desktop computer hard disc drives - 2.54 mm pitch, 40 pins, 2×20 (2 rows of 20 pins)
- 2.5 in IDE notebook computer hard disc drives - 2.00 mm pitch, 44 pins, 2×22 (2 rows of 22 pins)
- Serial DE-9 on Motherboards - 2.54 mm pitch, 10 pins, 2×5 (2 rows of 5 pins) - sometimes called *everex*
- Serial DB-25 on Motherboards

Gender Changer



Gender changer

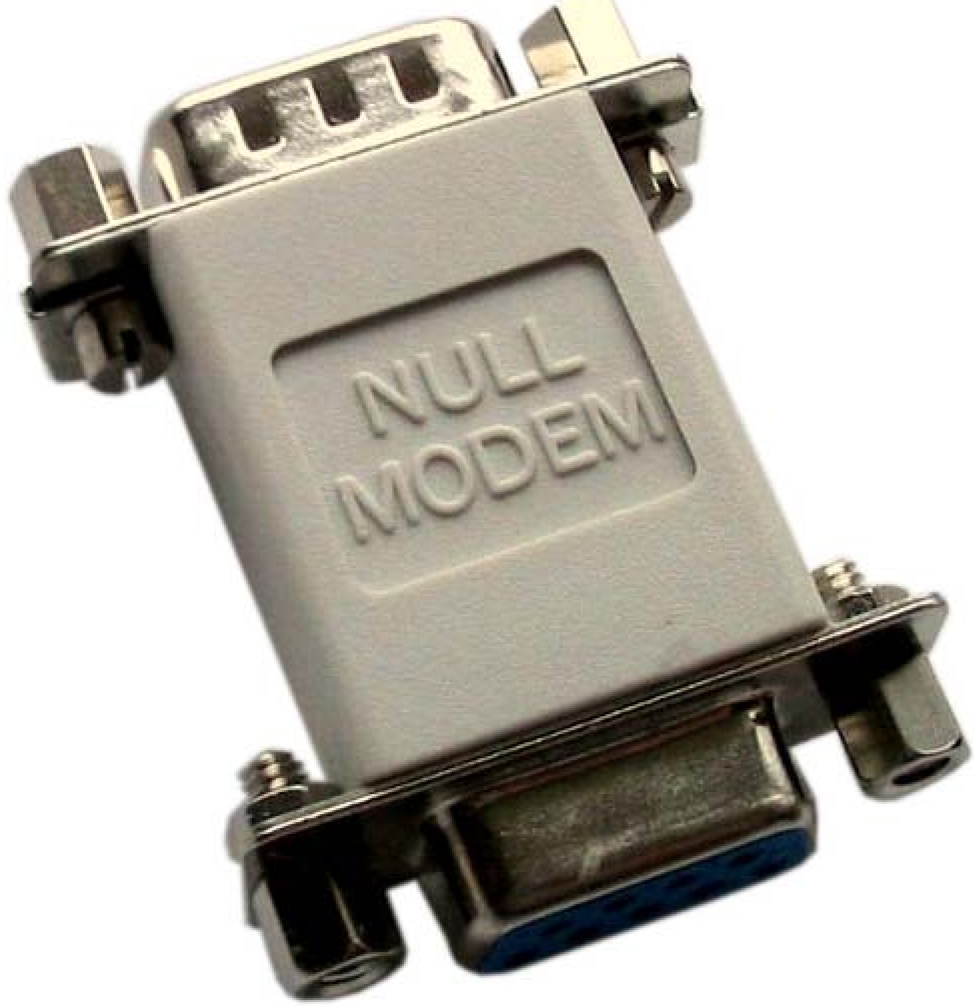
A **gender changer** is a hardware device placed between two cable connectors of the same type and gender. An example is a cable connector shell with either two female or two male connectors on it (male-to-male or female-to-female), used to correct the mismatches that result when interconnecting two devices or cables with the same gender of connector.

Gender changers are used for RS-232C ports in either the original DB-25 or the IBM AT DE-9 format. They are also used when extending any sort of cable that normally has plugs on both ends (rather than a socket on one and plug on the other), however in this case it is usually called just an "extender", such as with F connectors, BNC connectors, and various RJ connectors used in telephony and computer networking.

Gender changers are used in professional audio to adapt XLR connectors, RCA connectors, Speakon connectors and TRS connectors.

Alternative names for a gender changer are "gender bender", "gender blender", and "gender mender".

Null modem



A null modem should not be confused with a gender changer, even if it changes gender

In serial communications, there exists a type of adapter that is similar in appearance to a gender changer, and in fact may provide the function of changing the gender, but is not the same thing. This device is called a null modem. Despite the word modem appearing in the name, it is not a modem. Rather, it is a device with the appearance of a gender changer that imitates the presence of a modem.

A normal gender changer simply changes the gender without rerouting any pins. Therefore, pin 1 connects to pin 1 on the other side, pin 2 connects to 2, pin 3 connects to 3, and so forth.

A null modem reroutes wiring so that two serial devices may connect directly to one another without any communications hardware. For example, a null modem crosses pins 2 and 3, so that pin 2 on one side is connected to pin 3 on the other. This causes the "transmit" from each side to be routed into the "receive" side of the other, similar to how a crossover cable is used in Ethernet to connect two devices directly without a hub or switch. Two to three other pairs are similarly crossed in a null modem.

A null modem may also act as a gender changer if it has the same gender connector on both sides. Other null modems have a different gender on each side. It is important to recognize that a null modem used in place of a gender changer (or a gender changer used in place of a null modem) will result in an inoperable connection, even if the connectors physically fit.

Because of the significance of this distinction, gender changers and null modems for serial communications are typically labeled with the words *Gender Changer* or *Null Modem* to clarify the internal wiring.