

# Handbook of Mains and DC Power Connectors (Electrical Components)



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## Chapter 1

# AC Power Plugs and Sockets



CEE 7/4 Type F plug and socket



CEE 7/5 Type E socket

Plugs and sockets may sometimes combine male and female aspects, but the exposed pins or terminals in the socket are generally safe to touch.

**AC power plugs** and **sockets** are devices for removably connecting electrically operated devices to the power supply.

An **electric plug** connects mechanically to a matching socket. Usually plugs are movable connectors, and sockets are fixed to equipment.

**Wall sockets** (also known as **power points**, **power sockets**, **electric receptacles**, **plug sockets**, **electrical outlets** or just **sockets**) are mostly or completely female electrical connectors that have slots or holes which accept and deliver current to the prongs of inserted plugs.

To reduce the risk of injury or death by electric shock, some plug and socket systems incorporate a variety of safety features. Sockets can be designed to accept only compatible plugs and reject all others. There is some variation in male/female mating, in that some plugs can have sockets or exposed contact plates, while some wall sockets have pins or exposed contact plates. The exposed contacts in the wall socket are commonly used for safety purposes such as grounding and electrostatic energy dissipation.

## Terminology

There are differences between British and American nomenclature related to power plugs and sockets. Other regional variations (e.g. Australian) also exist.

British English	American English	Other Terms	Meaning
mains power	line power service entrance conductors		Primary electrical power supply wires serving a building, connected to the main fuses or circuit breakers.
domestic power 230 volt power	residential power household power AC power		Single-phase 120 or 230 V AC power as used in a single-family residence
earth connection	ground wire grounding conductor (NEC)		Safety connection to the earth or ground
live connection active connection line connection (rare)	hot wire live wire supply wire ungrounded conductor (NEC)	phase conductor (electrical engineers)	Phase or active connection
neutral connection	cold wire neutral wire return wire grounded conductor (old NEC) identified conductor (old NEC)		Return or neutral connection
pin plug	plug pin prong		Part of male electrical connector
power port socket	receptacle socket outlet jack	power point	Female electrical connector
flex lead mains lead mains wire mains wiring	line cord power cord	power lead lead	Flexible electric cable from plug to appliance

mains extension lead	extension cord drop cord		Device providing single outlet at a distance from a single outlet
4, 6, or 8 way mains extension lead	power bar	power board	Device providing multiple outlets from a single outlet
mains extension adaptor	power strip	board	

Previous to 2008, the old US National Electrical Code (NEC) distinguished the terms *grounding*, *grounded*, and *ungrounded* conductor. As of 2008, the NEC has officially defined **neutral conductor** and is phasing out the use of the term **grounded conductor**.

In United Kingdom electrical engineering, the *line* voltage is that between the live conductors of the three-phase distribution system, while the *phase* voltage is that between live and neutral.

### ***The three contacts***

Each receptacle has two or three wired contacts. The contacts may be steel or brass, and may be plated with zinc, tin, or nickel. The **live** contact carries current from the source to the load. The **neutral** returns current to the source. Many receptacles and plugs also include a third contact for a connection to earth ground, intended to protect against insulation failure of the connected device. A common approach is for electrical sockets to have three holes, which can accommodate either 3-pin earthed or 2-pin non earthed plugs. The types below B, H, I, J, K and L use this approach (type B accepting type A plugs and types H, J, K and L accepting type C). The Europlug (type C) will fit type E and F sockets, and the earthed type E / F 2-pin plugs will fit type C (and certain hybrid) sockets though without making earthing contact. Types D, G and M plugs are exclusively 3-pin, used for both earthed and non-earthed appliances.

### **Polarization**

*Polarized* plugs and sockets are those designed to connect only in one orientation, so the live and neutral conductors of the outlet are connected (respectively) to the live and neutral poles of the appliance. Polarization is maintained by the shape, size, or position of plug pins and socket holes to ensure that a plug fits only one way into a socket. The switch of the appliance is then connected in series with the live wire. If the neutral wire were interrupted instead, the device would be deactivated but its internal wiring would still remain live. This is a shock hazard; if the energized parts are touched, current travels to earth through the body. Devices that especially present this hazard include toasters and other appliances with exposed heating elements, which with reversed polarity can remain live even when they are cool to the touch. Screw-in light bulbs with reversed polarity may have exposed portions of the socket still energized even though the lamp is switched off. Transposition of the live and neutral wires in the wiring to sockets defeats the safety

purpose of polarized sockets and plugs; a circuit tester can be used to detect swapped wires.

*Unpolarized* plugs and sockets are those which can connect either way around, so live and neutral wires are connected arbitrarily. Unpolarized plug/socket systems such as the Europlug rely on device construction requirements to avoid the shock hazards created by interchange of live and neutral connections.

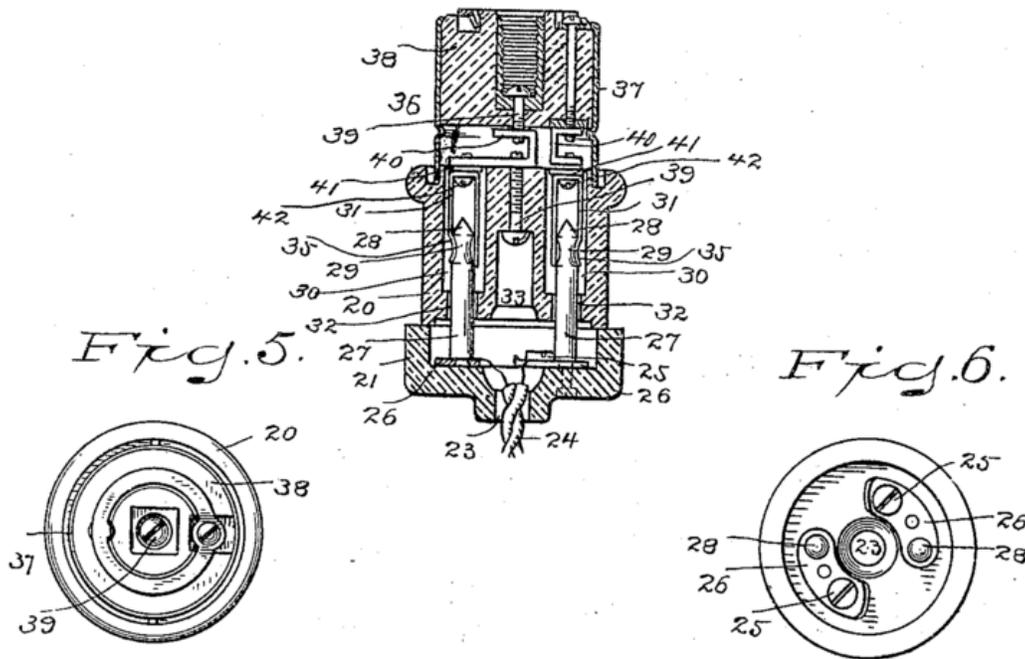
### ***Interchange hazards***

Plugs and sockets are designed as a system to meet standards for safety and reliability. Some types of receptacles may accept more than one type of plug; where this is an official, approved intention of the receptacle design, all the approved combinations will be tested to the applicable safety standards. Occasionally, plug and receptacle combinations may allow power to flow but may not meet product standards for mating force, grounding, current capacity, life expectancy, or safety. Improvised or user-modified connectors will not meet the product safety standards.

## ***History***

### **Early history**

When electricity was first introduced into the household, it was primarily used for lighting. At that time, many electricity companies operated a split-tariff system where the cost of electricity for lighting was lower than that for other purposes. This led to portable appliances (such as vacuum cleaners, electric fans, and hair driers) being connected to light bulb sockets.



U.S. Patent 774,250. The first electric power plug and receptacle.

However, as electricity became a common method of lighting houses and operating labour-saving appliances, a safe means of connection to the electric system other than using a light socket was needed. The original two pin electrical plug and socket were invented by Harvey Hubbell and patented in 1904. The original socket into which the user inserted the appliance's plug (of Hubbell's design) itself screwed into the sort of socket used for light bulbs, rather than being directly connected to the building's fixed wiring. (U.S. Patent #774,250) Other manufacturers adopted the Hubbell pattern and by 1915 they were widespread, although in the 1920s and even later, household and light commercial equipment was still powered through cables connected with Edison screw-base adapters to lampholders.

The grounded consumer plug has several claimants to its invention. The earliest patent for a grounded plug appears to be one applied for on January 11, 1915 by George P. Knapp, on behalf of the Harvey Hubbell company and granted on April 18, 1916. This patent covers the use of a grounding pin which extends further than the other two contacts to ensure that it is engaged first. However, the suggested configuration of the pins was that found in the Type I plug used today primarily in Australasia and China, which was not interoperable with existing two-contact ungrounded plugs. Other grounded plugs that are widely used today were developed later by others so as to be interoperable with ungrounded plugs.

The Schuko-system plug was invented by Albert Büttner, who patented it in 1926. The current American version of the grounded plug, with two vertical blades and a round grounding pin was invented by Philip F. Labre, while he was attending the Milwaukee

School of Engineering (MSOE). It is said that his landlady had a cat which would knock over her fan when it came in the window. When she plugged the fan back in, she would get an electric shock. Labre figured out that if the plug were grounded, the electricity would go to earth through the plug rather than through his landlady. He applied a patent on May 12, 1927 and was issued a US patent for grounding receptacle and plug in June, 1928. As the need for safer installations became apparent, earthed three-contact systems were made mandatory in most industrial countries.

## **Proliferation of standards**

During the first fifty years of commercial use of electric power, standards developed rapidly based on growing experience. Technical, safety, and economic factors influenced the development of all wiring devices and numerous varieties were invented. Gradually the desire for trade eliminated some standards that had been used only in a few countries. Former colonies may retain the standards of the colonising country, occasionally—as with the UK and a number of its former colonies—after the colonising country has changed its standard. Sometimes offshore industrial plants or overseas military bases use the wiring practices of their controlling country instead of the surrounding region. Hotels and airports may maintain receptacles of foreign standards for the convenience of travellers. Some countries have multiple voltages, frequencies and plug designs in use, which can create inconvenience and safety hazards.

## **Design for safety**

Design features and aspects of plugs and sockets have gradually developed to reduce the risk of electric shock and appliance destruction. Depending on the plug and socket system, safety measures may include pin and slot composition to permit only the precise insertion of plug into socket, earth pins longer than power pins so the device becomes earthed before power is connected, electrical insulation of pin shanks to reduce or eradicate live-contact exposure when a plug is partially inserted in a socket, socket slot shutters that open only for the correct plug, as well as inbuilt fuses and switches.

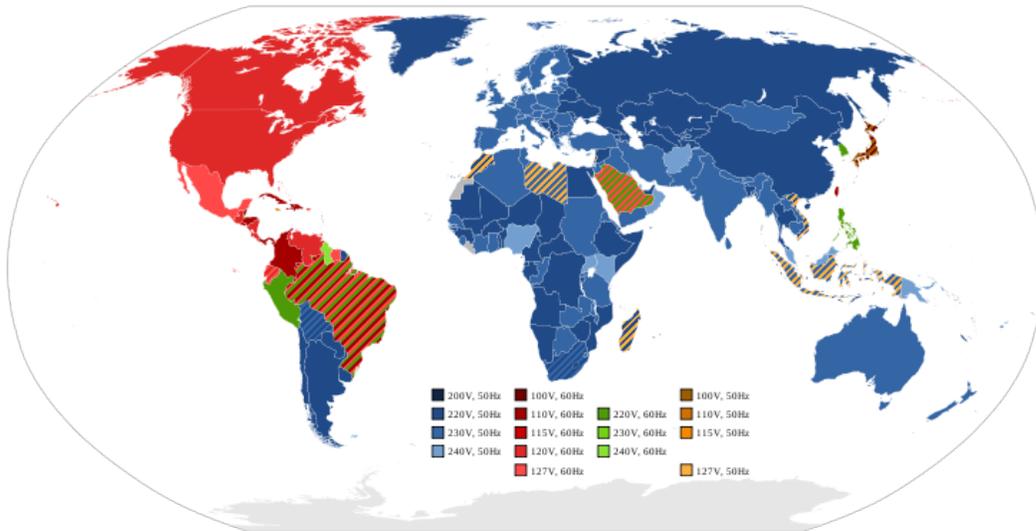
## **Consolidation of standards**

In recent years many countries have settled on one of a few *de facto* standards, which became formalised as official national standards, although there remain older installations of obsolete wiring in most countries. Some buildings have wiring that has been in use for almost a century and which pre-dates all modern standards.

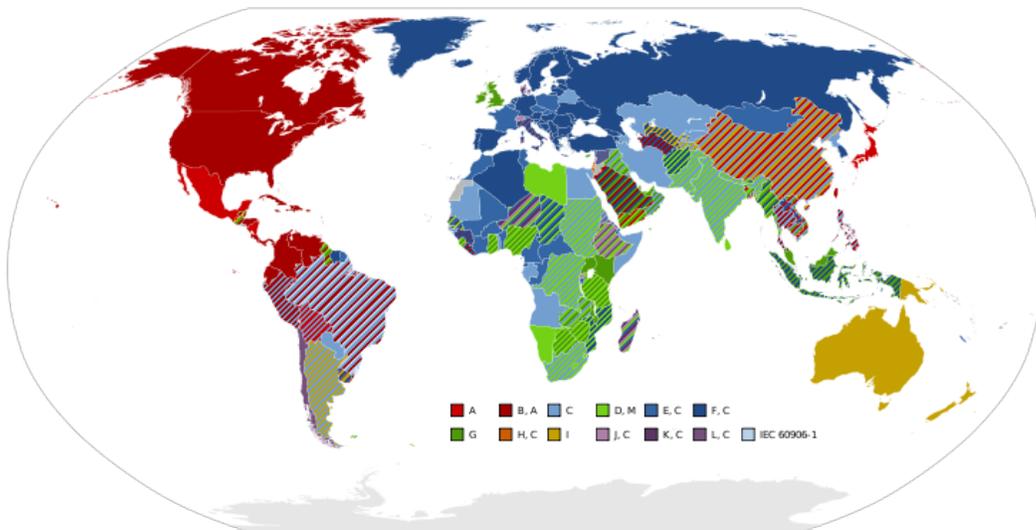
There has been some movement towards consolidation of standards for international interoperability. For example, the CEE 7/7 plug has been adopted in several European countries and is compatible with both Type E and Type F sockets, while the ungrounded and unpolarised Europlug is compatible with an even greater proportion of European and other socket types. IEC 60906-1 has been proposed as a common standard for all 230 V plugs and sockets worldwide but has only been adopted in Brazil to date.

Many manufacturers of electrical devices like personal computers have adopted the practice of putting a single world-standard IEC connector on the device, and supplying for each country a power cord equipped with a standard IEC connector on one end and a national power plug at the other. The electrical device itself is designed to adapt to a wide range of voltage and frequency standards. This has the practical benefit of reducing the amount of testing required for approval, and reduces the number of different product variations that must be produced to serve world markets.

### World maps



Voltage/Frequency.



Plugs.

There are two basic standards for voltage and frequency in the world. One is the North American standard of 120 volts at a frequency of 60 Hz, which uses plugs A and B, and the other is the European standard of 220–240 volts at 50 Hz, which uses plugs C to M.

Countries on other continents have adopted one of these two voltage standards, although some countries use variations or a mixture of standards. The outline maps show the different plug types, voltages and frequencies used around the world, color-coded for easy reference.

### ***Types in present use***

Electrical plugs and their sockets differ by country in shape, size and type of connectors. The type used in each country is set by national standards legislation. Here each type is designated by a letter designation from a U.S. government publication, plus a short comment in parentheses giving its country of origin and number of contacts. Subsections then detail the subtypes of each type as used in different parts of the world.

In many areas, different types of plugs are used depending on the IEC classes assigned to the electrical device. The assigned class depends on whether or not the device is earthed, and the degree of insulation it incorporates. Class I, for example, refers to earthed equipment, while class II refers to unearthed equipment protected by double insulation.

Special purpose sockets may be found in residential, industrial, commercial or institutional buildings. These may be merely labelled or coloured, or may have different arrangements of pins or keying provisions. Some special-purpose systems are incompatible with general-purpose lighting and appliances. Examples of systems using special purpose sockets include:

- "clean" ground for use with computer systems,
- emergency power supply,
- uninterruptible power supply, for critical or life-support equipment,
- isolated power for medical instruments,
- "balanced" or "technical" power used in audio and video production studios,
- theatrical lighting
- outlets for electric clothes dryers, electric ovens, and air conditioners with higher current rating.

Depending on the nature of the system, special-purpose sockets may just identify a reserved use of a system (for example, computer power) or may be physically incompatible with utility sockets to prevent use of unintended equipment which could create electrical noise or other problems for the intended equipment on the line.

## Type A



Unpolarized type A plug

NEMA 1–15 (North American 15 A/125 V ungrounded)

This plug and socket, with two flat parallel non-coplanar blades and slots, is used in most of North America and on the east coast of South America on devices not requiring a ground connection, such as lamps and "double insulated" small appliances. It has been adopted by 38 countries outside North America, and is standardized in the U.S. by the National Electrical Manufacturers Association. NEMA 1–15 sockets have been prohibited in new construction in the United States and Canada since 1962, but remain in many older homes and are still sold for replacement. Type A plugs are still very common because they are also compatible with newer type B (three-prong) sockets. In Pakistan Type A plug is used with hybrid socket, for home and small offices.

Initially, the plug's prongs and the socket's slots were the same width (or height, in a vertical orientation), so the plug could be inserted into the socket either way around. Most sockets and plugs manufactured from the 1950s onward are polarized by means of a neutral blade/slot wider than the live blade/slot, so the plug can be inserted only the right way. Polarized type A plugs will not fit into unpolarized type A sockets, which possess only narrow slots. But both unpolarized and polarized type A plugs will fit into polarized type A sockets and into type B (three-prong) sockets. Some devices that do not

distinguish between neutral and live, such as internally isolated electronic power supplies, are still produced with unpolarized type A pins (both narrow).

JIS C 8303, Class II (Japanese 15 A/100 V ungrounded)



Japanese outlet with ground post, for a washing machine.

The Japanese plug and socket appear physically identical to NEMA 1–15. However, the Japanese system incorporates stricter dimensional requirements for the plug housing, different marking requirements, and mandatory testing and approval by MITI or JIS.

Many Japanese outlets and multi-plug adapters are unpolarized—the slots in the sockets are the same size—and will accept only unpolarized plugs. Japanese plugs generally fit into most North American outlets without modification, but polarized North American

plugs may require adapters or replacement non-polarized plugs to connect to older Japanese outlets. However, in Japan the voltage is supplied at only 100 volts, and the frequency in eastern Japan is 50 rather than 60 Hz. Therefore, many North American devices which can be physically plugged into Japanese sockets may not function properly, though some devices with rectified power supplies may work without problems.

### **Type B**



NEMA 5-15 plug, left. Decorative-style duplex outlet, right



Ordinary duplex outlet

The type B plug has two flat parallel blades like type A, but also adds a round or U-shaped grounding prong (American standard NEMA 5-15/CSA 22.2, No.42). It is rated for 15 amperes at 125 volts. The ground pin is longer than the live and neutral blades, so the device is grounded before the power is connected. Both current-carrying blades on type B plugs are narrow, since the ground pin enforces polarity. Type A plugs are also compatible with type B sockets, in which case the socket enforces polarity by means of a wide and a narrow slot.

Adapters that allow a Type B plug to be fitted to a Type A outlet are readily available. Proper grounding is dependent on the outlet being an ordinary duplex receptacle with a

grounded center screw, and the grounding tab of the adapter being connected to that screw.

The 5–15 socket is standard in all of North America (Canada, the United States, and Mexico). It is also used in Central America, the Caribbean, northern South America (Colombia, Ecuador, Venezuela and part of Brazil), Japan, Taiwan and Saudi Arabia. Looking directly at a type B outlet with the ground at the bottom, the neutral slot is on the left, and the live slot is on the right. Outlets may also be installed oriented with the ground at the top, or on either side. Typically connections are:

- Ground: bottom, round hole, green terminal, green or bare wire
- Neutral: top left, larger flat slot, silver terminal, white wire
- Live/Hot: top right, narrower flat slot, brass terminal, black wire (or red wire for 2nd live circuit, top and bottom socket are then separated)

In some parts of the United States and all of Canada, tamper-resistant outlets are now required in new construction. These prevent contact by objects like keys or paper clips inserted into the receptacle.



5–20RA (Canada) or 5-20R (USA) T-slot receptacle mounted with the ground hole up. The neutral connection is the wider T-shaped slot on the lower right.

In theater lighting, this connector is sometimes known as *PBG* for "Parallel Blade with Ground", *Edison* or *Hubbell*, the name of a common manufacturer.

NEMA 5–20 (North American 20 A/125 V grounded)

This is a 20 amperes receptacle; type 5-20 A has a T-slot for the neutral blade which allows either 15 amperes parallel-blade plugs or 20 amperes plugs to be used.

JIS C 8303, Class I (Japanese 15 A/100 V grounded)

Japan also uses a Type B plug similar to the North American one. However it is less common than its Type A equivalent.

### **Type C**

CEE 7/16 (Europlug 2.5 A/250 V ungrounded)



**CEE 7/16 plug and old type c socket**

This two-prong plug is popularly known as the Europlug. The plug is ungrounded and has two round 4 mm (0.157 in) pins, which usually converge slightly towards their free ends. It is described in CEE 7/16 and is also defined in Italian standard CEI 23-5 and Russian standard GOST 7396. This plug is intended for use with devices that require 2.5 amperes or less. Because it is unpolarised, it can be inserted in either direction into the socket, so live and neutral are connected arbitrarily. The separation and length of the pins allow its safe insertion in most Type E (French), type F (CEE 7/4 "Schuko"), Type H (Israeli), CEE 7/7, Type J (Swiss), Type K (Danish) and Type L (Italian) outlets, as well as BS 4573 UK shaver sockets. It can be forced into type D (5 amperes) and some G sockets, if the shutters are opened, though the connection may be neither reliable in either case, nor safe regarding overcurrent or short-circuit protection with type G sockets which may well be wired on a ring circuit with a 30 A rewirable (semi-enclosed) BS3036 fuse or 32 A circuit breaker.

The Europlug (plug only, not socket from the picture) is used in Class II applications throughout continental Europe (Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Czech Republic, Croatia, Denmark, Estonia, Finland, France, Germany, Greece, Greenland, Hungary, Iceland, Italy, Latvia, Lithuania, Luxembourg, Macedonia, the Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey). It is also used in the Middle East, most African nations, South America (Brazil, Chile, Argentina, Uruguay, Peru and Bolivia), Asia (Bangladesh, Sri Lanka, Indonesia, Pakistan and the Philippines) as well as Russia and the former Soviet republics, such as Ukraine, Armenia, Georgia, and many developing nations. It is also used alongside the BS 1363 in many nations, particularly former British colonies.

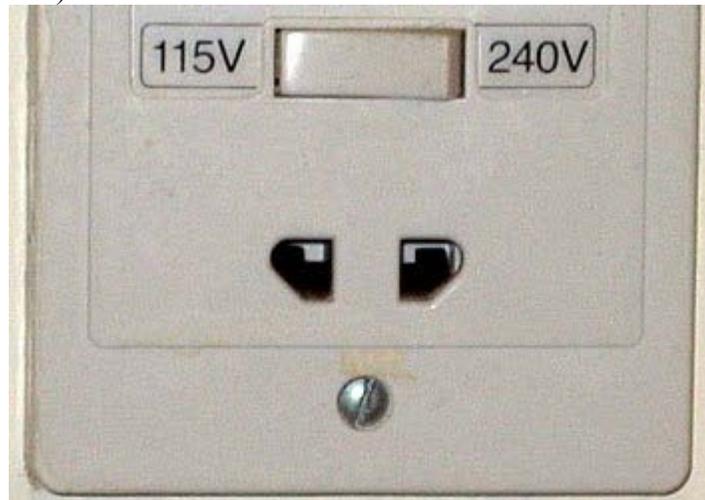
CEE 7/17 (German/French 16 A/250 V ungrounded)



CEE 7/17 plug

This plug also has two round pins but the pins are 4.8 mm (0.189 in) in diameter like types E and F and the plug has a round plastic or rubber base that stops it being inserted into small sockets intended for the Europlug. Instead, it fits only into large round sockets intended for types E and F. The base has holes in it to accommodate both side contacts and socket earth pins. It is used for large appliances, and in South Korea for all domestic non-earthed appliances. It is also defined in Italian standard CEI 23-5. Can also be safely inserted in to Israeli type H sockets, although with some difficulty.

BS 4573 (UK shaver)



**BS 4573** socket

In the United Kingdom and Ireland, what appears to be a larger version of the type C plug exists for use with shavers (electric razors) in bath or shower rooms. In fact it was not derived from the type C plug at all, but was a legacy from the obsolete 2 pin 5 amperes plug used in Britain in the 1920s and 1930s but still prevalent, especially in bathrooms, as late as the 1960s. It has 0.2 in (5.08 mm) diameter pins  $\frac{5}{8}$  in (15.88 mm) apart, and the sockets for this plug are often designed to accept unearthed CEE 7/16, US or Australian plugs as well. Sockets are often able to supply either 230 V or 115 V. In wet zones, they must contain an isolation transformer compliant with BS 3535.

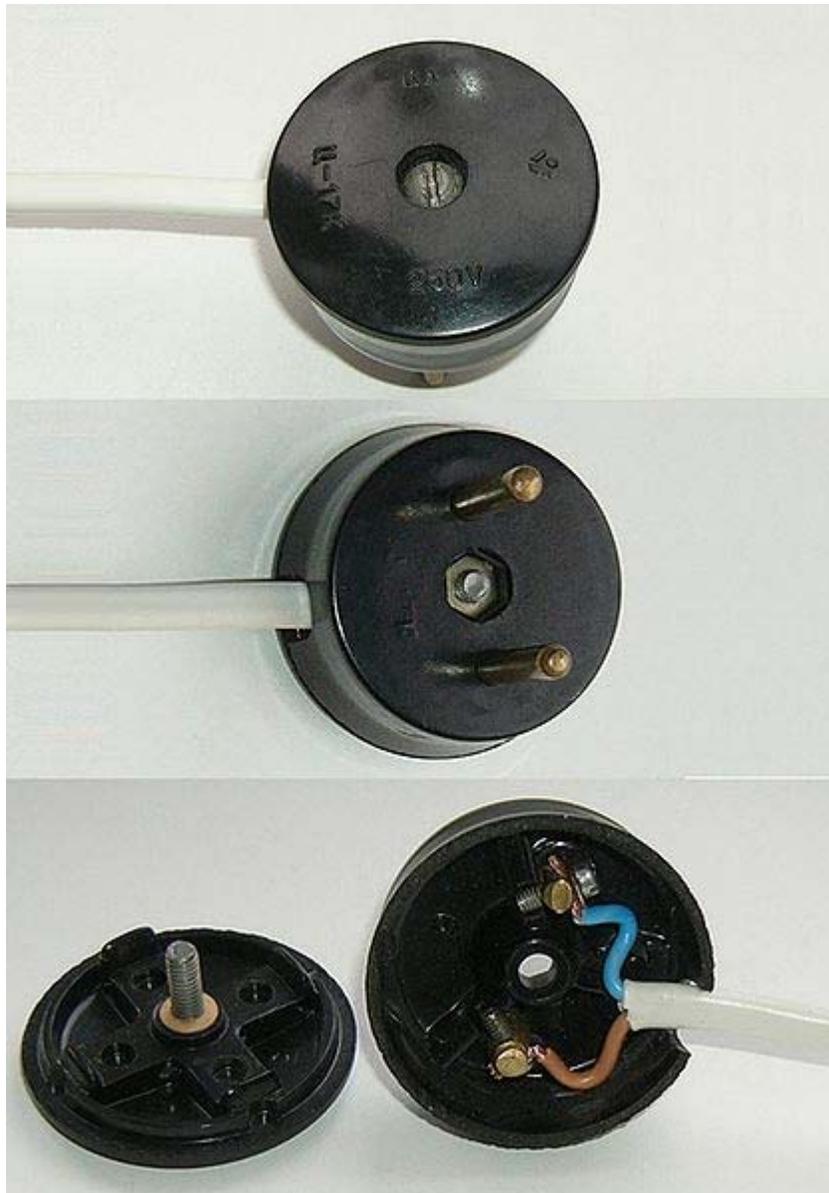
GOST 7396 C 1 (6 A or 16 A /250 V ungrounded)

This Soviet plug, still widely used in modern Russia, has pin dimensions and spacing equal to the Europlug, but lacks the insulation sleeves. Unlike the Europlug, it was rated for 6 A. It has a round body like the French type E or flat body with a round base like CEE 7/17. The round base has no notches. The pins are parallel and do not converge. The body is made of fire resistant thermoset plastic. The corresponding 6 A socket accept the Europlug, but not the type E or F plugs, nor the CEE 7/17 as the 4.5 holes are too small to accept the 4.8 mm pins of those plugs.

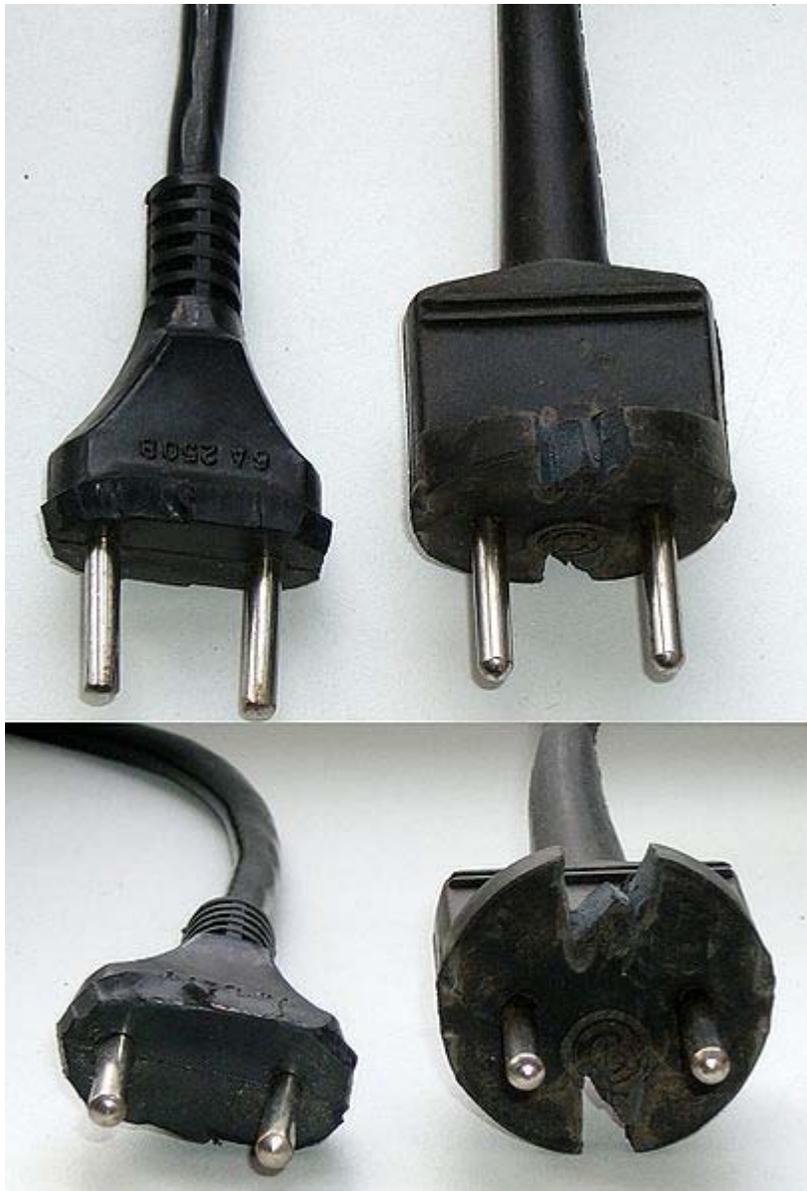
There were also moulded rubber plugs available for devices up to 16 A similar to CEE 7/17, but with a round base without any notches. They could be altered to fit a type E or F socket by cutting notches with a sharp knife.



Soviet grip plug, 6 A 250 V AC, thermoset plastic



Soviet round plug, 6 A 250 V AC, thermoset plastic, half height



Moulded rubber soviet plugs cut with knife in attempt to be similar to CEE 7/16 (left) and CEE 7/17 (right). Originally the plugs had a round base.



Soviet shaver power cord. The plug is similar to CEE7/16, but has different configuration. Thermoplastic plug is rated for 6 A 250 V.

#### Variations in sockets



Unearthed socket compatible with both Schuko and French plugs

Type C sockets have no ground provisions and consequently have been phased out in most countries. For example, in Germany, ungrounded outlets are rare, found only in very old installations, whereas in the Netherlands they are common in "dry areas" such as in bedrooms or living rooms. Standards also vary between countries as to whether child-resistant shutters are required. Depending on the country and the age of the socket these sockets may have 4.0 or 4.8 mm receptacles. The latter accept type E and F plugs in addition to type C, though without ground connection. Countries using the type E or F standards vary in whether ungrounded type C outlets are still permitted in environments where the need for grounding is less critical. Adaptors and trailing sockets and power strips designed to accept only Europlugs with 4 mm (0.157 in) pins may also have plastic barriers in place to prevent CEE 7/17, Schuko or French plugs from entering.

### **Type D**

BS 546 (United Kingdom, 5 A/250 V grounded), equivalent to IA6A3 (India), rated at 6 A / 250 V



D Plug

India and Pakistan have standardised on a plug which was originally defined in British standard BS 546. It has three large round pins in a triangular pattern. The BS 546 standard is also used in parts of the Middle East (Kuwait, Qatar) and parts of Asia and South East Asia that were electrified by the British. This type was also previously used in South Africa, but has been phased out in favour of the 15 A version there. Similarly, in Ghana, Kenya and Nigeria, the plug has been mostly replaced by the British 3-pin (Type G). This 5 A plug, along with its smaller 2 A cousin, is sometimes used in the UK for centrally switched domestic lighting circuits, in order to distinguish them from normal power circuits.

BS 546 (United Kingdom, 15 A/250 V grounded), equivalent to IA16A3 (India) & SABS 164 (South Africa), rated at 16 A / 250 V



M Plug

This plug is sometimes referred to as type M, but it is in fact merely the 15 A version of the plug above, though its pins are much larger at 7.05 by 21.1 mm (0.278 by 0.831 in). Live and neutral are spaced 1 in (25.4 mm) apart, and earth is  $1\frac{1}{8}$  in (28.58 mm) away from each of them. Although the 5 A version is standard in India, Pakistan, Sri Lanka, Nepal and Namibia, the 15 A version is also used in these countries for larger appliances. Some countries like South Africa use it as the main domestic plug and socket type, where sockets always have an on-off switch built into them. Type M is still commonly found in installations in Hong Kong and Botswana, alongside type G. The Type M was almost universally used in the UK and Ireland for indoor dimmable theatre and architectural lighting installations, but there is now a widespread move to using CEE 16 A industrial sockets in new installations. It was also often used for non-dimmed but centrally controlled sockets within such installations. The main reason for doing this is that fused plugs, while convenient for domestic wiring (as they allow 32 A socket circuits to be used safely), are not convenient if the plugs and sockets are in hard-to-access locations (like lighting bars) or if using chains of extension cords since it is hard to figure out which fuse has blown. Both of these situations are common in theatre wiring. This plug is also widely used in Israel, Singapore, Sri Lanka and Malaysia for air conditioners and clothes dryers.

A socket has been developed for the Indian subcontinent that accepts both type D and type M plugs, with adjacent holes of the appropriate gauge.

### **Type E**

CEE 7/5 (French type E)



French socket



French plug

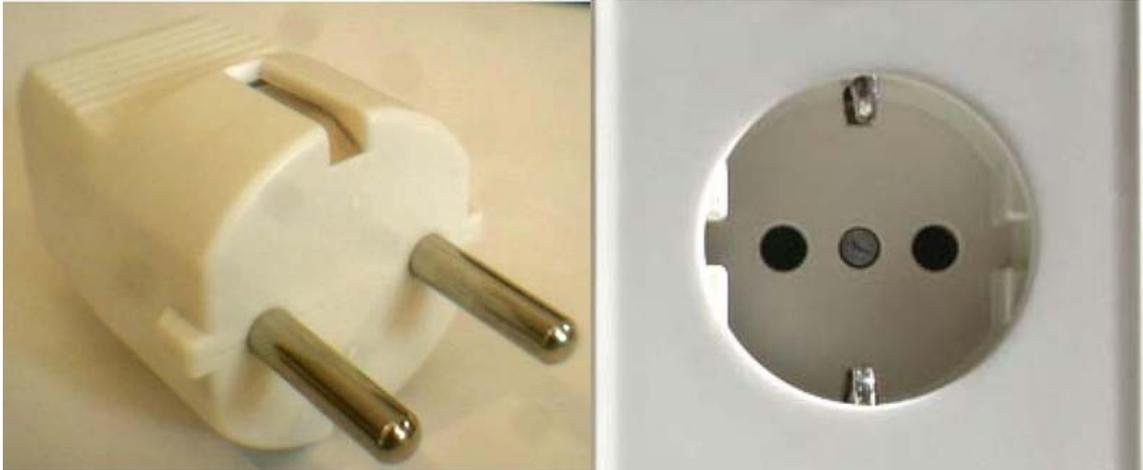
France, Belgium, Poland, Czech Republic, Slovakia and some other countries have standardized on a round plug with two round pins measuring 4.8 by 19 mm (0.189 by 0.748 in), spaced 19 mm (0.748 in) apart and with a hole for the socket's ground pin. This standard will also accept Europlug (type C) and CEE 7/17 plugs. Sockets are installed with the earth pin upwards. Although the plug is polarised, there is no universally observed standard for connecting the live and neutral. In the former Czechoslovakia Standard ČSN 33 2180:1979, section 6.2.2. required live to be on the left side of socket. Child-resistant outlet shutters are required by French and Belgian standards, however they are not required in all countries where this type is used.

Although similar under many aspects, type E plug is not compatible with the CEE 7/4 socket (type F) standard in Germany and other continental European countries. The reason for incompatibility is that grounding in the E socket is done by a round male pin permanently mounted in the socket. As well as type F plug below, type E plug will fit some other types of socket either easily or with force. However, there will be no ground connection with such sockets, and in some cases forcing the plug may damage the socket.

This type has been authorised in Denmark since 1 July 2008, but sockets of this kind are not yet common.

## Type F

CEE 7/4 (German "Schuko" 16 A/250 V grounded)



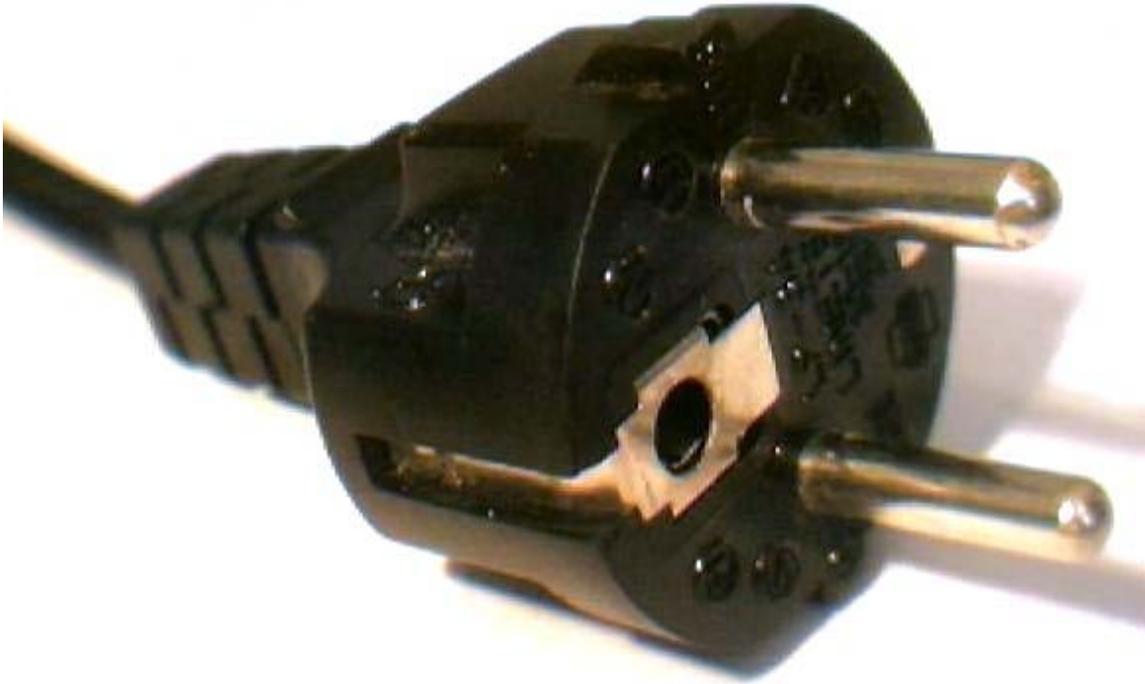
Schuko plug and socket

The type F plug, defined in CEE 7/4 and commonly called a "Schuko plug", is like type E except that it has two grounding clips on the sides of the plug instead of a female ground contact. The Schuko connection system is symmetrical and unpolarised by design, allowing live and neutral to be reversed. The socket also accepts Europlugs and CEE 7/17 plugs. It supplies up to 16 amperes. It is used in Austria, Bulgaria, Chile, Croatia, Estonia, Finland, Germany, Greece, Hungary, Iceland, Indonesia, Italy, Latvia, Luxembourg, the Netherlands, Norway, Pakistan, Portugal, Romania, Russia, Serbia, Slovenia, South Korea, Spain, Sweden, Turkey and Uruguay.

"Schuko" is an abbreviation for the German word *Schutzkontakt*, which means "Protective (that is, grounded) contact".

Some countries – notably Finland, Norway and Sweden – require child-proof outlet shutters; the German Schuko standard does not have this requirement.

## Type E / F hybrid



CEE 7/7 plug

CEE 7/7 (French/German 16 A/250 V grounded)

In order to bridge the differences between sockets E and F, the CEE 7/7 plug was developed. It is polarised to prevent the live and neutral connections from being reversed when used with a type E outlet, but allows polarity reversal when inserted into a type F socket. The plug is rated at 16 A. It has grounding clips on both sides to connect with the CEE 7/4 socket and a female contact to accept the grounding pin of the type E socket. It is also used in Spain and Portugal. Currently, when appliances are sold with type E/F plugs attached, the plugs are CEE 7/7 and non-rewirable. This means that the plugs are now identical between countries like France and Germany, but the sockets are different.

## Type G

BS 1363 (British 13 A/230-240 V 50 Hz grounded and fused), equivalent to IS 401 & 411 (Ireland), MS 589 (Malaysia) and SS 145 (Singapore), SASO 2203 (Saudi Arabia)



BS 1363

The British Standards 1363 plug. This design is used not only in the United Kingdom, but also in Pakistan, Ireland, Sri Lanka, Maldives, Bahrain, UAE, Qatar, Yemen, Oman, Jordan, Cyprus, Malta, Gibraltar, Botswana, Ghana, Hong Kong, Macau, Brunei, Malaysia, Singapore, Indonesia, Bangladesh, Kenya, Uganda, Malawi, Nigeria, Mauritius, Iraq, Kuwait, Tanzania, Zambia and Zimbabwe. BS 1363 is also standard in several of the former British Caribbean colonies such as Belize, Dominica, St. Lucia, Saint Vincent and the Grenadines and Grenada. It is also used in Saudi Arabia in 220 V installations although 110 V installations using the NEMA connector are more common.

This plug, commonly known as a "13 amp plug", is a large plug that has three rectangular prongs forming a triangle. Live and neutral are 18 mm (0.709 in) long, and spaced 22 mm (0.866 in) apart. 9 mm (0.354 in) of insulation at the trailing ends of the prongs prevents accidental contact with a bare connector while the plug is partially inserted. The earth prong is approximately 4 by 8 mm (0.157 by 0.315 in) and 23 mm (0.906 in) long.

The plug has a fuse inside. The fuse is required to protect the cord, as British wiring standards allow very high current ring main circuits to the socket. Accepted practice is to choose the smallest standard fuse (3, 5 or 13 A) that will allow the appliance to function. Using a 13 A fuse on an appliance with thin cord is a fire hazard. The fuse is 1 in (25.40 mm) long, conforming to standard BS 1362. Sockets are required to be wired with neutral on the left and live on the right (viewed from the front of the socket) so that the fuse in the plug disconnects the live feed if it blows. The same convention is used for all British sockets connected directly to "mains" wiring.

UK wiring regulations (BS 7671) require sockets in homes to have shutters over the live and neutral connections to prevent the insertion of objects other than electric plugs. On most designs, these shutters are opened by the insertion of the longer earth prong. On some designs they are opened by the simultaneous insertion of the live and neutral prongs

of the right shape and spacing. The effect of the shutters is to help prevent the use of plugs made to other standards, and to prevent children and others poking things into the dangerous connections. On plugs for Class II appliances that do not require an earth, the earth pin is often plastic and serves only to open the shutters and to enforce the correct orientation of live and neutral. It may be possible to open the shutters by putting a screwdriver blade into the earth socket, so as to insert a Type C Plug (but not the BS 4573 UK shaver) or other plug types, but this can be dangerous for such plugs will not have a fuse and will often not fit properly.

BS 1363 plugs and sockets started appearing in 1946 and BS 1363 was first published in 1947. By the end of the 1950s, it had replaced the earlier type D BS 546 in new installations, and by the end of the 1960s, most earlier type D installations had been rewired to BS 1363 standards. Outlets usually include switches on the live side for convenience and safety.

### **Type H**



Two Israeli plugs and one socket. The left plug is the old standard, the one on the right is the 1989 revision.

SI 32 (Israeli 16 A/250 V grounded)

This plug, defined in SI 32 (IS16A-R), is unique to Israel and is incompatible with all other sockets. It has three flat pins to form a Y-shape. Live and neutral are spaced 19 mm

(0.75 in) apart. The Type H plug is rated at 16 A but in practice the thin flat pins can cause the plug to overheat when connecting large appliances. In 1989, the standard was revised to use three round 4.5 mm (0.177 in) pins in the same locations. Sockets made since 1989 accept both flat and round pins for compatibility with both old and new plugs. This also allows the Type H socket to accommodate the type C plugs used in Israel for non-earthed appliances. Older sockets, from about the 1970s, have both flat and round holes for live and neutral in order to accept both Type C (CEE 7/16 Europlug) and Type H plugs. As of 2008, type H sockets which accept only old-style type H plugs are very rare in Israel.

This plug is also used in the areas controlled by the Palestinian National Authority in the West Bank and all of the Gaza Strip.

Thai 3 pin plug TIS 166-2549 (2006)

Thai multi-standard 3-pin sockets (like that shown in the section on multi-standard sockets below) safely accept type A, B, C and H plugs, and also the Thai 3 pin plug. This round-pin plug is similar to the Israeli plug but its pin dimensions are 4.8 mm instead of 4.0 mm and the pins are insulated.

## **Type I**

AUS/NZS 3112 (Australasian 10 A/240 V)



Australasian switched 3-pin dual power point (socket)

This plug, used in Australia, New Zealand, Fiji, Argentina, Solomon Islands and Papua New Guinea, has a grounding pin, and two flat current-carrying pins forming an upside down V-shape. The flat blades measure 6.5 by 1.6 mm (0.256 by 0.063 in) and are set at 30° to the vertical at a nominal pitch of 13.7 mm (0.539 in). Australian and New Zealand wall sockets almost always have switches on them for extra safety, as in the UK. An unearthed version of this plug with two angled power pins but no earthing pin is used with small double-insulated appliances, but the powerpoint (wall) outlets always have three pins, including a ground pin.

There are several AS/NZS 3112 plug variants, including ones with larger pins and/or differently shaped ground pins used for devices drawing 15, 20, 25 and 32 amps. These sockets accept plugs of equal or of a lower current capacity, but not of higher capacity. For example, a 10 A plug will fit all sockets but a 20 A plug will fit only 20, 25 and 32 A outlets.



Australian 2005 standard power plug

Australasia's standard plug/socket system was originally codified as standard C112 (floated provisionally in 1937, and adopted as a formal standard in 1938), which was superseded by AS 3112 in 1990. As of 2005, the latest major update is AS/NZS 3112:2004, which mandated insulated pins by 2005 at the point of sale in all Australian States and New Zealand. However, equipment and cords made before 2003 can still be used.



Chinese sockets accepting plug types A, C (upper) and I (lower, standard)

CPCS-CCC (Chinese 10 A/250 V)

Although the pins on the Chinese plug are 1 mm (0.039 in) longer, the Australasian plug can be used with mainland Chinese socket. The standard for Chinese plugs and sockets is set out in GB 2099.1–2008 and GB 1002–2008. As part of China's commitment for entry into the WTO, the new CPCS (Compulsory Product Certification System) has been introduced, and compliant Chinese plugs have been awarded the CCC Mark by this system. The plug is three wire, earthed, rated at 10 A, 250 V and used for Class 1 applications.

In China, the sockets are installed upside-down relative to the Australasian ones.

China also uses American/Japanese "Type A" sockets and plugs for Class-II appliances. However, the voltage across the pins of a Chinese socket will always be 220, no matter what the plug type.

IRAM 2073 (Argentinian 10 A/250 V)

The Argentinian plug is a three-wire earthed plug rated at 10 A, 250 V defined by IRAM and used in Class 1 applications in Argentina and Uruguay.

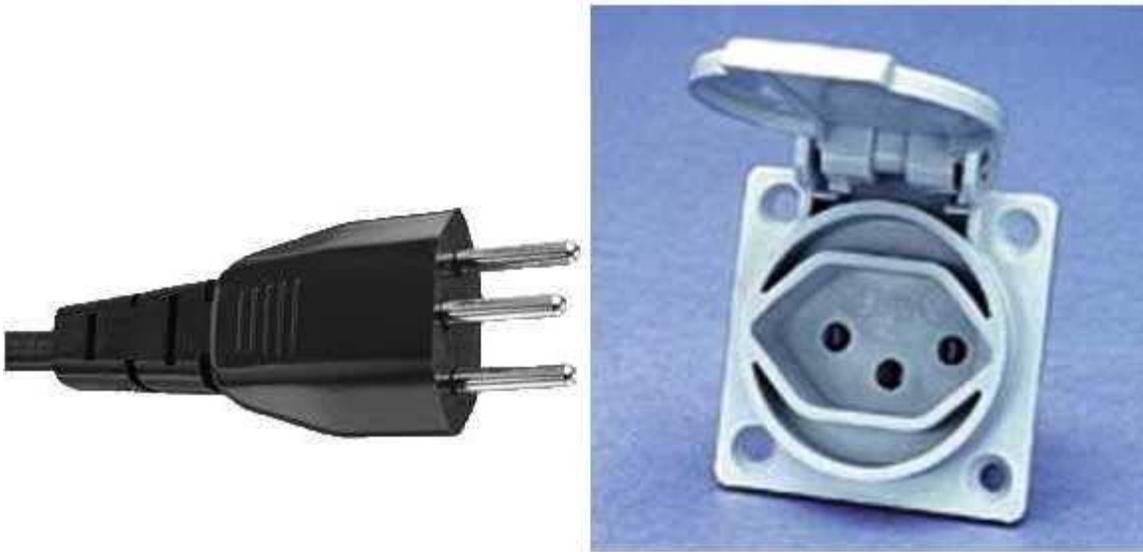
This plug is similar in appearance to the Australasian and Chinese plugs. The pin length is same as the Chinese version. The most important difference from the Australasian plug is that the Argentinian plug is wired with the live and neutral contacts reversed.

### Brazil

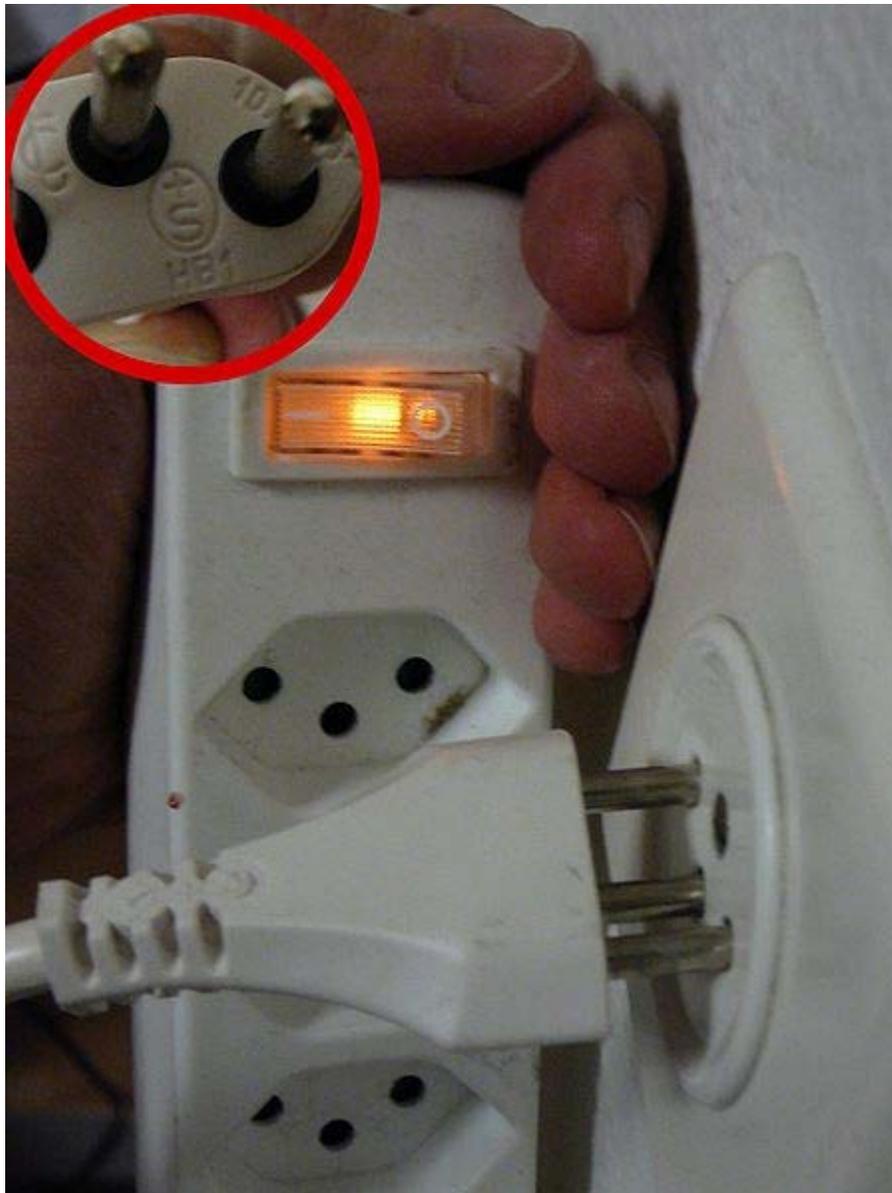
In Brazil, this kind of plug is still commonly found in high-power appliances like air conditioners, dishwashers, and household oven. Since the adopted IEC 60906-1 standard prescribes a high-current plug version, the original motivation to use the "Argentinian" plug ceased to exist, and the new standard should prevail in the long term.

### **Type J**

SEV 1011 (Swiss 10 A/250 V)



regular Type J plug and covered socket



Type J plugs and non-SEV 1011 socket showing a potential shock hazard: the appliance is energised although the plug is not fully inserted.

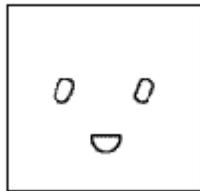
Switzerland has its own standard which is described in SEV 1011. (ASE1011/1959 SW10A-R) This plug is similar to the type C Europlug (CEE 7/16), except that it has an offset earth pin and the pin shanks are not insulated, so plugs partially inserted into non-recessed sockets present a shock hazard. Sockets used in kitchens, bathrooms and other wet areas are recessed, while those used elsewhere are not. Some plugs and adaptors have a tapered form and can be used in either environment, while others will fit only the non-recessed sockets. Swiss sockets accept Swiss plugs or Europlugs (CEE 7/16). There is also a non-earthed two-pin variant with the same pin shape, size, and spacing as the SEV 1011's live and neutral pins, but with a more flattened hexagonal form. It fits into round and hexagonal Swiss sockets and CEE 7/16 sockets, and is rated for up to 10 A.

A less-common variant has 3 square pins and is rated for 16 amperes. Above 16 amperes, equipment must either be hardwired to the electrical supply system with appropriate branch circuit protection, or connected to the mains with an appropriate high power industrial connector.

### **Type K (Danish standard)**



Danish 107-2-D1, standard DK 2-1a, with round power pins and half round ground pin



Outlet for Danish computer equipment plug's tilted flattened pins and half round ground pin (mainly used in professional environment), standard DK 2-5a  
Section 107-2-D1 (Danish 13 A/250 V earthed)

This Danish standard plug is described in the Danish Plug Equipment Section 107-2-D1 Standard sheet (SRAF1962/DB 16/87 DN10A-R). The plug is similar to the French type E except that it has an earthing pin instead of an earthing hole (and vice versa on the socket). This makes the Danish socket more unobtrusive than the French socket which is a cavity into the wall to protect the earthing pin from mechanical damage (and to protect from touching the live pins). The Danish standard provides for outlets to have child-resistant shutters.

The Danish socket will also accept the type C CEE 7/16 Europlug or type E/F CEE 7/17 Schuko-French hybrid plug. Type F CEE 7/4 (Schuko), type E/F CEE 7/7 (Schuko-French hybrid), and grounded type E French plugs will also fit into the socket but should not be used for appliances that need earth contact. The current rating on both plugs is 13 A.

A variation (standard DK 2-5a) of the Danish plug is for use only on surge protected computer outlets. It fits into the corresponding computer socket and the normal type K socket, but normal type K plugs deliberately don't fit into the special computer socket. The plug is often used in companies, but rarely in private homes.

There is a variation for hospital equipment with a rectangular left pin, it is used for life support equipment.

Traditionally all Danish sockets were equipped with a switch to prevent touching live pins when connecting/disconnecting the plug. Today, sockets without switch are allowed, but then it is a requirement that the sockets have a cavity to prevent touching the live pins. However, the shape of the plugs generally makes it difficult to touch the pins when connecting/disconnecting.

Since the early 1990s grounded outlets have been required in all new electric installations in Denmark. Older outlets need not be grounded, but all outlets, including old installations, must be protected by ground-fault interrupters (HFI or HPFI in Danish) by 1 July 2008.

As of 1 July 2008, wall outlets for type E (French 2-pin, female earth) are permitted for installations in Denmark. This was done because no electrical equipment sold to private users is equipped with a type K plug, and to break the monopoly of Lauritz Knudsen — the only company making type K sockets and plugs.

Sockets for the Schuko F type will not be permitted. The reason is that a large number of currently used Danish plugs (coincidentally made by the afore mentioned Lauritz Knudsen monopoly) will jam when inserted into a Schuko socket. This may cause damage to the socket. It may also result in a bad connection of the pins, with resultant risk of overheating and fire. Broken type F sockets are often seen in German hotels visited by Danes. Many international travel adapter sets sold outside Denmark match type C CEE 7/16 (Europlug) and type E/F CEE 7/7 (Schuko-French hybrid) plugs which can readily be used in Denmark.

### **Type L**

CEI 23-16/VII (Italian 10 A/250 V and 16 A/250 V)



23-16/VII plug with socket



Side by side comparison of Italian type L plugs rated 16 amperes (left) and 10 amperes (right).



An Italian installation carrying both Italian type L sockets (16 A on the left; 10 A on the right).

The Italian earthed plug/socket standard, CEI 23-16/VII, includes two models rated at 10 A and 16 A that differ in contact diameter and spacing. Both are symmetrical, allowing the live and neutral contacts to be inserted in either direction.

The double standard was initially adopted because in Italy, up to the second half of the twentieth century, the electric power used for lamps (*Luce* = lighting) and the one used for all other appliances (*Forza* = electromotive force; or *Usa Promiscuo* = general purpose) were sold at different fares, charged with different taxes, accounted with separated electricity meters, and sent on different wire lines that ended with different sockets. Even though the two electric lines (and respective fares) were definitively unified during the summer of 1974 many houses kept twin wires and twin electricity meters for years thereafter. The two gauges for plugs and sockets thus became a de facto standard which is still in use today and has been standardized with CEI 23-16/VII. Older installations often have sockets that are limited to either the 10 A or the 16 A style plug, requiring the use of an adapter if the other gauge needs to be connected.

CEE 7/16 (type C) ungrounded Europlugs are also in common use; they are standardized in Italy as CEI 23-5 and fit most of the appliances with low current requirement and double insulation.

Appliances with CEE 7/7 Schuko-French plugs are often sold in Italy too; however not every socket will accept them since the pins of the CEE 7/7 Schuko-French plugs are thicker than the Italian ones. Adapters are cheap and commonly used to connect CEE 7/7 plugs to CEI 23-16/VII sockets, though the power rating may be mismatched (16 A to 10 A) and may lead to potentially unsafe connection in some cases.

The current Italian standard provides for outlets to have child-resistant shutters.

CEI 23-16/VII (Italian 10 A/250 V)

The 10 (former 6) amperes style extends CEE 7/16 by adding a central earthing pin of the same gauge. Thus, CEI 23-16-VII 10 A sockets can accept CEE 7/16 Europlugs. This is the plug shown in the first picture.

CEI 23-16/VII (Italian 16 A/250 V)

The 16 amperes style looks like a magnified version of the 10 A style, identical in shape. However, the pins are 5 mm (0.197 in) thick (being 4 mm (0.157 in) thick in 10 A type), 8 mm (0.315 in) apart (while 5.5 mm (0.217 in) apart in 10 A type) and 7 mm (0.276 in) longer. The packaging of these plugs in Italy may claim they are a "North European" type. In the past they were also referred to as *per la forza motrice* (for electromotive force, see above) or sometimes *industriale* (industrial), although the latter has never been a correct definition as factories used predominantly three-phase current and specialized connectors.

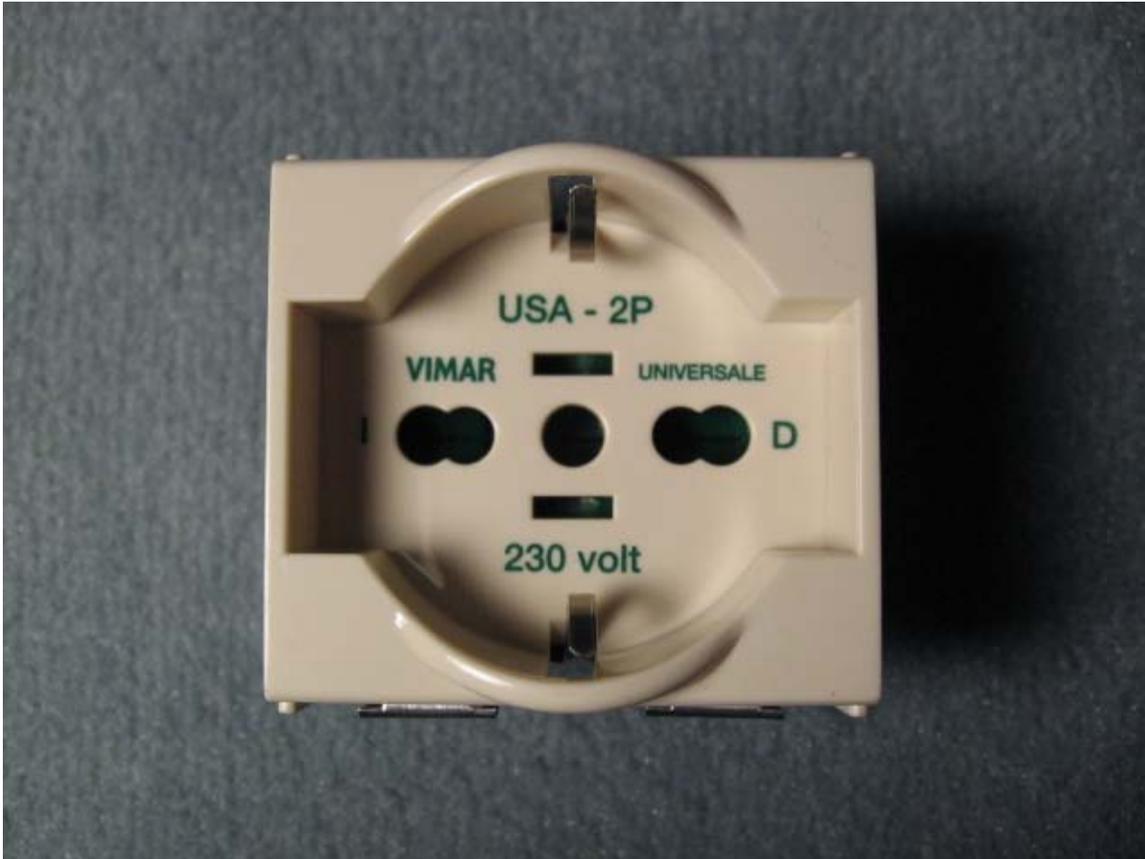
Twin-gauge or multi-type sockets



A *bipasso* socket (number 1) and an Italian adapted *schuko* (number 2 in the photo) in a modern installation.

Given that the plug with which appliances are fitted and sold varies, modern installations in Italy (and in other countries where type L plugs are used) are likely to use sockets that can accept more than one standard. The simpler type has a central round hole and two 8-shaped holes above and below. This design allows the connection of both styles of type L

plugs (CEI 23-16/VII 10 A and 16 A) and the type C CEE 7/16 Europlug. The advantage of this socket style is its small, compact face. VIMAR brand claims to have patented this socket first in 1975 with their *Bpresa* model; however soon other brands started selling similar products mostly naming them with the generic term *presa bipasso* (twin-gauge socket) that is now of common use.



An Italian VIMAR brand *universale* socket which can accept type C (most sorts of), F, and E/F hybrid plugs as well as both 10 A and 16 A type L plugs.

A second, quite common type looks like a type F socket, but adds a central grounding hole. This design can accept CEE 7/7 (type E/F) plugs, in addition to type C and type L 10 A plugs. Some of these sockets may also have 8-shaped holes to accept type L 16 A plugs as well. One drawback is that it is twice as large as a normal type L socket; also, 90° angled type L plugs often do not fit these sockets because they are too much recessed.

Other types may push compatibility even further. The VIMAR-brand *universale* (all purpose) socket, for example, accepts CEE 7/7 (type E/F) plugs, type C plugs, both 10 A and 16 A type L plugs, and American/Japanese type A plugs as well.

Other countries

Outside of Italy, type L CEI 23-16/VII (Italian 10 A/250 V) plug is found in Syria, Libya, Ethiopia, Chile, Uruguay, various countries in North Africa, and occasionally in older buildings in Spain.

### **Type M**

BS 546 (South African 15 A/250 V)

Type M is sometimes used to describe the 15 A version of the old British type D, used in South Africa and elsewhere.

### **North American oven and dryer outlets**

NEMA 14-30

A 30 amperes, 3 wire single-phase grounding receptacle is often used for electric clothes dryers. 240 volts from the split phase system is used for the heating elements, and the motor and controls run on 120 volts.

NEMA 14-50

A 50 amperes 3 wire single-phase grounding outlet is usually installed in kitchens and used for electric cooking ranges and ovens. As for dryers, lighting and motors run on 120 V and the main heating element is connected for 240 V.

## ***Proposed common standard***



A Brazilian socket for 20 A/250 V, meant for use with larger pins than 10 A version IEC 60906-1 (Brazilian 10 A and 20 A /250 V - NBR 14136:2002)

In 1986, the International Electrotechnical Commission published IEC 60906-1, the specification for a plug that looks similar but is not identical to the Swiss (Type J) plug. This plug was intended to one day become the common standard for all of Europe and other regions with 230 V mains, but the effort to adopt it as a European Union standard was put on hold in the mid 1990s.

Brazil, which had been using mostly Class II Europlugs (while households also commonly presenting socket fittings for the NEMA 1–15 and NEMA 5–15 standards), set out IEC 60906-1 as the national standard in 2001 under specification NBR 14136. However, this standard was never really enforced or encouraged in that country until 2007, when the adoption of IEC 60906-1 was made optional for manufacturers. Also, it helped domestic consumers that most of Class II plugs fitted in the new IEC 60906-1 socket.

Since January 1, 2010, new electrical appliances in Brazil must now comply with the new IEC 60906-1 requirement. End-user stores and resellers can sell equipments without adoption deadlines, but importers will no longer be allowed to bring in nonconforming devices, nor will manufacturers be able to sell them in Brazil.

There are two types of sockets and plugs in this system: one for 10 A, with a 4mm pin diameter, and another for 20 A, with a 4.8 mm pin diameter, the latter used for heavier appliances such as microwave ovens.

South Africa has also introduced the IEC 60906 standard as SANS 164-2 in parallel with the types C and M standard.

### **Comparison of plugs**

Type	Plug standard	Power rating	Grounded	Polarised	Fused	Insulated pins
A	NEMA 1–15 unpolarised	15 A/125 V	No	No	No	No
	NEMA 1–15 polarised	15 A/125 V	No	Yes	No	No
	JIS C 8303, Class II	15 A/100 V	No	No	No	No
B	NEMA 5–15	15 A/125 V	Yes	Yes	No	No
	NEMA 5–20	20 A/125 V	Yes	Yes	No	No
	JIS C 8303, Class I	15 A/100 V	Yes	Yes	No	No
C	CEE 7/16 (Europlug)	2.5 A/250 V	No	No	No	Yes
	CEE 7/17	16 A/250 V	No	No <sup>1</sup>	No	No
	GOST 7396 C 1	6 A/250 V 16 A/250 V	No	No	No	No
D	BS 546 (2 pin)	2 A/250 V 5 A/250 V = BS 4573	No	No	No	No
	BS 546 (3 pin)	2 A/250 V 5 A/250 V 15 A/250 V = SABS 164 30 A/250 V	Yes	Yes	No	No
E	CEE 7/5	16 A/250 V	Yes	Yes	No	No
F	CEE 7/4 (Schuko)	16 A/250 V	Yes	No	No	No
E+F	CEE 7/7	16 A/250 V	Yes	Yes <sup>2</sup>	No	No
G	BS 1363, IS 401 & 411, MS 589, SS 145	13 A/230-240 V	Yes	Yes	Yes	Yes

H	SI 32	16 A/250 V	Yes	Yes	No	No
	TIS 166–2549	16 A/250 V	Yes	Yes	No	Yes
I	AS/NZS 3112	10 A/240 V 20 A/240 V 25 A/240 V 32 A/240 V	Yes and No	Yes	No	Yes
	CPCS-CCC	10 A/250 V	Yes	Yes	No	No
	IRAM 2073	10 A/250 V	Yes	Yes	No	No
J	SEV 1011	10 A/250 V 16 A/250 V	Yes	Yes	No	No
K	Section 107-2-D1	13 A/250 V	Yes	Yes	No	No
L	CEI 23-16/VII	10 A/250 V 16 A/250 V	Yes	No	No	Yes
—	IEC 60906-1 (2 pin)	10 A and 20 A/250 V	No	No	No	Yes
	IEC 60906-1 (3 pin)	10 A and 20 A/250 V	Yes	Yes	No	Yes

<sup>1</sup> There are some CEE 7/17 plugs with special shape which are polarised when used with french socket of type E (mechanically only)

<sup>2</sup> Plug can only be inserted one way with French socket of type E, but lack of wiring convention means that the type is not polarised in practice

### **Multi-standard sockets**



A standard grounded **Thai** outlet supporting European 2-pin plugs and earthed and unearthed American plugs and Thai 3 pin plugs. Though this receptacle accepts standard US Type A or B plugs, the standard Thai voltage is 220 volts.

Sockets that take a variety of plug types can be found in various countries where market size or local market conditions make a specific plug standard impractical to implement. These socket accept plugs fitting various European, Asian and North American standards. Since many plug standards are also associated with corresponding voltages, multi-standard sockets do not safeguard against devices being damaged by the wrong voltage. This forces users to be aware of the voltage requirements of their appliances as well as the prevailing local voltage. Devices designed to adapt automatically to whatever voltage and frequency is supplied, and which don't require grounding, are generally safe to use with these sockets.

These sockets have one or more ground holes to allow 3-pin plugs. On properly wired circuits, the ground contact may be actually grounded; however, as with most other forms of plugs, they are not immune to poor wiring. They may also not provide grounding to all types of plugs, as is the case of Schuko or French plugs where the grounding pin that mates with the plug is part of the socket rather than the plug.

### **Adapters**

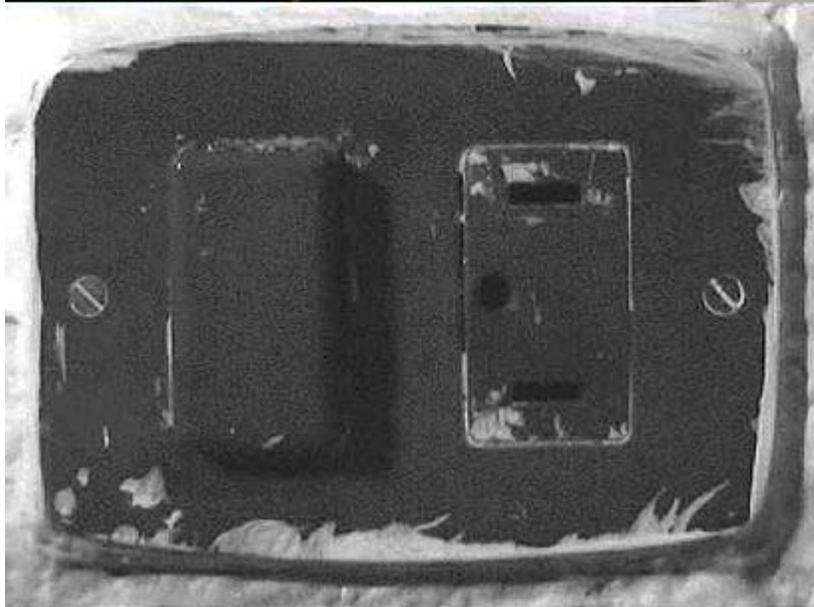
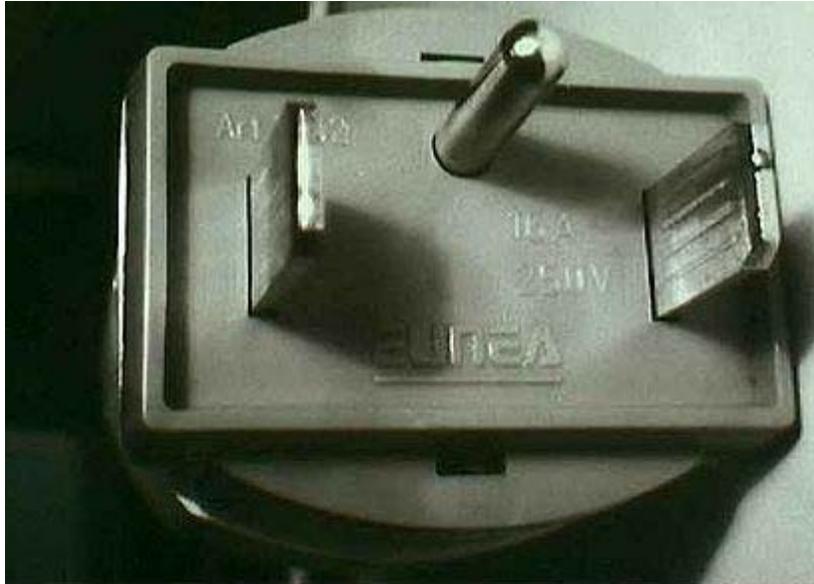


A type M (15 A version of type D) travel adapter

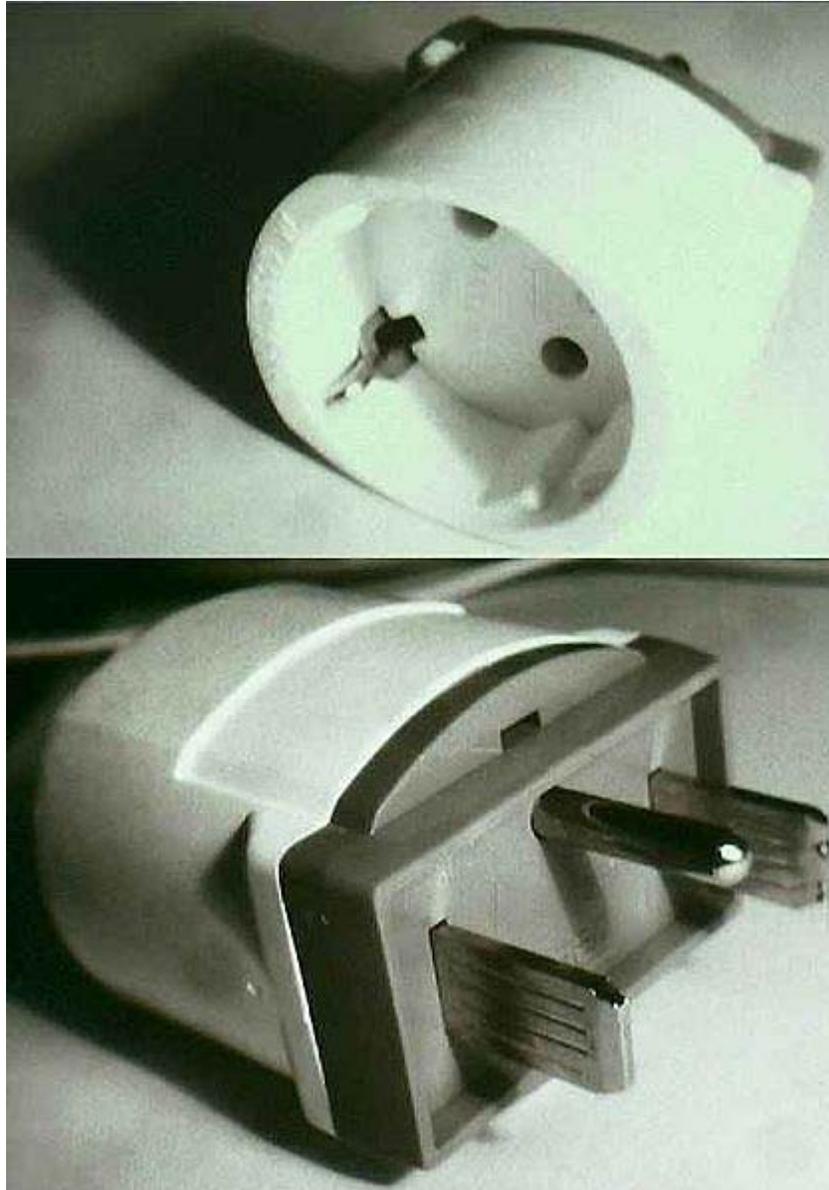
To facilitate travelers' use of personal electric devices, adapters are available to permit the interconnection of normally incompatible plugs and sockets. Such adapters overcome only the physical incompatibilities between plugs and sockets built to different standards; often a voltage converter is required for electrical compatibility.

***Obsolete types***

**Old Spanish sockets**



Spanish three-prong plug and socket, with easily removable fuse



An adapter to allow types C and F to be inserted

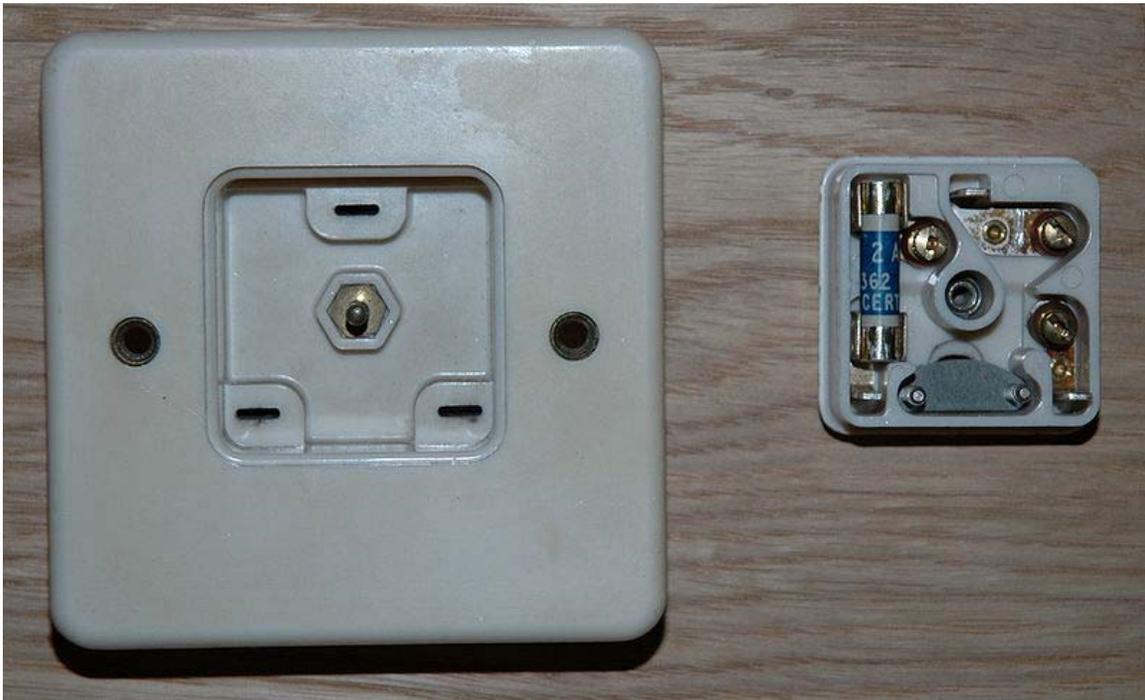
Some older industrial buildings in Spain used sockets that took a particular type of plug which was rated for higher current and had two flat contacts and a round ground pin, somewhat similar in design to the ones found on American plugs but larger in size.

The live and neutral measure 9 by 2 mm (0.354 by 0.079 in), and are 30 mm (1.181 in) apart. All three pins are 19 mm (0.748 in) long, and the earth pin is a cylinder of 4.8 mm (0.189 in) diameter.

While the plug resembles an American connector, the two flat contacts are much wider apart than on a standard American plug, which will therefore not fit in these sockets.

No domestic appliances were ever sold with these plugs.

### **UK electric clock connector**



British electric clock connector, 3-pin made by MK. Showing the rear of the plug with its 2 A fuse. Different manufacturers' clock connectors were generally not compatible.

Fused plugs and sockets of various proprietary and non-interchangeable types are found in older public buildings in the UK, where they are used to feed AC electric wall clocks. They are smaller than conventional socket outlets, commonly being made to fit BESA junction boxes, and are often of very low profile. Early types were available fused in both poles, later types fused in the live only and provided an earth pin. Most are equipped with a retaining screw or clip to prevent accidental disconnection. The prevalence of battery powered quartz controlled wall clocks has meant that this connector is rarely seen in new installations.

## NEMA 1-15 5-receptacle Type A outlet



Unusual American 5-receptacle Type A outlet, ca. 1928

This is a very rare 5-way outlet from circa 1928, and is able to accept modern ungrounded polarized NEMA 1-15 plugs because the outlet itself is polarized. However, the outlet itself is still obsolete as the NEMA standard only provides for having at most 3 outlets from a single wallplate.

## American "Type I"



American Type I duplex outlet



### Compatibility of American and Australian Type I plugs

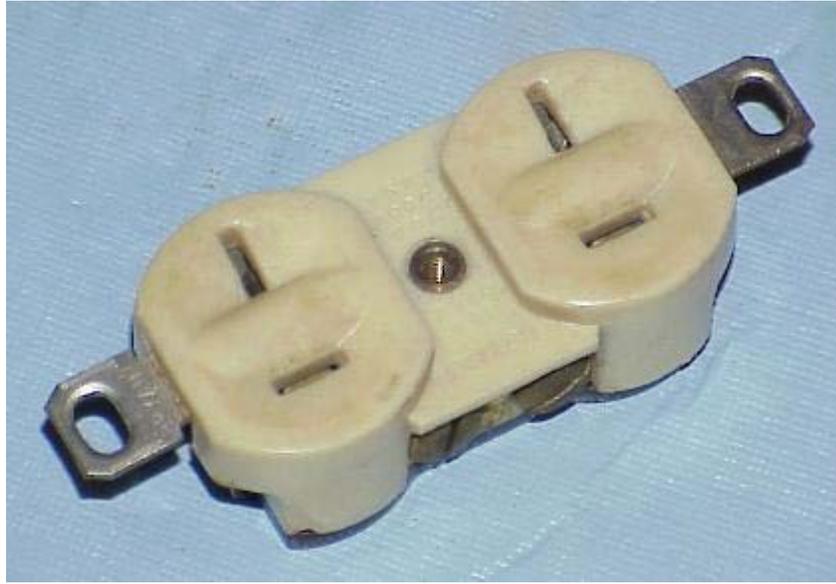
The American electrical supply manufacturers Hubbell, Eagle, and possibly others made outlets and plugs that would match Type I plugs and sockets exactly. Type I connectors are used in Australia for 240 V service. These American outlets date back to at least 1915 (as seen in US Patent 1,179,728 filed in 1915), antedating the American 3 prong Type B sockets and plugs. They were meant for appliances that needed grounding (120 V at 15 amperes), and to be used in laundry rooms for washing machines and gas dryers (to power the motor). These did not become popular because American type A 2-prong plugs would not fit.

### Split current/voltage ratings

Many older North American receptacles have two different current and voltage ratings, most commonly 10 A 250 V/15 A 125 V. This has to do with a peculiarity of the National Electrical Code from 1923 to the 1950s. Originally, receptacles were rated at 10 A 250 V, because the NEC limited lighting circuits to 10 amperes. In 1923, the code changed to allow lighting circuits to be fused at 15 amperes; however, the old rule still applied to circuits over 125 volts. The higher voltages were rarely used for lighting and appliances. Most receptacles with this rating are of the "T-slot" type. This type of rating was phased out in the 1950s, and finally abolished in the 1960s with the adoption of the current NEMA standards.

Pre-NEMA *twist-lock* devices can sometimes be found with split 250/600 V ratings. These are also obsolete.

## U.S. perpendicular outlet



Perpendicular slot duplex outlet



## **Розетка РП-2Б ~10А 42В**

Perpendicular slot RP-2B outlet 10 A 42 V AC

Another obsolete outlet, made by Bryant, 125 V 15 A and 250 V 10 A rating. A NEMA 5-20 125 V 20 A or 6-15 250 V 15 A plug with a missing ground pin would fit this outlet, but a NEMA 2-20 plug is slightly too big to fit.

The upper slots as seen in the illustration connect to silver-colored wiring screws on the upper side, and the lower slots connect to brass-colored wiring screws on the lower side.

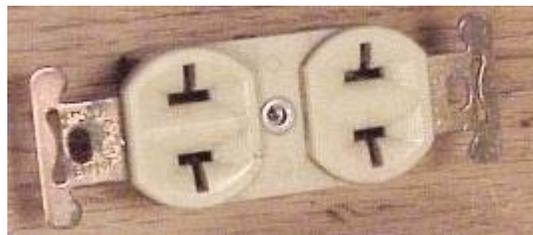
In Australia, the same or similar T-configuration sockets are used for DC power outlets, such as in stand-alone power systems (SAPS) or on boats.

In Soviet Union and now Russia this socket is commonly used for wiring in places where the voltage is lowered for safety purposes, like in schools, gas stations or in wet areas, rated 42 V 10 A AC. Such an unusual connection is intended specifically to make the connection of standard higher-voltage equipment impossible.

### **U.S. Combination duplex outlet**



An extremely old "Nurpolian"-brand black parallel and tandem duplex outlet rated at 250 V 10 A (although this type was normally supplied with 120 V).



T-slot duplex outlet.

The parallel and tandem outlet accepts normal parallel NEMA 1–15 plugs and also tandem NEMA 2–15 plugs. Both pair of receptacles are fed internally by the same supply.

A more recent and fairly common version of this type is the T-slot outlet, in which the locations of the tandem and the parallel slots were combined to create T-shaped slots. This version also accepts normal parallel NEMA 1–15 plugs and also tandem NEMA 2–15 plugs. Incidentally, a NEMA 5–20 (125 V, 20 A), a NEMA 6-15 (250 V, 15 A) or 6–20 (250 V, 20 A) plug with a missing ground pin would fit this outlet. This type is no longer available in retail shops since the 1960s.

## U.K. Dorman & Smith (D&S)



D&S Socket

The D&S plugs and sockets were rated at 13 amperes and were one of the early competing types for use on ring main circuits. They were never popular in private houses but were widely deployed in prefabricated houses and council housing. The BBC also used them. D&S supplied the sockets to local authorities at very low cost, with the intention of making money out of the sales of plugs typically priced at 4 times the price of a type G plug. It is not known exactly when D&S ceased manufacturing the plugs and sockets but some local authorities continued to use them in new installations until the late 1950s. Many D&S sockets were still in use until the early 1980s, although the difficulty in obtaining plugs for them after around 1970 often forced their users to replace them with type G sockets. This generally violated local authority regulations on alterations to council housing. The D&S plug suffered from a serious design fault: the live pin was a fuse which screwed into the plug body and tended to come unscrewed on its own in use. A fuse that worked loose could end up protruding from the socket, electrically live and posing a shock hazard, when the plug was removed.

## U.K. Wylex Plug



Wylex 13A Plug

The Wylex plugs and sockets were produced by Wylex Electrical Supplies Ltd. as a competitor to the type G and D&S sockets for use on ring main circuits. The plugs were available in both 5 A and 13 A versions, differing only by the widths of the live and neutral pins, and contained an internal fuse of the same rating as the plug. A plug had a central round earth pin and two flat pins, one on each side of the earth pin, for live and neutral. The two flat pins were slightly offset above and below the line cutting through the horizontal diameter of the earth pin. Wall sockets were rated at 13 amperes and took both 5 A and 13 A plugs. Many 13 A plugs had a socket on the back which took a 5 A plug, but would not take another 13 A plug because the slots for the live and neutral pins were narrower than those of the wall sockets, resulting in a stacked arrangement. Wylex sockets were used in council housing and public sector buildings, and for a short while in private housing. They were particularly popular in the Manchester area although they were installed throughout England, mainly in schools, university accommodation, and government laboratories. Wylex plugs and sockets continued to be manufactured for several years after type G sockets became standard and were commonly used by banks and in computer rooms during the 1960s and 70s for uninterruptible power supplies or "clean" filtered mains supplies. It is not known exactly when Wylex ceased manufacturing its plugs and sockets; however plugs were available in electrical shops of the Manchester area until the mid 1980s.

### Lampholder plug



Two Italian bypass lampholder plugs with Edison screw mount. Left: early type (porcelain and brass, circa 1930); right: late type (black plastic, circa 1970).

A lampholder plug fits into the Bayonet cap or Edison screw socket of a lampholder in place of a light bulb and enables an electrical appliance to be powered from a wall or ceiling light fitting. They were commonly used during the 1920s to 1960s when wall sockets were scarce or nonexistent in many houses. Lampholder plugs were rarely fused.

Conventional practice in the U.K. is to protect lighting circuits with a 5 A or 6 A fuse or circuit breaker, which will rapidly blow or trip when one attempts to utilise a lampholder plug to power an appliance requiring significantly more than 5 A or 6 A. If the current-draw is only slightly higher (e.g. 45%) than the circuit breaker rating, the circuit breaker may take more than 1 minute to trip and can take 1 hour to trip with a current that is 10% above the rating of the circuit breaker. Wiring regulations in the U.K. and some other countries no longer approve lampholder plugs because of the risks of overheating and fire.

In Italy, bypass lampholder plugs with Edison screw mount were in broad use until light wire cables were separated from general purpose wire cables and some areas of the house (cellars, etc.) were commonly not provided with sockets.

Edison screw lampholder adaptors (for Type A plugs) are still easily found and commonly used in the Americas.

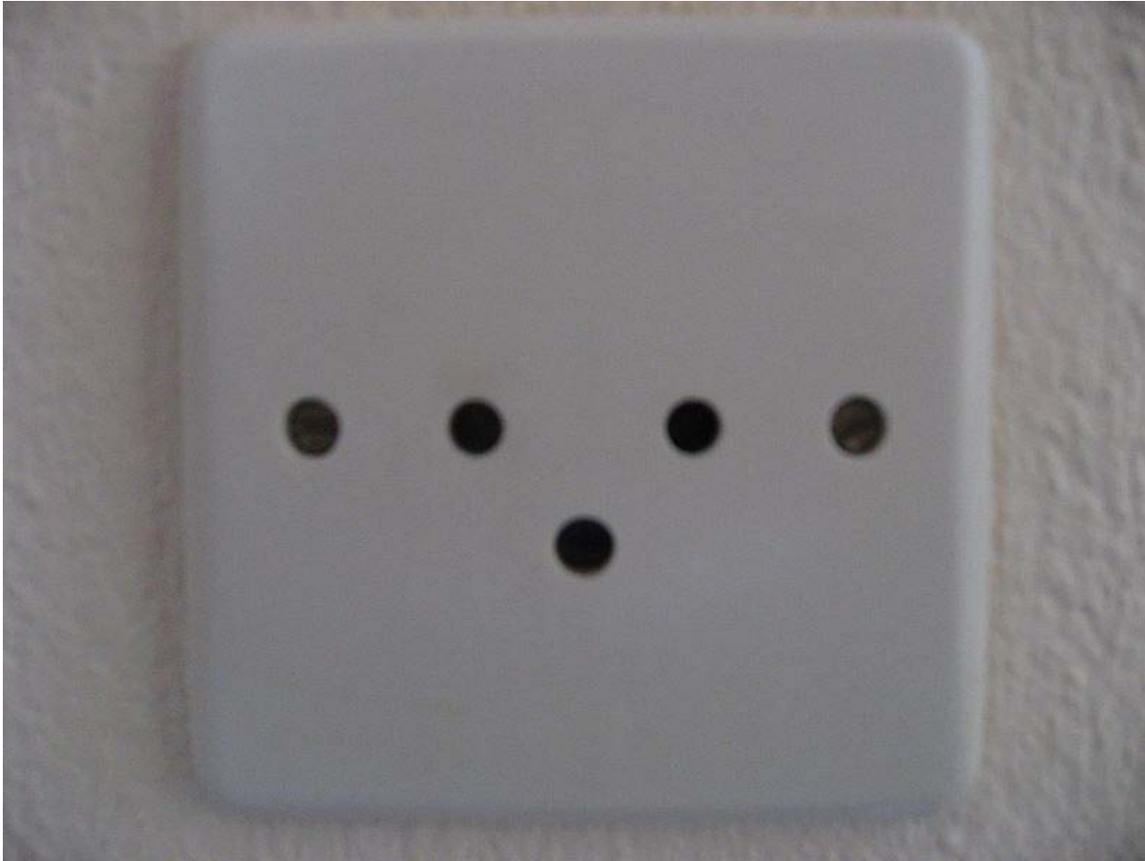
### **Old Greek sockets**



old earthed standard adaptor



plugs



socket

Called "Tripoliki" (τριπολικές) the 3 Pin round standard similar to type J and post-1989 type H, virtually abandoned by 1995.

Previous to the large-scale adoption of schuko plugs, this was the only way to use an earthed appliance.

### ***Unusual types***

#### **NEMA 2–15 and 2–20**

These ungrounded plugs with two flat parallel prongs are variants of the 1–15 but are intended to deliver 240 volts instead of 120. The 2–15 has coplanar current prongs (rotated 90° from ordinary American plugs), and is used for 240 V service at 15 amperes, while the 2–20 has the two current prongs rotated 90° relative to each other (one vertical, one horizontal) and is used for 240 V service at 20 amperes. NEMA 2 plugs and sockets are rare because they have been prohibited for household use in the United States and Canada for several decades. They are potentially hazardous since they have no ground or neutral, and in some cases plugs can be inserted into incorrect-voltage sockets. Prior to the adoption of the NEMA standard, a plug nearly identical to the 2–20 was used for 120

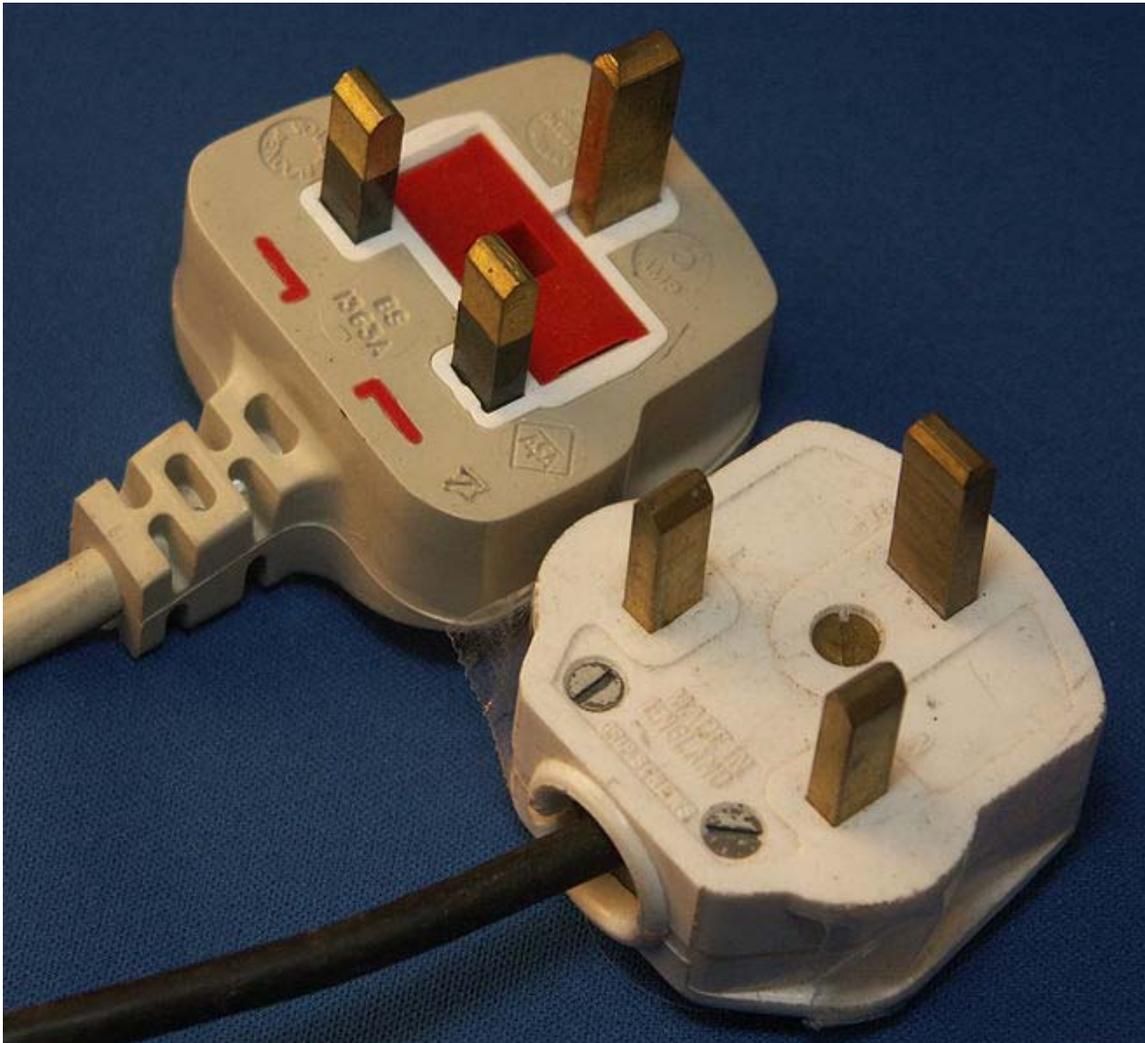
V at 20 A. That obsolete plug would fit into 5–20 and 6–20 sockets, which supply different voltages, but the NEMA 2-20 plug is dimensionally incompatible.

### **Soviet adaptor plugs**



Some appliances sold in the Soviet Union had a flat unearthed plug with an additional pass-through socket on the top, allowing stacked arrangement of plugs. This design was very helpful (for the usual Soviet apartment of the 1960s had very few wall sockets), but completely unsafe, as the brass cylinders of the secondary socket were uncovered at the ends (to unscrew them easily), recessed only for 3 mm and provided bad contact because they relied on the secondary plug's bisected expanding pins. The pins of the secondary plug (without insulation sleeves) could not be inserted into the cylinders completely, and were accessible through a 5mm gap between the primary and secondary plugs.

## U.K. Walsall Gauge plug



Walsall Gauge 13 A plug (bottom) compared to regular BS 1363 plug

Unlike the standard BS 1363 plugs found in the U.K., the earth pin is on a horizontal axis and the live and neutral pins on a vertical axis. This style of plug/socket was used by University laboratories (from batteries) and the BBC, and is still in use on parts of the London Underground for 220V DC voltage supply.

**Italian Bticino brand Magic security connector**



Bticino Magic Security receptacle, detail.



assortment of Magic Security receptacles (in orange, the industrial three-phase type).



assortment of Magic Security plugs.

This style of connector, produced by Italian brand Bticino, appeared in the 1960s and was intended as an alternative to the Europlug or type L connectors then in use. The socket is an almost rectangular receptacle, with one or more lateral key pins and indents to prevent inverting the plug (it is polarised), or connecting plugs and sockets with different ampere ratings. At least four models were produced: three single-phase general purpose connectors rated respectively 10 A, 16 A and 20 A; plus a three-phase industrial connector rated 10 A; all of them have different key-pin positioning so plugs and sockets cannot be mismatched. The socket is closed by a safety lid (bearing the word “Magic” on it) which can be opened only with an even pressure on its surface, thus preventing the insertion of objects (except the plug itself) inside the socket. The contacts are blades positioned on both sides of the plug; the plug is energized only when it is inserted fully into the socket.

The obvious drawback of the system is that it is not compatible with europlugs. As household appliances were never sold fitted with these security plugs and the use of adapters would defeat all of the newly introduced safety features, once this system is adopted all standard plugs must be cut off and replaced with the appropriate security connector. However, the *Magic* security system had some success at first because its enhanced safety features appealed to customers; standard connectors of the day were considered not safe enough. The decline of the system occurred when safety lids similar

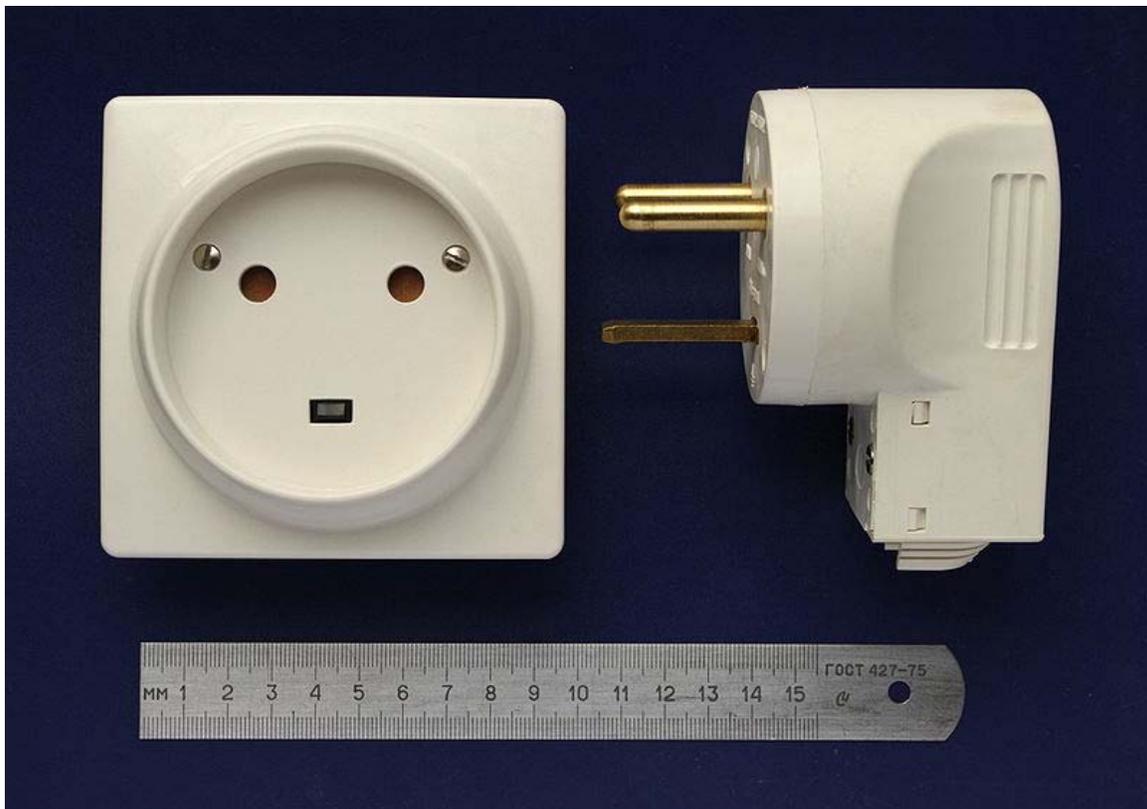
to the Magic type were developed (VIMAR Sicury) and then applied to standard type L sockets by third brands and by Bticino itself.

In Italy, the system was never definitively abandoned and, though rarely seen today, is still marked as available in Bticino's products catalogue.

In Chile, 10 [A] Magic connectors are commonly used for computer/laboratory power networks, as well as for communications or data equipment. This allows delicate electronics equipment to be connected to an independent circuit breaker, usually including a surge protector or an uninterruptible power supply backup. The different style of plug makes it more difficult for office workers to connect computer equipment to a standard unprotected power line, or to overload the UPS by connecting other office appliances.

In Iceland, Magic connectors were widely used in homes and businesses alongside Europlug and Schuko installations. Their installation in new homes was still quite common even in the late 1980s.

### ***Single phase electric stove plugs and sockets***



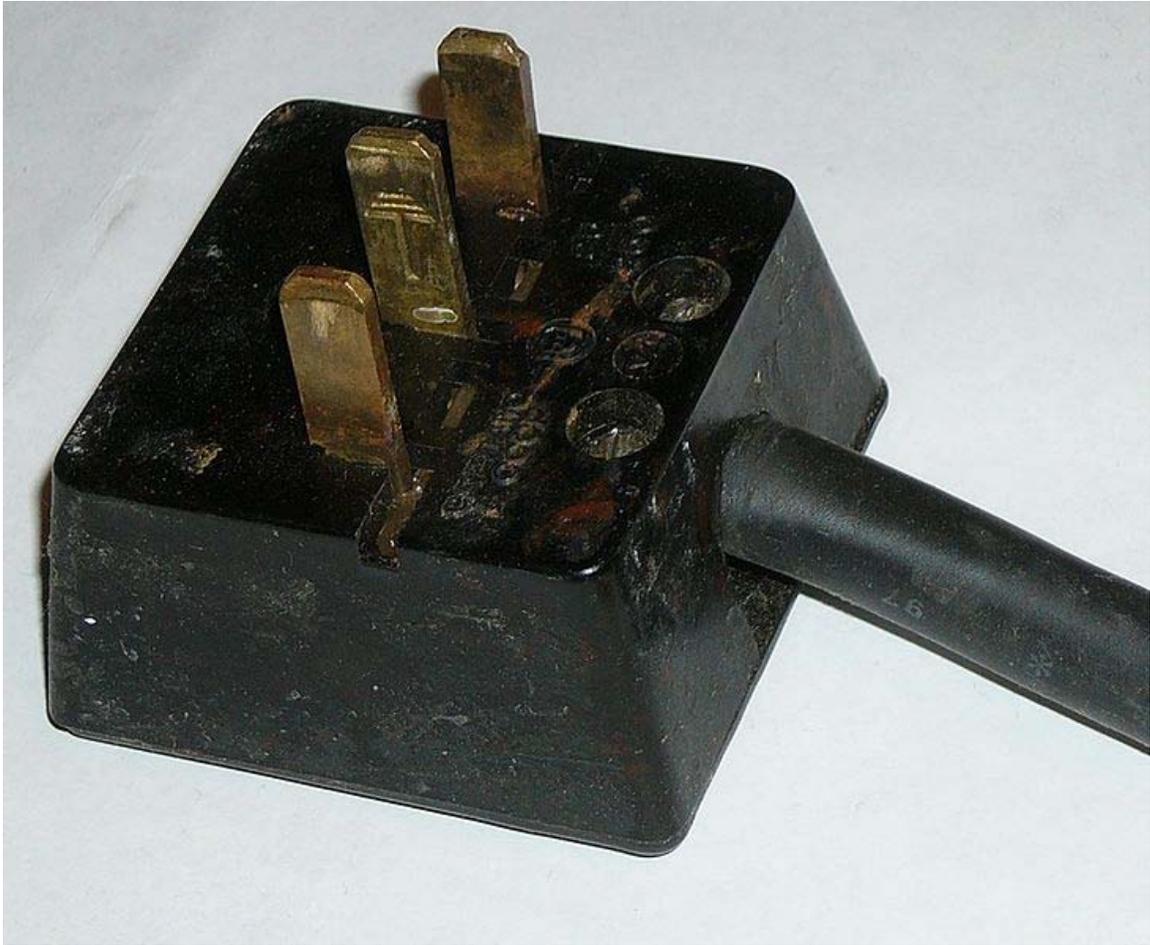
Power connector Legrand (400 V, 32 A)



Russian stove connectors rated for 250 V 25 A AC. Plug and Socket



Socket.



Plug

The plugs and sockets used to power electric stoves from a single-phase line have to be rated for greater current values than ones for three-phase system because all the power has to be transferred through a single line. Electric stoves are often hardwired to the electrical supply system, connected to the mains with an appropriate high power industrial connector or with non-standard high power proprietary domestic connector (as some countries do not have wiring regulations for single-phase electric stoves). In Russia an electric stove can be often seen connected with an 25–32 amperes connector.

## Chapter 2

# BS 1363



Top: a typical moulded BS 1363 plug, showing the fuse access from the underside of the plug. Bottom: a typical rewireable plug; the large central screw releases the cover, allowing access to the terminals and also the fuse

**BS 1363** is a British Standard which specifies the most common type of domestic AC power plugs and sockets that are used in the United Kingdom, Cyprus, Hong Kong, Ireland, Malta, Malaysia, Singapore, and many former British colonies. Of these, Ireland, Malaysia and Singapore have equivalent standards—IS 401 & 411, MS 589, and SS 145, respectively. The standard was introduced in 1947, shortly after the Second World War, as part of a new standard for electrical wiring in the United Kingdom.

Trading standards legislation in both the UK and Ireland requires that all domestic electrical goods sold in either country should be fitted with a BS 1363 or IS 401 (as applicable) plug.

Other plug types used in the same area include IEC 60309, only used in industrial and some outdoor applications, and BS 546, limited to old installations and specialised applications where either the BS 1363 plug is unsuitable or where mateability with the standard variety is not desired (for example, where lamps are controlled by a switch or dimmer).

## ***Origins***



BS 1363 type electrical socket. The closed shutters block entry of foreign objects

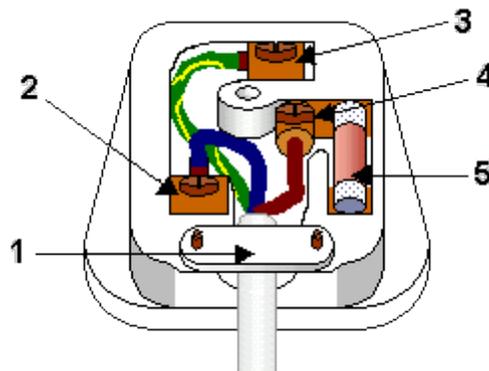
In 1941 Lord Reith, the then minister of Works and Planning, instigated the establishment of a series of committees to investigate and report on the problems likely to affect the peace time rebuilding of Britain. One of these, the Electrical Installations Committee, was charged with the study of all aspects of electrical installations in buildings. Convened in 1942, they reported in 1944.

One of the most far reaching recommendations, still in effect in the 21st century, was the introduction of the ring circuit system (often informally called "ring main"), where, instead of each socket being individually wired, a cable was brought from the fuse or circuit breaker in the distribution board and wired in sequence to a number of sockets before being taken back to the distribution board and wired to the same fuse or circuit breaker. This provided considerable savings in the copper required to wire the circuit.

Since the fuse or circuit breaker had to be rated for the maximum current the ring could carry (30 A or 32 A for breaker), it was required that the plugs used to connect to the ring each contained their own fuse rated for the appliance that it connected.

The plug and socket system defined in BS 1363 is a result of another of the report's recommendations. Britain had previously used a combination of 5 amp and 15 amp round pin sockets, where each had to be wired to the distribution board where it would be provided with its own fuse. In a supplementary report, published as an appendix to the main report (July 1944), the committee proposed a completely new socket outlet and fused plug should be adopted as the "all-purpose" domestic standard. A number of technical details were required of the new standard, first of which was that "To ensure the safety of young children it is of considerable importance that the contacts of the socket-outlet should be protected by shutters or other like means, or by the inherent design of the socket outlet." This requirement for a new system of plugs and sockets led to the publishing in 1947 of "British Standard 1363 : 1947 Fused-Plugs and Shuttered Socket-Outlets".

## ***Design***



Internal wiring. There is more slack in the neutral wire than the live, ensuring that if the lead is forcibly removed, the live wire will disconnect first. #1 Cable grip; #2 Neutral terminal; #3 Earth terminal; #4 Line terminal; #5 Fuse

A BS 1363 plug has two horizontal, rectangular pins for line (commonly termed "live") and neutral, and above these pins, a larger, vertical pin for an earth connection. Unlike most other types of sockets, the earth pin is necessary for use of the BS 1363 plug, as it is needed to push open a shutter in the socket to allow the line and neutral pins to be inserted. It also polarises the plug, ensuring that the line pin is connected to the correct terminal in the socket. Moulded plugs for unearthed, double-insulated appliances may substitute this contact with a non-conductive plastic pin to open the shutter. Most non-fixed domestic equipment is connected using the BS 1363 plugs, the main exceptions being equipment requiring more than 13 amps (e.g. larger electric cookers, which are hard-wired); remotely switched, non-fixed lighting (which use proprietary or BS 546 plugs); and low-power portable equipment, such as shavers, which may be used in several countries. Many bathrooms, particularly in hotels, have 2-pin standard "shaver sockets", which usually accommodate both European and US 2-pin plugs.

BS 1363 part 1 is the specification for the plug. As there are no moving parts in a plug it is practicable to define the dimensions of the plug in an absolute manner. BS 1363 part 2 contains the specifications for sockets, to allow some flexibility in design the socket is defined partly in terms of the plug with which it will be used. It therefore follows that the performance of the socket is unpredictable if anything other than a BS 1363 compliant device is inserted into the socket.

The requirement for smaller plugs which may easily fit into laptop bags etc has led to several designs of folding plugs with varying degrees of success.

## Shuttering



Detail of an MK Logic Plus wall socket showing shutters which are operated only when all three pins are simultaneously inserted

As mentioned in "Origins" above, standard UK sockets incorporate shutters on the line and neutral contacts to prevent the insertion of a foreign object into the socket. Sockets from most manufacturers have shutters which are opened by the earth pin alone. This is longer than the others and must always be present (though on double insulated equipment it may be plastic). Sockets manufactured by MK use a proprietary system which requires that both line and neutral pins as well as the earth pin of correct dimensions must be inserted simultaneously.

It is of interest to note that the concept of automatic shutters being used in UK sockets for protection dates back to at least 1927.

Socket covers are marketed as preventing children from inserting objects into sockets. The UK Government safety advice is that sockets are safe and covers unnecessary. Similar advice is given by RoSPA and CAPT. Despite the official advice, plug-in socket covers are generally available, it is normal for such socket covers to be only approximately in conformance with the BS 1363 standard for plugs, and therefore the performance of the socket and cover combination is unpredictable. Which? has reported on the danger which results from children inserting easy to remove socket covers into the earth hole only, thus opening the shutters in conventional sockets. Research has shown that there are no socket covers which comply to BS 1363 dimensions. None of the plug-in covers on the UK market has been shown to conform to the recommendations which have been made by ANEC (European Association for Consumer Representation in Standardisation) setting out the basic requirements and proposed test methods which

should be adopted by EU Member States to ensure that child safety devices are effective and safe.

The majority of these plug-in devices can be inserted upside down, which serves to disable the internal shutters and results in compromised safety. It has been demonstrated that some of the most popular types on the market actually allow objects such as paper clips to be inserted alongside the line pin of the socket cover. The [FatallyFlawed.org.uk](http://FatallyFlawed.org.uk) campaign was founded in August 2008 to raise awareness of this issue and publishes photographic and video evidence of the dangers.

BS 1363 places no restrictions on the distance of the earth pin to the top edge of the socket faceplate (although there is a minimum distance specified between the power pins and the lower edge of the faceplate). As a result there are many designs of multi-way extension sockets (and also the older multi-way adapter blocks) which allow a normal plug to be inserted upside down. This completely defeats the correct operation of the safety shutters. This method is sometimes used to allow a European-style plug (with two small round pins and no earth pin) to be inserted into the open line and neutral ports.

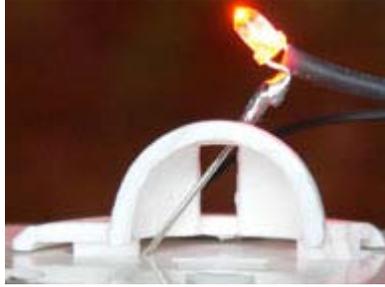
#### **Dangers caused by socket covers**



Shows how an inverted socket cover opens shutters to expose live parts.



Common socket cover type allows paper clips etc. to be inserted into live socket.



Extraction hole in domed socket cover allows access to live parts (cutaway cover).

**Shows how an error in BS 1363 permits dangerous multi-way extensions.**

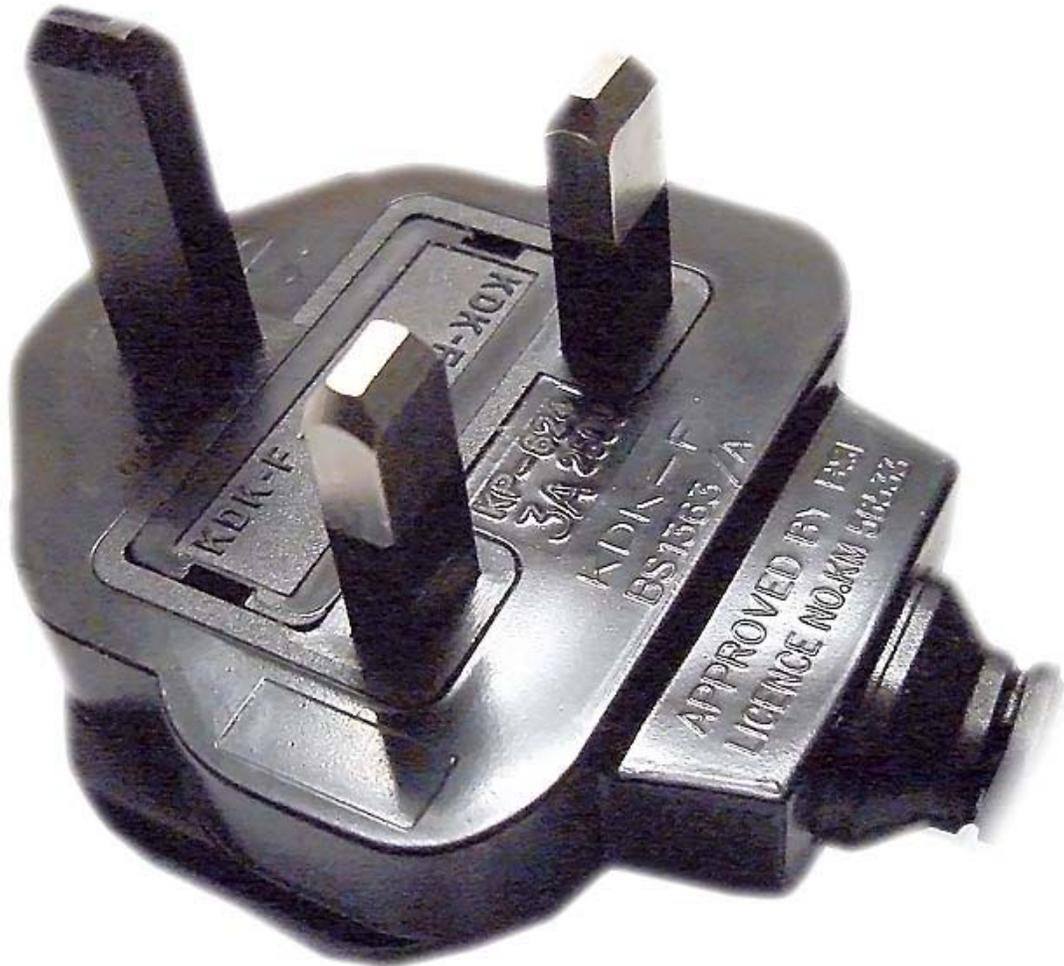


Shows a multi-way extension with insufficient distance between the earth pin and edge of faceplate, this allows an inverted plug to be placed in the extension.



Shows how an inverted plug can open shutters in a multi-way extension to expose live parts.

## Pin insulation



BS 1363 plug, with an ISOD (Insulated Shutter Opening Device) which is used when an earth pin is not required

The phase and neutral pins on modern plugs have insulated bases to prevent finger contact with pins and also to stop metal sheets (for example, fallen window blind slats) from becoming live if lodged between the wall and a partly pulled out plug.

## Dimensions

The line and neutral pins have a rectangular cross section  $6.35 \pm 0.13$  mm wide and  $3.975 \pm 0.075$  mm height. They are  $17.7 \pm 0.5$  mm long and their centre lines are horizontally  $11.115 \pm 0.065$  mm on either side of the symmetry plane of the plug. The protective-earth pin is centred on the symmetry plane, is  $22.73 \pm 0.5$  mm long and has a

cross section  $3.975 \pm 0.075$  mm wide and  $7.925 \pm 0.125$  mm height. The centre lines of the line/neutral pins and the protective pin are vertically  $22.23 \pm 0.13$  mm apart.

(These dimensions may be more easily remembered in the original imperial units, which are not mentioned in the current standard:  $1/4 \pm 0.005$  inch wide by  $5/32 \pm 0.0025$  inch high, and  $0.695 \pm 0.02$  inch long. They are  $7/8 \pm 0.005$  inch horizontally from each other, and the same distance vertically from the earth pin, which is  $0.895 \pm 0.02$  inch long. The pin lengths were presumably originally 0.7 and 0.9 inches, and assigned an asymmetric tolerance of  $+0.005/-0.015$ .)

### **Other safety features**

- The plug base is broadened near the pins to help keep fingers away from the pins (this was a very early modification to the standard, which was later improved by the use of the insulated pin bases described above).
- The plug sides are shaped to improve grip and make it easier to remove the plug from a socket without placing fingers behind the plug where the pins are.
- The plug is polarised, so that it cannot be inserted with the phase and neutral pins reversed. This feature is important to make sure the fuse is in the phase side of the supply.
- The longer earth pin ensures that the earth path is connected before the live pins, and remains connected after the live pins are removed.
- The design of the earth pin being of a larger dimension prevents it from being inserted into the phase or neutral sockets should this be attempted in error
- The plug is firmly fitting and therefore difficult to dislodge by accidental knocks or strains on the cord.
- The cable always enters the plug from the bottom, thus making it difficult for people to unplug the plug by tugging on the cable. This practice, possible with many other plug designs but difficult with BS 1363, can be hazardous as it can damage the cable insulation causing shorts or tear the conductors, leading to overheating or even internal arcing across the resulting break in the conductor. On the other hand this tight fitting and bottom entry of cable means that the stresses on the cable when it is pulled hard (by for example tripping over it) are even higher.
- If the cable is pulled from the plug with enough force to break the wires inside, the phase wire disconnects first, the neutral second, and the earth wire last. This is ensured by forcing the different wires to have varying amounts of slack in them by design of the internal channel of the plug.

## Fuses



BS 1362 fuses (for BS 1363 plugs)

Because typical British circuits (especially ring circuits) can deliver more current than many appliance power cords can safely handle, BS 1363 plugs are required to carry a cartridge fuse. The fuse is manufactured to **BS 1362** and are normally rated at 3, 5, 10, or 13 amperes. The maximum load that can be placed on a socket is 13 A; triple and larger sockets are fitted with a 13 A fuse of the same type used in the plugs. The plugs and sockets are designed to carry up to 250 volts AC, 50 hertz.

All plugs with the exception of some plug top power supply units are fused. This is in addition to the fuses or circuit breakers in consumer units/distribution boards.

Fuses are available in 1, 2, 3, 5, 7, 10, and 13 amps but commonly seen and used are only 2 (black or blue), 3 (red), 5 (black or grey), 10 (black or yellow), and 13 (brown) amps. Note that the use of black on 2, 5, and 10 amp fuses indicates a "non-standard" choice, since 3 and 13 amps have become the de facto standard choices and are by far the most common. Plugs (when supplied separately from any appliance) are normally fitted with a 13 A fuse, but the need to buy plugs has reduced considerably since moulded power cords are now supplied with most equipment — in part to avoid users failing to replace the 13 amp fuse in a newly-purchased plug with a lower-rated fuse when appropriate.

Prior to the introduction of the 13 amp plug the BS 546 2 A, 5 A, and 15 A plugs were used. With this system, the only fuses were in the consumer unit. 15 A sockets were generally given a dedicated 15 A circuit, while 5 A sockets might be on a 15 A circuit with multiple sockets or on a dedicated 5 A circuit. 2 A sockets were generally connected to the lighting circuit, which was fused at 5 A. Adaptors were available to use 5 A plugs in 15 A sockets and to use 2 A plugs in 5 A sockets, so it was quite possible for an appliance with the smallest size of flex to be protected only by a 15 A fuse.

When the practice of using 30 A ring circuits was introduced (to save copper while also allowing more flexibility), it was considered unsafe to allow appliance flexes to be connected to such a high rated circuit with no further protection, and the plug/socket combination had to provide the fuse. It was decided to place the fuse in the plug and to use a new plug configuration so that older, unfused plugs could not be used.

Putting the fuse in the plug also allows a range of ratings to be fitted, providing superior protection for smaller flexes. This is especially useful for long small flexes or for extension leads that are not rated at the full 13 A. Fuses for fittings to BS 1363 must conform to BS 1362. This specification describes a sand-filled ceramic-bodied cylindrical fuse, 1" (25.4 mm) in length, with two metallic end caps of 1/4" (6.3 mm) diameter and roughly 1/5" long.

BS 1362 specifies breaking-time/current characteristics only for fuses with a current rating of 3 A (marked in red) or 13 A (marked in brown). Examples for the required breaking-time ranges are

- For 3 A fuses: 0.02–80 s at 9 A, < 0.1 s at 20 A and < 0.03 s at 30 A.
- For 13 A fuses: 1–400 s at 30 A, 0.1–20 s at 50 A and 0.01–0.2 s at 100 A.

3 A fuses are intended mainly for small load (< 750 W) appliances, such as radios and lights. 13 A fuses are for larger load (<3.2 kW) appliances, such as heating and heavy-duty electric motors.

BS 1362 requires that plug fuses with any other current rating be marked in black. 5 A fuses are also commonly used for medium load (1250 W max.) appliances such as desktop computers and TV sets. Ratings of 1, 2, 7, and 10 amperes are also produced but rarely used (1 A, as found in some shaving-socket adapters, is 20 mm long (BS 646), but a BS 1362 version does exist).

The fuses are mechanically compatible; it is up to the user or appliance manufacturer to use the most appropriate rating.

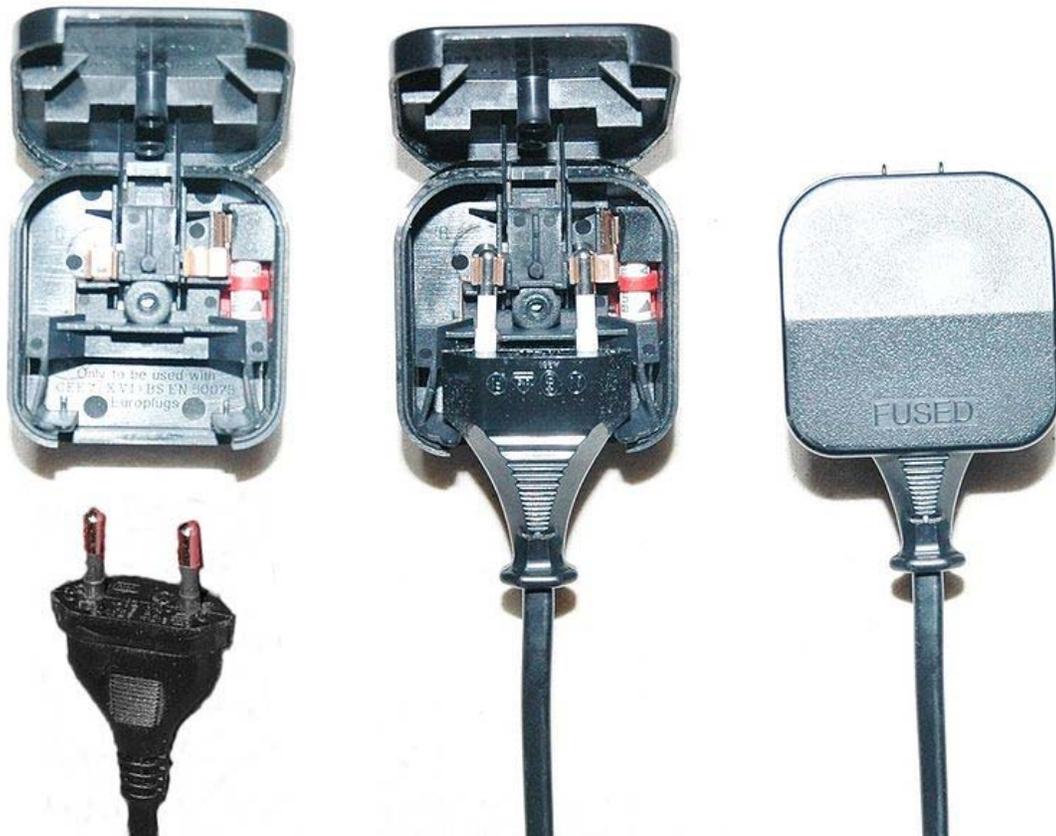
Rewirable BS 1363 plugs are always sold fitted with a fuse, usually 13 A. This fuse must be changed if fitting the plug to an appliance or flex which requires a fuse with a smaller rating. Plugs with smaller fuse sizes already fitted are sold but are not as common.

## **Replacement**

Plugs for hand-wiring are commonly available and are usually attached with instruction cards displaying recommended wire lengths. They can be assembled or opened with a flat-head and/or cross-head screwdriver—modern plugs often have external screws which accommodate both types, but the terminal screws inside are more often flat-headed; the cross-head and combination screw-heads tend to be made to accommodate Pozidriv rather than Phillips screwdrivers, but this varies between manufacturers. Most modern products come fitted with moulded plugs with removable fuse sections (these plugs can only be easily removed by cutting off), with some exceptions, such as most lamps, which usually have normal hand-wired plugs along with a label with wiring instructions wrapped around the flex.

The secondary school physics syllabuses in the United Kingdom, Hong Kong and Singapore include the procedure for wiring BS 1363 plugs, as well as the concept of a ring circuit and a radial circuit (except in Hong Kong). In Malaysia, however, the procedure for wiring BS 1363 plug are taught in Living Skills subject (*Kemahiran Hidup*) for Form 1 (secondary school year 1) students.

## **Compatibility**



euro converter plug, empty, europlug inserted and closed

Some manufacturers/distributors use a special type of plug for conversion of Class 2 appliances from mainland Europe which are fitted with moulded europlugs. Unlike a travel adaptor these plugs when closed look fairly similar to normal plugs, although larger and squarer. Inside are two metal clips into which the metal ends of the europlugs pins are clipped. The body of the converter plug is shaped to grip the europlug. The hinged lid is then shut to cover the connections to the europlug and is screwed shut. These plugs have a plastic earth pin and a fuse accessible from the outside and in some cases are fitted with screws that are made to be difficult to unscrew. Similar converters are available for a variety of other plug types but do not seem to be seen much in practice.

These adaptors are usually supplied fitted on all recent Class 2 Sony electrical products with fixed wiring (and not IEC C7 cables) sold in the British Isles instead of typical moulded plugs, probably as a measure to reduce costs by fitting the same plug for all European markets.

### **Adoption**

The BS 1363 design is not only in use in the United Kingdom and Ireland, but also in Sri Lanka, Kuwait, Bahrain, UAE, Qatar, Yemen, Oman, Cyprus, Malta, Gibraltar, Botswana, Ghana, Hong Kong, Jordan, Macau, Brunei, Malaysia, Singapore, Kenya, Uganda, Nigeria, Iraq, Tanzania, Zambia and Zimbabwe. BS 1363 is also standard in several of the former British Caribbean colonies such as Belize, Dominica, St. Lucia, St. Vincent, and Grenada. It is also used in Saudi Arabia in 230 V installations, although 110 V installations using the NEMA connector are more common.

The National Standards Authority of Ireland (*NSAI*) issued the Irish Standard "I.S. 401 Safety Requirements for Rewireable 13A Fused Plugs for Normal and Rough Use Having Insulating Sleeves on Line and Neutral Pins", which is largely similar to BS 1363. Any relevant plugs originating or sold in the country must pass the Irish Standard or an equivalent standard of a member of the European Union, which includes BS 1363.

The UK, and some of these other countries, also use the older BS 546 round-pin socket standard.

BS 546 is duplicated by Group B2 of the Soviet GOST 7396 standard.

In some continental European countries (e.g., Germany), the BS 1363 system is today often used for Low Voltage (12 V or 24 V) DC connections in photovoltaic systems, because it provides easily available high-current connectors with fixed polarity that cannot accidentally be connected into higher-voltage Schuko system and Europlug sockets.

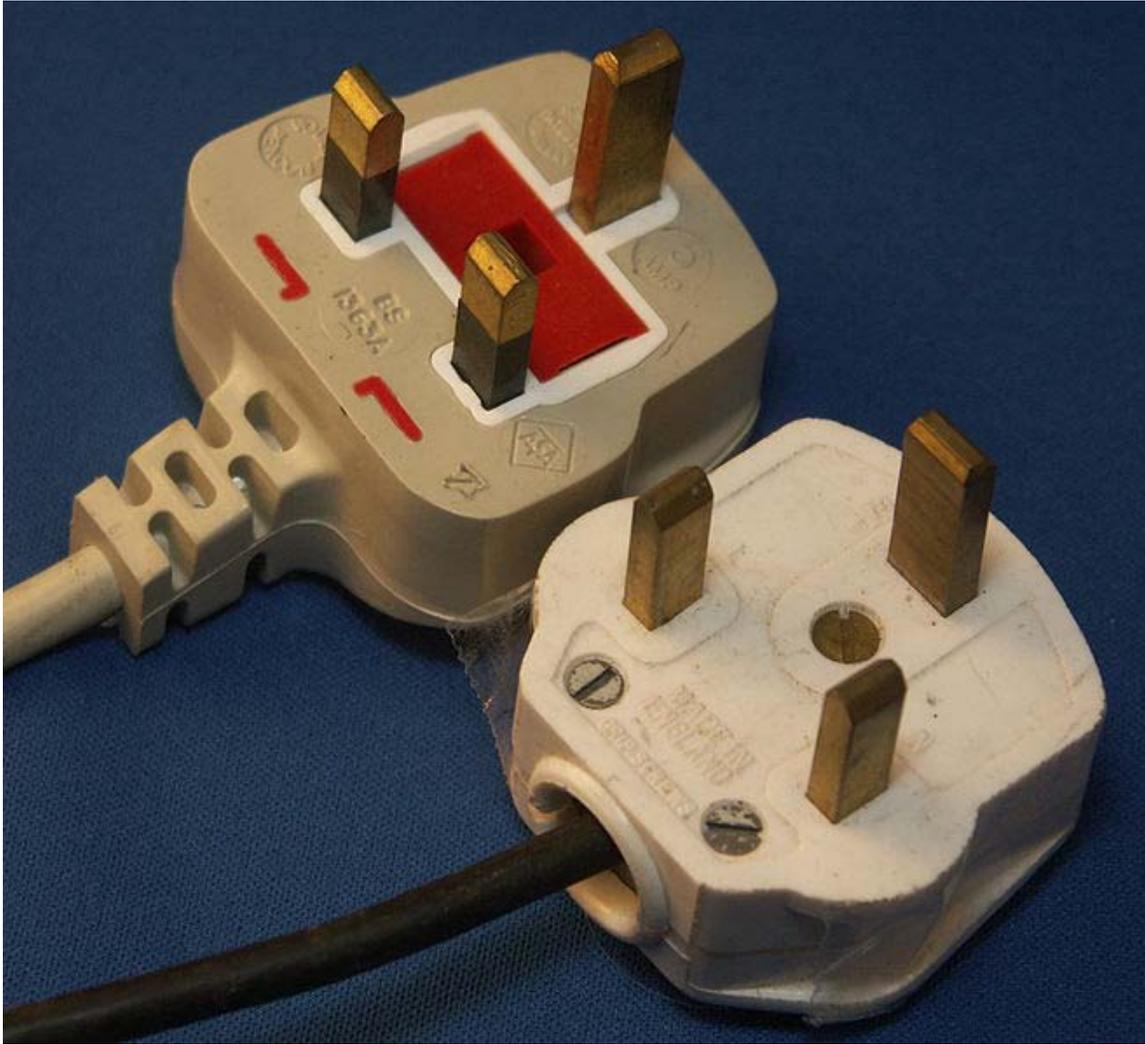
## ***Variants***

Several manufacturers have made deliberately incompatible variants for use where intermateability with standard plugs and sockets is not acceptable. Examples include filtered supplies for computer equipment and cleaners' supplies in public buildings and areas (to prevent visitors plugging things in). The most commonly seen variant is one made by MK that has a T-shaped earth pin.

The Walsall Gauge 13 A plug, which has each pin rotated 90°, was used by the BBC for technical supplies, and sockets for these plugs can be seen in some London Underground stations.

Due to the size of the standard UK power plug BS 1363, a number of attempts have been made to develop a UK folding plug. Only one of these has been approved for sale (as at 21/08/10), the SlimPlug, which is available only as part of a complete power lead terminating in an IEC C7 unpolarized connector. In 2009 another concept of folding plug, the ThinPlug, received a "red dot" award for product design, the ThinPlug has now received BS 1363 approval. Another design (The Folding Plug), featuring a pivot which allows the plug's pins to be aligned vertically, won the Brit Insurance design of the year award in 2010, but as described in the promotional video it does not meet BS 1363, and has not been approved for sale in the UK. An international patent application for the Folding Plug describes various alternative configurations, but inspection of the application shows that an actual plug incorporating the safety requirements of BS 1363 would differ significantly from the design which won the award.

## Variant plugs



Walsall Gauge 13 A plug (bottom) compared to regular BS 1363 plug



Walsall Gauge 13 A plug



MK 13 A Plug with a T-shaped earth pin



The SlimPlug folding plug



The SlimPlug folding plug with pins retracted

### ***Other devices in the standard***

BS 1363 specifies 13 A plugs and sockets. It also specifies the following devices:

- Adaptors, which permit two or more plugs to share one socket.
- Switched and unswitched fused connection units, which take the same BS 1362 fuses as the plugs. These are the standard means of connecting permanently wired appliances to a socket circuit (most often but not always a 30 A ring circuit). They are also used in other situations where a fuse or switch (or both) is required, such as when feeding lighting off a socket circuit, to protect spurs off a ring circuit with more than one socket, and sometimes to switch feeds to otherwise concealed sockets for kitchen appliances (20 A DP switches are also sometimes used for this, but doing so can easily violate the rule of no more non-fused spurs than sockets on the ring).

## Chapter 3

# BS 546



BS 546 3-pin plugs. Left to right: 15 A, 5 A and 2 A.

**BS 546** is an old British Standard for domestic AC power plugs and sockets that is also the precursor of current Indian and South African plug standards. This plug is also used in Singapore to a limited extent. These are also known as type D (for the 5-A 3-pin) and type M (for the 15-A 3-pin) in US documentation. When viewed in photographs with no indication of scale the different ratings look similar, but where a photograph shows more than one type the difference in size is obvious. There are 6 different versions that are not interconnectable. Whilst these sockets are no longer used in Britain for general appliances (although still permitted by the UK wiring regulations), some of the varieties remain in use in other countries and in more specialist applications (a notable example being stage lighting).

Prior to the development of the BS 546 standards there were around two dozen different types of power socket in use throughout Britain with different types in use in different cities.

15 A sockets were generally given a dedicated 15 A circuit. 5 A sockets might be on a 15 A circuit with multiple sockets or on a dedicated 5 A circuit. 2 A sockets were generally connected to the lighting circuit which was fused at 5 A. Adaptors were available from 15 A down to 5 A and from 5 A down to 2 A so in practice it was quite possible for an appliance with the smallest size of flex to be protected only by a 15 A fuse. This is a similar level of protection to that seen for portable appliances in other countries but less than that offered by the BS 1363 fused plug that replaced them. Fused BS 546 plugs using a BS 646 fuse are available but are rarely seen in practice.

In theory, 15 A plugs were proposed to be used for larger appliances (e.g. electric heaters) while smaller appliances (e.g. radios, table lamps) were supposed to use 5 A. In practice this was found to be inconvenient and in many households the 15 amp plug was used for everything. Adaptors were available which allowed 2 or 5 amp plugs to be used in 15 amp sockets.

The 3-pin sockets were not shuttered when BS 546 was in common use domestically in the UK, but the current revision of the standard does specify shutters and BS 546 sockets sold in the UK today are shuttered in the same basic manner as BS 1363 ones. Current UK wiring regulations require socket outlets installed in homes to be shuttered. The three pin variety had the larger top pin as the earth connection, the left hand pin as neutral and the right hand pin as live (when looking at a socket or at the rear of a plug).

BS 546 is duplicated by Group B1 of the GOST 7396 standard.

## **2 A 2 pin**



BS 546 un-shuttered 5 A and 2 A 2 pin sockets

This plug did not find general use and is now rarely seen. It was rendered incompatible with the 2 A 3 pin variant by variation of the pin gauge and this may have contributed to its lack of adoption.

## **5 A 2 pin**

This plug is what became the UK standard shaver plug (BS 4573) and is similar but slightly larger than the Europlug (and the pins are only 16mm apart). British shaver sockets and adaptors tend to be sized to accept this, Europlugs and two pin American and Australian plugs.

## **2 A 3 pin**

This plug was used to connect low power appliances to the lighting circuit (and to adaptors from the larger socket types). Sometimes still used to connect lamps (and other lights which aren't attached, or built-in to the fabric of the building - e.g. lights which are mounted on kitchen cabinets, bookshelves etc.) to the lighting circuit.

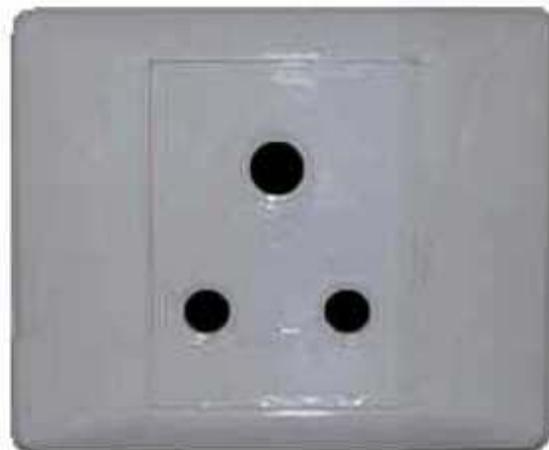
### **5 A 3 pin**



This plug was used for moderate sized appliances either being on its own 5 A circuit or a multi socket 15 A circuit and also on many adaptors (both multi socket 5 A adaptors and adaptors that also had 15 A pins). Some 5 A 3 pin sockets also have 2 extra holes above the live and neutral holes to allow a 5 A 2 pin plug to be connected.

India has standardised on this plug as Indian Standard IA6A3, rated at 6A / 250V, and it is now almost exclusively used in India, Sri Lanka, Nepal and Namibia. However, this 5 A plug, along with its 2 A cousin, is sometimes used in the UK for centrally switched domestic lighting circuits, in order to distinguish them from normal power circuits. This is quite common in hotel rooms. This plug was also once used in theatrical installations for the same reasons as the 15 A model below, but is now only used for this purpose in schools and other rarely used installations (presumably because those operating multiple installations wanted to standardise on one plug type for all their lights and the 5 A plug was unsuitable for larger lights).

### **15 A 3 pin**



This is the largest plug in domestic use. Live and neutral are spaced 1 inch apart, and earth is 1½ inches away from each of them. Although the preceding type is standard in Pakistan, India, Sri Lanka, Nepal, and Namibia, the 15 A version is also used in these countries for larger appliances. In India it is rated at 16A under Indian Standard IA16A3. Some countries like South Africa use it as the main domestic plug and socket type as South African standard SABS 164. Sockets almost always have an on–off switch built into them. The Type M is almost universally used in the UK for indoor dimmable theatre and architectural lighting installations. It is also often used for non-dimmed but centrally controlled sockets within such installations. The main reason for doing this is that fused plugs, while convenient for domestic wiring (as they allow 32 A socket circuits to be used safely), are not convenient if the plugs and sockets are in hard to access locations (like lighting bars) or if using chains of extension leads (since it is hard to figure out which fuse has blown). Both of these situations are common in theatre wiring. This plug is also widely used in Israel, Malaysia and Singapore for air conditioners and washing machines.

### **30 A 3 pin**

The 30 A plug is the largest of the family, being slightly larger than the 15 A plug. This was used for high power industrial equipment up to 7.2 kW, such as industrial kitchen appliances, dimmer racks for stage lighting, etc. Plugs and sockets were usually of an industrial waterproof design with a screw locking ring on the plug to hold it in the socket against waterproof seals, and sockets often had a screw cap chained to them to be used when no plug was inserted to keep them waterproof. Use of the BS 546 30 A plugs and sockets diminished through the 1970s as they were replaced with BS 4343 (which later became IEC 60309) industrial combo plugs and sockets.

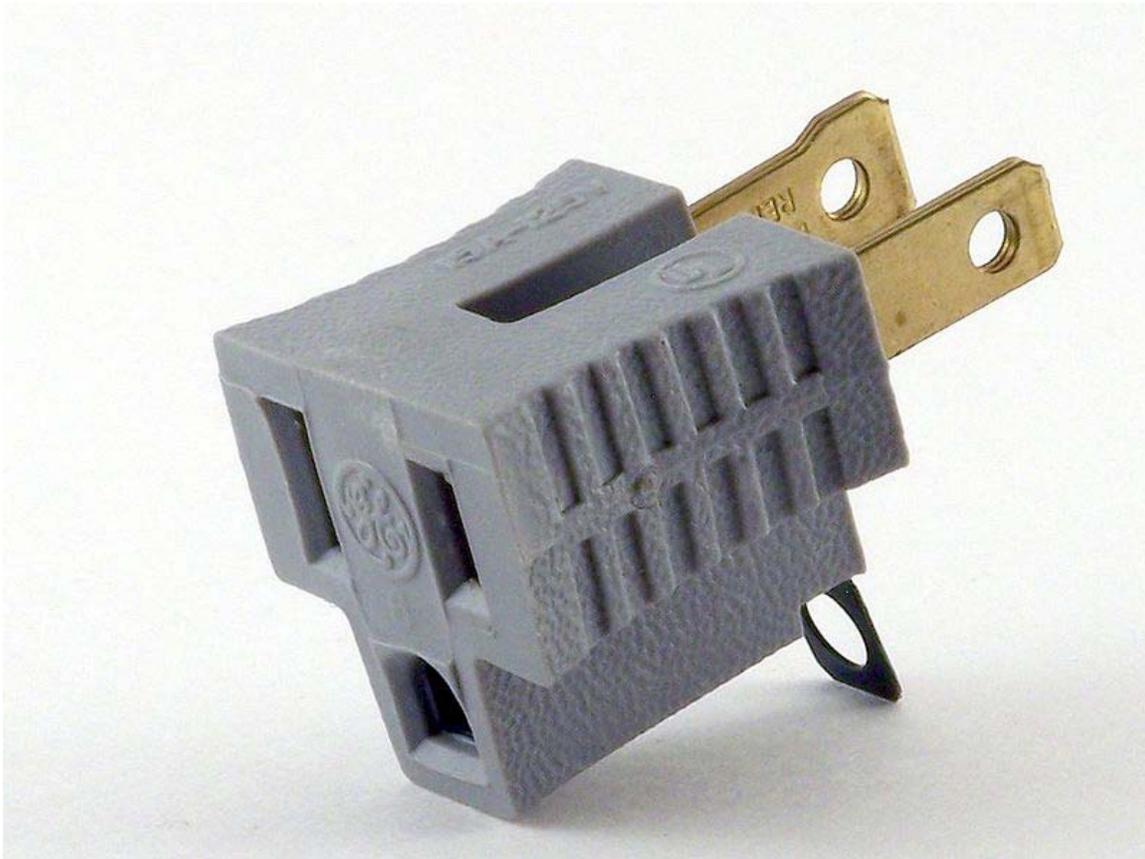
### **Characteristics of BS 546 plugs**

	<b>type ? 30A</b>	<b>type M 15A</b>	<b>type D 5A</b>	<b>type ? 2A</b>
Diameter L and N pins	7.92 mm	7.06 mm	5.08 mm	3.56 mm
Diameter earth pin	9.53 mm	8.71 mm	7.06 mm	5.08 mm
Centre distance between L and N pin	36.50 mm	25.40 mm	19.05 mm	14.48 mm

## Chapter 4

# Cheater Plug & Europlug

## Cheater Plug



A cheater plug, with metal grounding tab

A **cheater plug**, **AC ground lifter** or **three-prong/two-prong adapter** is an adapter that allows a NEMA 5-15P grounding-type plug (three prongs) to connect to a NEMA 1-15R non-grounding receptacle (two slots). The use of such an adapter avoids the need to

replace receptacles, but is potentially hazardous, if the grounding tab is not actually connected to electrical ground. An alternative identified in the U.S. and Canadian electrical codes is to replace the outlet with a GFCI breaker outlet.

Cheater plugs were previously available with a short flexible grounding wire rather than a screw tab. This allows use of the second duplex outlet that does not have a faceplate screw in the correct location for the screw tab. The grounding wire would be wrapped around the adapter to reach the faceplate screw. However, this ground-wire style of cheater plug was discontinued when it was noted that a loose unattached grounding wire could by accident become inserted into the "hot" blade socket of a nearby outlet, potentially leading to electrocution.

Cheater plugs are also used to break ground loops in audio systems. This practice has been condemned as disregarding electrical safety.

### ***Use in residences***

Three-prong plugs do not fit into the older, two-prong receptacles. When used as intended, the ground pin of the 3-wire receptacle is to be connected to the grounded cover screw, or to an external ground. In 1969 Underwriters Laboratories mandated three-prong plugs on small appliances for safety. At that time, only half of the receptacles in U.S. homes were three-prong. Wiring in most homes did not include a grounding wire. The screws and outlet boxes were either connected to the neutral, or connected to nothing. Only in rare jurisdictions where non-metallic cable was prohibited, and armored cable required, do cheater plugs work as intended. In 1971 the U.S. National Electrical Code (NEC) required grounded receptacles in all locations of the home (effective January 1, 1974).

### ***Safety***

In the professional audio and video fields, the cheater plug has been identified as a serious safety problem. Its casual use as a method for avoiding ground loops in analog audio and video signals (to eliminate hums and buzzes) is dangerous. Bill Whitlock, president of Jensen Transformers, writes, "never, ever use devices such as 3 to 2-prong AC plug adapters, a.k.a. 'ground lifters', to solve a noise problem!" Whitlock relates how an electrical fault in one device that is connected to its electricity source through an ungrounded cheater plug will result in dangerous, high current flowing through audio or video cables. Whitlock notes that in 1997, consumer audio and video equipment electrocuted nine people.

The cheater plug is also recognized as a safety hazard in laboratory settings. For example, in August 2005, Tarun Mal, an associate professor at Cleveland State University, was electrocuted when he plugged a defective fluorescent lamp into a lamp timer using a cheater plug. Subsequently, the state of Ohio issued seven citations to the university for unsafe electrical conditions. *The Scientist* notes that four of the University's seven environmental safety experts agreed that use of the cheater plug "is not uncommon in US

university labs". Jim Kaufman, CEO of the Laboratory Safety Institute, says, "When you inspect labs, it's not unusual to find anywhere from one to seven that way."

## ***Alternatives***

There are several alternatives for connecting newer appliances to two-prong receptacles without rewiring the building: removing the grounding pin of the plug, replacing the receptacle with a three-prong outlet, or replacing the receptacle with a GFCI; only the last (GFCI) is safe.

Removing the grounding pin of the appliance's plug leaves the appliance without proper grounding even when relocated and plugged into a properly grounded three-prong receptacle.

Replacing the receptacle with the three-prong type and leaving the ground screw unconnected is neither more safe nor less safe than using a cheater plug. However, if the ground screw of the receptacle is connected to the neutral side, electric shock is possible even if the appliance is properly functioning. This is called a "false" or "bootleg" ground and is a serious safety hazard often undetected by common receptacle testers.

Replacing the receptacle with a GFCI receptacle is the safest alternative. If a GFCI receptacle is properly functioning, then it will shut off the power to a faulty appliance to prevent electric shock. As a safe option that protects all appliances plugged into that receptacle, the National Electrical Code permits such replacement if the installer marks the GFCI as having "No Equipment Ground".

# Europlug



Example of a Europlug



Italian plug type L, grounded, similar, but not equal to Europlug

The **Europlug** (CEE 7/16) is a flat, two-pole domestic AC power plug that is generally supplied moulded on the end of an appliance's flex or a power cord, designed for voltages up to 250 V and currents up to 2.5 A. It was designed such that it can safely be used in the domestic power sockets of all European countries, except for the BS 1363 system found in Britain, Cyprus, Gibraltar, Ireland and Malta.

### ***History***

The Europlug design appeared first in 1963 as Standard Sheet XVI in the second edition of CEE Publication 7, a document that summarized all the national domestic AC plugs and sockets used across Europe. The Europlug is therefore sometimes also referred to as the "CEE 7/16" plug. It was also adopted in 1975 as plug C5 in IEC Technical Report 83 (now IEC/TR 60083), and as European standard EN 50075 in July 1990.

### ***Design considerations***

The dimensions of the Europlug were chosen for compatibility and safe use, such that with all European domestic power sockets

- reliable contact is established when the plug is fully inserted;

- no live conductive parts are accessible while the plug is inserted into each type of socket;
- it is not possible to establish a connection between one pin and a live socket contact while the other pin is accessible.

Europlugs are only designed for low-power (less than 2.5 A) Class II (double-insulated) devices that operate at normal room temperature and do not require a protective-earth connection.

### ***Details***

The pins of the Europlug are 19 mm long. They consist of a 9 mm long conductive tip of 4 mm diameter with a rounded ending, followed by a 10 mm long flexible insulated shaft of not more than 3.8 mm diameter. The two pins are not exactly parallel and converge slightly; their centres are 17.5 mm apart at the tip and 18.6 mm apart at the base. The elasticity of the converging pins provides sufficient contact force for the Europlug's current rating with a variety of socket-hole arrangements. The entire plug is 35.3 mm wide and 13.7 mm high, and must not exceed these dimensions within 18 mm behind its front plane (this allows for the recesses on many European socket types). The left and right side of the plug are formed by surfaces that are at 45° relative to the horizontal plane.

### ***Incompatibility with British sockets***

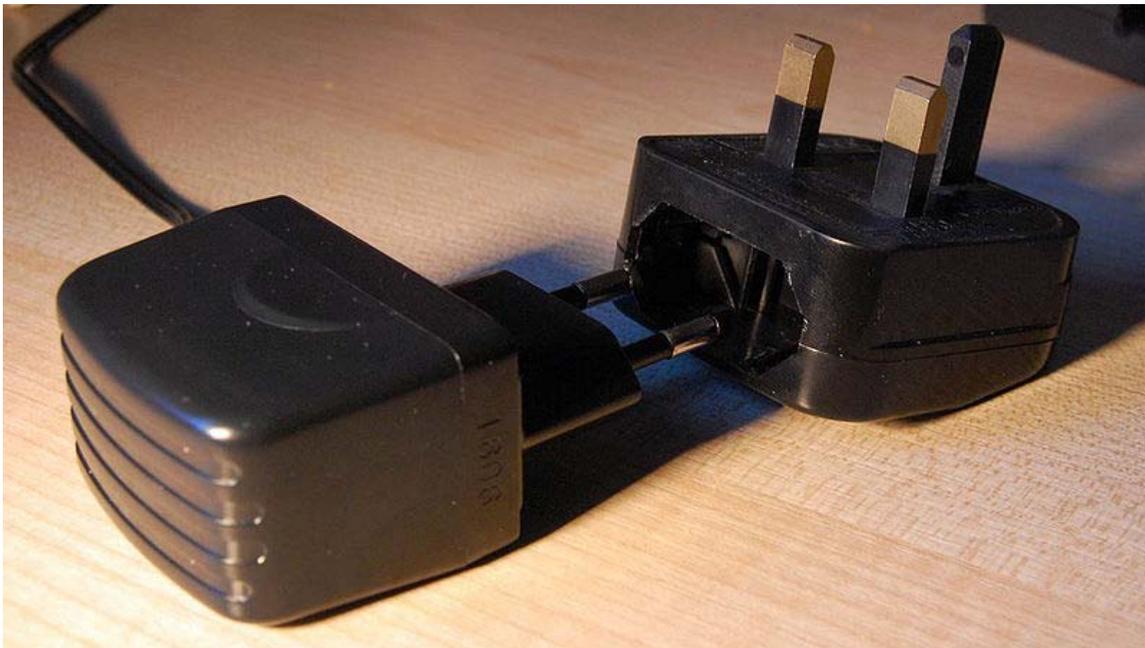
The Europlug is not compatible with British BS 1363 13 A sockets for (at least) three reasons:

- BS 1363 sockets contain a child-safety shutter and need an earth pin to be inserted before the live and neutral contacts become accessible.
- The ring circuits found in many British homes are only protected by high-current breakers (typically 32 A) and therefore rely on a lower-current fuse (typically 3–13 A) in each plug to protect the appliance cable from dangerous overcurrents when a fault occurs. Europlugs are not designed to contain fuses or switches. In most other European countries, it is customary to use radial circuits, where smaller groups of sockets are each protected with a fast-acting 10–16A circuit breaker, a current limit that even Europlug cords can support briefly in fault situations.
- The free space between Europlug pins ( $13.5 \pm 0.5$  mm) is about 2 mm less than the corresponding dimension in a BS 1363 socket (15.8 mm). To force a Europlug into a UK socket, each pin has to be bent by about 1 mm. The pins' flexibility usually allows for this, but the resulting bending force plus the fact that the conductive tip of each pin is 0.2 mm wider than the non-conductive shaft can sometimes make the pins difficult to remove from a BS 1363 socket. Although the 4 mm diameter of the Europlug pin gives it the same height as the corresponding

BS 1363 pins, the latter are with 6.35 mm substantially wider, and are also located further apart. Therefore, whether a Europlug can achieve proper contact inside a BS 1363 socket depends on the exact manufacturer-specific construction of the contacts inside the socket. Proper contact is not guaranteed by the relevant standards.

It is, in principle, possible to insert a Europlug into a BS 1363 socket by inserting another object (such as a screwdriver or key) into the earth hole first. Doing so is not recommended for the above reasons. An easy method however is to use a 4-way extension socket and place a G type plug into the earth pin inverted, lowering the shutter and exposing the live and neutral sockets, allowing a Europlug to be inserted easily. Nevertheless, in many countries where both BS 1363 and Europlug connectors are on the market (e.g., Malaysia, Singapore), such forcing of a Europlug into a BS 1363 socket is not an uncommon practice. It may also be possible to remove the safety shutter from the socket completely, depending on the design of the socket.

Equipment sold in Britain with a Europlug must be marked with or accompanied by a warning that it is not suitable for use in a British mains socket. The exception is that shavers, electric toothbrushes and similar personal hygiene products may be supplied with a europlug as an alternative to the larger BS 4573 2-pin plug. The Europlug is compatible with 2-pin shaver sockets used in British bathrooms, which have isolating transformers.



Europlug with fused BS 1363 converter plug



Side by side comparison of converter plug, typical BS1363 plug and Schuko adaptor

The flat design of the Europlug and the comparatively large shape of the British plug made it possible to design fused converter plugs that have outer dimensions only slightly larger than most normal BS 1363 plugs and that encapsulate an entire Europlug internally. They can be fitted quickly and safely by relatively unskilled personnel (there is no real way to get it wrong unlike a normal rewirable plug which can be miswired), making them attractive to manufacturers and importers who sell equipment in the UK that was manufactured using moulded Europlugs.

### **BS 546**

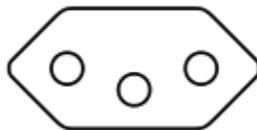
While most modern BS 546 sockets include the safety shutter found on BS 1363 sockets the Europlug should fit in the 5A type of BS 546 socket. In modern sockets it may also be possible to push down the shutter with a blunt object or remove it completely.

## Chapter 5

# IEC 60906-1 & GOST 7396

## IEC 60906-1

**IEC 60906-1** is the international standard 230 V household plug system. It was intended to become the common mains plug and socket standard, to be used one day everywhere in Europe and other regions with 230 V mains. The standard was published by the International Electrotechnical Commission in 1986. So far, only Brazil and South Africa introduced a standard based on it. The biggest differences being that in parts of Brazil the mains voltage is 127 V and the introduced standard has a pin diameter of 4mm for the 10A plug and 4.8mm for the 20A plug, while the original standard has a single pin diameter of 4.5mm and a maximum current of 16A. Although it looks similar to the Swiss plug, its dimensions are different.



IEC-906-1-plug

### **Features**

The IEC 60906-1 system is rated for AC voltages up to 250 V and currents up to 16 A. It defines both 3-pin connectors for Class I appliances and 2-pin versions for Class II appliances.

The plug

- has round (cylindrical) live and neutral pins, which are 19 mm apart and 4.5 mm in diameter (similar to the Schuko plug);

- has an insulating sleeve around the base of the live and neutral pin (similar to the Europlug);
- is smaller than any other European 3-pin plug, and only slightly larger than the 2-pin 2.5 A Europlug.

#### The socket

- has either a 10 mm deep recess or a 12 mm high rim, to ensure that no commonly used plug can be inserted in a way that establishes contact to one pin while leaving the other pin exposed;
- ensures that the protective-earth pin establishes contact before the live and neutral pins;
- can be equipped with a child-safety shutter for the live and neutral contacts (similar to BS 1363 sockets);
- is compatible with the Europlug;
- is compact enough to permit the installation of two sockets in the space needed by a single Schuko or BS 1363 socket.

For most existing European systems (Schuko, etc.), it would be possible to design sockets that can accept both the traditional plug as well as the IEC 60906-1 Class I and II plugs, thereby enabling a smooth transition to the new system. However, the IEC 60906-1 standard explicitly discourages the use of multi-standard sockets, claiming that such sockets are likely to create safety problems when used with plugs from other countries.



A 20A Brazilian socket based on the in IEC 60906-1 standard

### ***Comparison with traditional systems***

Thanks to modern injection molding technology, robust and safe plugs can have much smaller dimensions today than what was considered feasible when the old Schuko and BS 1363 systems were designed in the early and mid 20th century.

### **BS 1363**

The IEC 60906-1 system features many of the advantages of the BS 1363 plug, but avoids the main problems with the system currently used in Britain, Ireland and many Commonwealth countries:

- incompatibility with the ubiquitous Europlug (though this could easily be changed if wiring regulations were changed to make it safe to do so);
- lack of a practical way to design a migration socket that also accommodates the Schuko system;
- large size;
- current capacity limited to 13 amps (as opposed to 16 amps for Schuko and IEC 60906-1);

- risk of foot injury through a plug shape that makes it likely that the sharp pins face upwards when a plug lies on the floor.

However, unlike with BS 1363, IEC 60906 does not mandate a fuse in each plug. It may well be feasible to design IEC 60906-1 plugs with an integrated fuse. Handing over the protection measures to sockets would violate British wiring rules because each plug is hardwired to its power cord and each power cord, depending on wire thickness, requires an appropriate fuse. The socket can not have a universal fuse which would match the power cord's current capacity of each appliance. The other way to meet British wiring rules is to use power cord for 16 Amps (maximum for IEC 60906-1) regardless of device power rating. Also the plug is unlikely to have as low a profile to the wall, making use behind cupboards harder. (It is technically possible to make an IEC 60906-1 plug/socket combination with a similar profile to a BS 1363, but only if the socket has a recess and the cord exit angle exceeds the recommendations of the specification.)

## **Schuko**

The IEC 60906-1 system also avoids the problems of the Schuko system currently used in most of Europe and large parts of Asia:

- Ambiguity between live and neutral.
- Lack of a practical way to design a migration socket that also accommodates the BS 1363 system;
- Large size;
- Mateability of Class I plugs with commonly used (non-Schuko) sockets that lack protective-earth contacts.

## **Swiss plug**

Although the IEC 60906-1 plug looks remarkably similar to the Swiss SEV 1011 plug, there are a number of significant differences. The Swiss plug

- lacks insulating sleeves around the live and neutral pins
- has the earth pin further away from the centre line (5 mm instead of 3 mm)
- has slightly thinner pins (4 mm instead of 4.5 mm)

## ***Dimensions***

The Class I and II plugs' shapes are similar to the Europlug; their front profile is also a flat hexagon, but it is slightly thicker. Both plugs are 35.5 mm wide. The 3-pin Class I plug is 17 mm high, whereas the 2-pin Class II plug is with only 14 mm slightly slimmer (the Europlug is only 0.3 mm smaller). The parallel side faces are 26 mm apart, and the two pairs of side faces are orthogonal to each other. As on the Schuko plug, the live and neutral pin have 19 mm center distance and 19 mm length. However, their diameter is 4.5mm, unlike the Schuko and the Class I-lookalike Brazilian 20-amp NBR 14136 plug, which both have 4.8mm pin diameter, while the 10A Brazilian plug has a diameter of

4mm. A further distinction with the Schuko plug is the insulating sleeve around the base of the live and neutral pin (as on the Europlug). The 3-pin version also has a round protective-earth pin. It has the same length and diameter as the live and neutral pins, but lacks an insulating sleeve. The protective-earth pin's center is offset 3 mm from the center point between the live and neutral pin.

### ***Class 0 plug and socket***

In addition to the hexagonal Class I and Class II plugs and sockets, Appendix A of the standard also defines a 2-pin plug and socket with oval profile, for countries that still permit the use of Class 0 appliances, which are considered unsafe in most industrialised countries today. The Class II plug fits also into Class 0 sockets; it is up to national regulations of countries using the Class 0 socket, whether they permit an additional dummy hole in it, such that even Class I plugs will fit. However, none of the Class 0 plugs fit into a Class I or Class II socket. This way, the system prevents that Class 0 equipment can be operated easily in regions that do not permit such devices. The full mateability matrix of all plugs and sockets defined in IEC 60906-1 looks like this:

		Plug		
		Class 0 (2 pin)	Class I (3 pin)	Class II (2 pin)
Socket	fits into			
	Class 0 (3 hole)	Yes	Yes	Yes
	Class 0 (2 hole)	Yes	No	Yes
	Class I (3 hole)	No	Yes	Yes
Class II (2 hole)	No	No	Yes	

As a result of the increasing global harmonization of electrical safety standards, IEC is phasing out the entire concept of Class 0 appliances from its standards. It is therefore unlikely that the oval Class 0 plug and socket variant will ever be introduced anywhere. The appendix that introduces it was probably merely added to address the concern that a system of country-independent plugs and sockets could permit the easy use of imported Class 0 equipment that does not meet national safety standards.

## **GOST 7396**

**GOST 7396** (*FOCT 7396* in Cyrillic) is a series of Soviet and later Russian standards that specify basic dimensions and safety requirements for power plugs and sockets used in Russia and other former Soviet Republics, as well as for export to markets that use American or British plugs.

Many official standards in Eastern Europe are virtually identical to the Schuko standard. One of the protocols governing the reunification of Germany required that the DIN and VDE standards would prevail without exception, so the former East Germany had to conform to the Schuko standard. Most other Eastern European countries use the Schuko

standard internally but, prior to its collapse, they exported large volumes of appliances to the Soviet Union with the Soviet standard plug installed. Because of that, many of the Russian plugs found their way into other Eastern European countries. One peculiarity of the Soviet standard is the use of an ungrounded plug with 4.0 mm diameter pins for 6 A and a corresponding socket that would not accept the 4.8 mm diameter pins of devices that could draw as much as 16 A. Another is that sockets that in other places would be supplied with 16 A may have been wired for only 10 A during the Soviet era.

The series includes the following standards:

- **GOST 7396.1-89** Plugs and Socket-Outlets for Household and Similar Purposes - Basic Dimensions
- **GOST 7396.2-91** Plugs and Socket-Outlets for Household and Similar Purposes - Particular Requirements for Fused Plugs - General Technical Specifications

### ***Group A***

Group A connectors consist of the non-locking NEMA connectors (Types A and B), which are defined for the assistance of exporters. Thus for example, an A 5-15 plug is the standard NEMA 5-15 household grounded plug used in North America.

### ***Group B***

Group B connectors are also defined for the assistance of exporters to countries that use connectors based on British standards. The B 1 series defines the BS 546 (Type D) 3 pin unfused plugs of 2 A, 5 A, and 15 A, while the B 2 plug is the same as the BS 1363 (Type G) fused plug.

## Group C



6 A variety of the C 1 plug

Group C connectors are various CEE 7 plugs used in continental Europe, with allowances made for various Soviet era plugs that are compatible with them. Note that under Soviet-era construction the 16 A versions may have been supplied with only a 10 A service.

### C 1 - 2 pin ungrounded 6 A and 16 A (Type C)

Both varieties of this connector use two pins with centers spaced 19.0 mm apart. The 6 A variety has pins on the plug with a 4.0 mm diameter with the corresponding socket holes having a diameter of 4.5 mm. The corresponding dimensions on the 16 A are 4.8 mm and 5.5 mm respectively. Thus a 6 A plug fits

into both varieties of this socket, but the 16 A plug does not fit into the 6 A socket.

**C 2 - CEE 7/4 Schuko 16 A (Type F)**

This is the standard Schuko connector used in much of continental Europe. The Schuko plug will fit into the 16 A variety of the C 1 socket, but will not be grounded.

**C 3 - CEE 7/5 French 16 A (Type E)**

This is the standard connector found in France, Belgium, Poland, Czech Republic, and Slovakia. The plug will fit into the 16 A variety of the C 1 socket, but will not be grounded.

**C 4 - CEE 7/7 16 A (Type E/F)**

This is the compromise plug designed to be accepted and to be grounded in both the Schuko and French sockets. The plug will fit into the 16 A variety of the C 1 socket, but will not be grounded.

**C 5 - CEE 7/16 Europlug 2.5 A (Type C)**

The standard Europlug is defined here, as is a version of the C 6 (CEE 7/17) plug, but with 4.0 mm diameter pins. The standard allows for the use of devices that draw as much as 6 A with these round variants.

**C 6 - CEE 7/17 16 A (Type C)**

The standard CEE 7/17 ungrounded plug with 4.8 mm diameter pins is defined here. Note that the GOST standard defines a variant with 4.0 mm diameter pins for use with devices of 6 A or less, which it classifies as a variant shape of the C 5 plug.

Compatibility Table

		Plugs						
		C 1		C 2	C 3	C 4	C 5	C 6
		6 A	16 A					
Sockets	C 1	Y	N	N	N	N	Y	N
	6 A	Y	N	N	N	N	Y	N
	C 1	Y	Y	Y	Y	Y	Y	Y
	16 A	Y	Y	Y	Y	Y	Y	Y
	C 2	N	N	Y	N	Y	Y	Y
C 3	N	N	N	Y	Y	Y	Y	

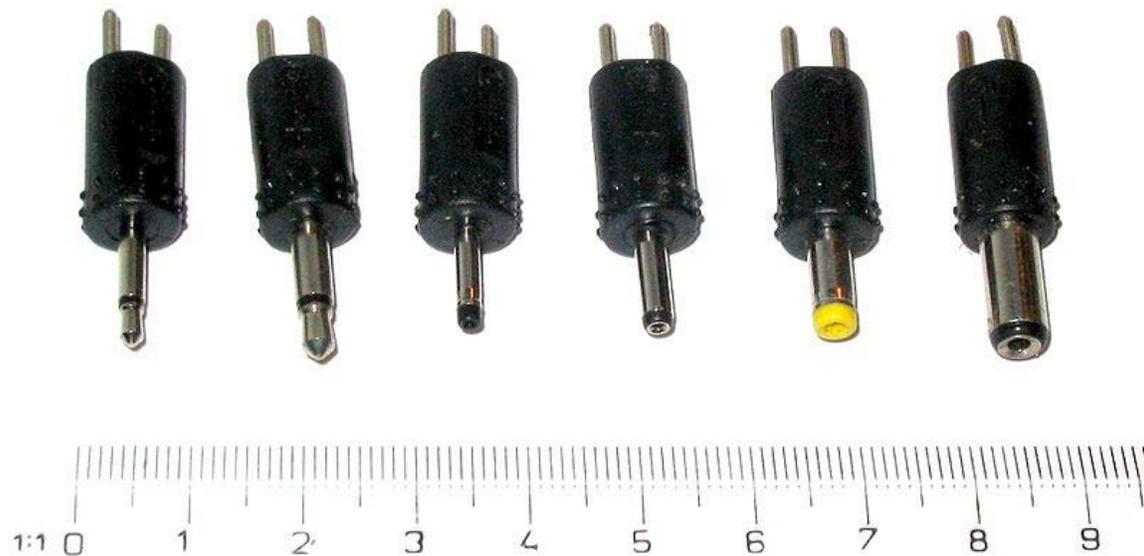
## Chapter 6

# DC Connector

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

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

### *Cylindrical types*



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

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

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

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

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

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

Contact ratings vary from unspecified (and probably less than 1 A in practice) up to 5 A, with 2 A typical. Voltage is again often unspecified, up to 48 V with 12 V typical. The smaller types usually have lower ratings, both for current and voltage. The *tip* (i.e. the inner conductor) *usually* carries the positive (+) pole.

## ***Snap and lock DC power connectors***

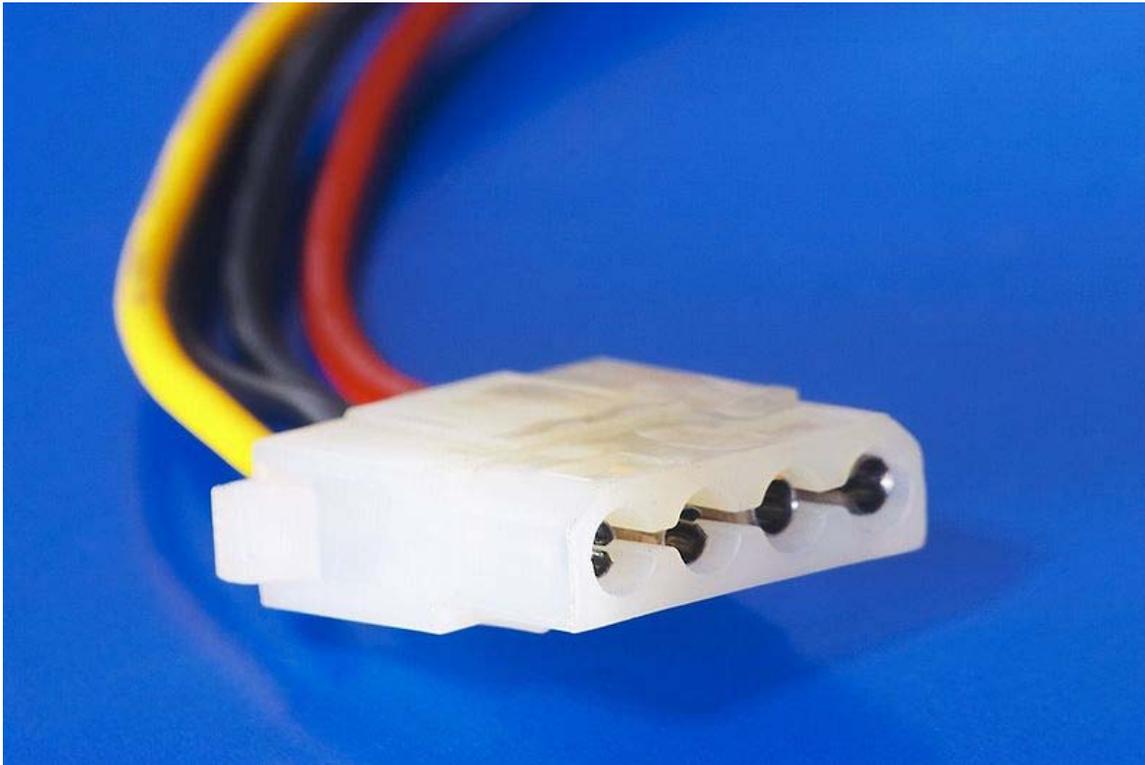


These connectors look similar to Mini-DIN connectors, but have either 3 or 4 thicker pins and a slightly larger mating shell. Because of this they do not mate with any of the Mini-DIN connectors. They can usually be identified by an engraved symbol on the backs of the plug, consisting of two wide arrows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

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

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

### **Molex connector**



Molex connector

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

### **IEC 60906-3:1994**

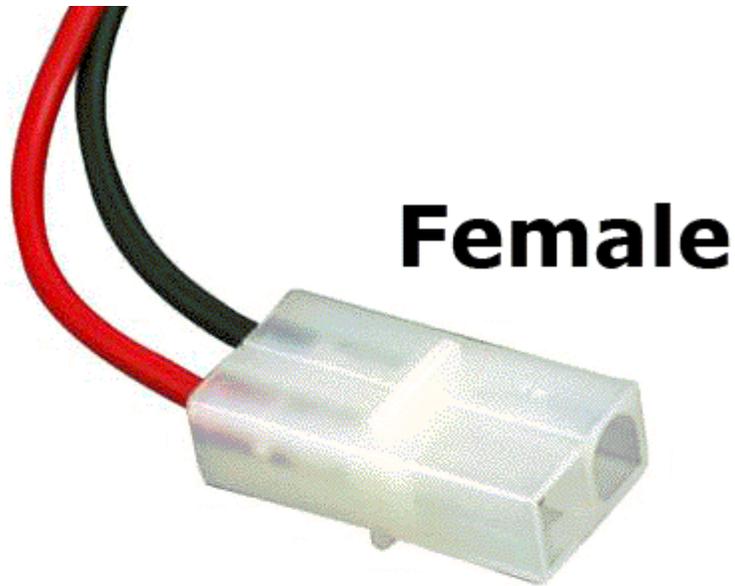
The International Electrotechnical Commission (IEC) has produced a standard for a system of plugs and socket-outlets for household and similar purposes in fixed and portable applications. Safety extra-low voltage (SELV) plugs and socket-outlets for 16 amperes and 6, 12, 24, or 48 volts AC and DC. For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

The dimensions are as follows:

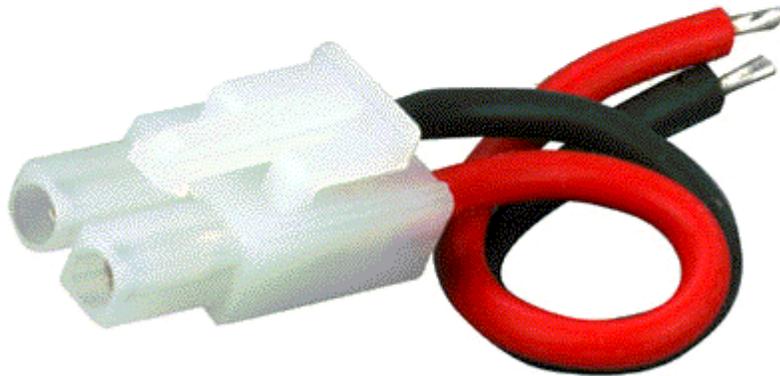
<b>Parameter</b>	<b>Value</b>
Pin-2-Pin distance	7 mm $\pm$ 0.1 mm
Pin diameter	3.5 mm +0/-0.075 mm
Female sleeve	4 mm
Pin length	10 mm
Connector diameter	19.4 mm

### ***Tamiya connector***

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



**Female**



**Male**

Tamiya connector

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

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

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

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

### ***Deans connectors***

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

### ***JST RCY connector***

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

### ***Locking Molex connector***

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

### ***Inverter tabs/lugs***



Inverter lugs

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

### ***Airline in-seat power supply system***

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

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

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

## ***Anderson Powerpole connectors***

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

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



Anderson Powerpole connectors with crimping tool

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

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

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

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

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

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

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

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

## **SAE connector**



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

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

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

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

## ***Cigar lighter sockets and plugs***



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

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

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

### ***DIN 4165 connector***

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

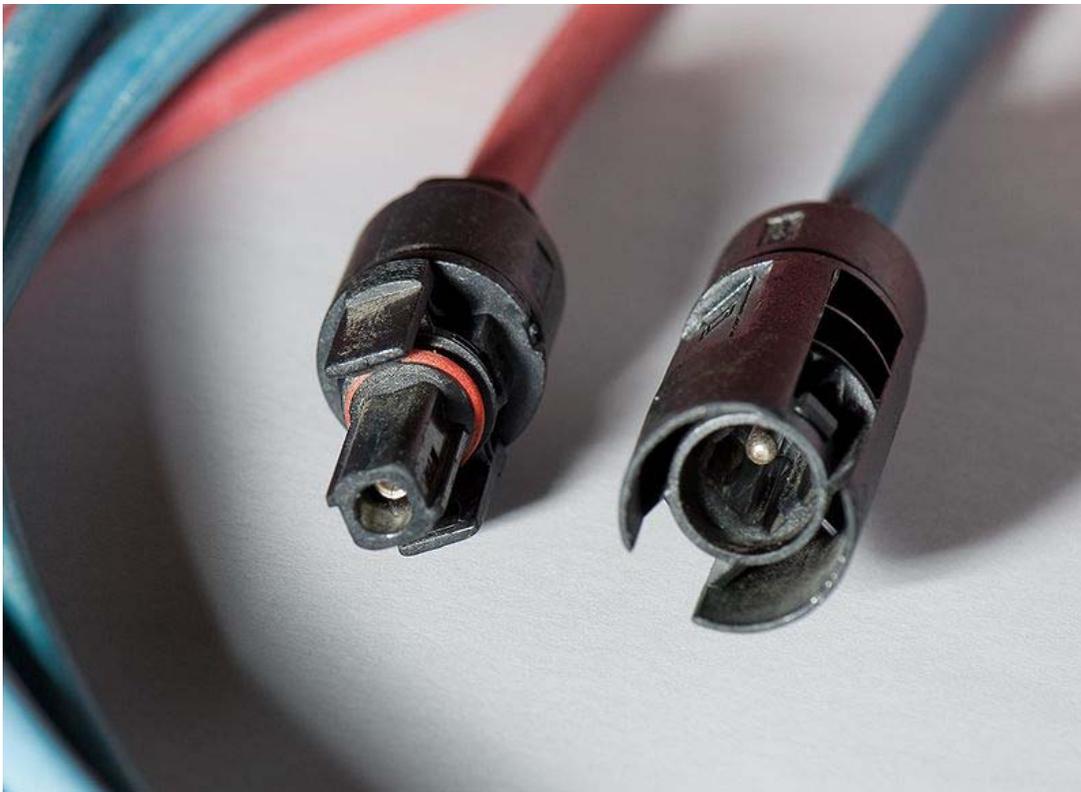
- Also known as Powerlet connector, BMW Accessory connector or Hella plug

### ***XLR connectors used for power***

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

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

### ***Other DC connectors***



Weatherproof DC connectors designed for connecting photovoltaic panels.



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

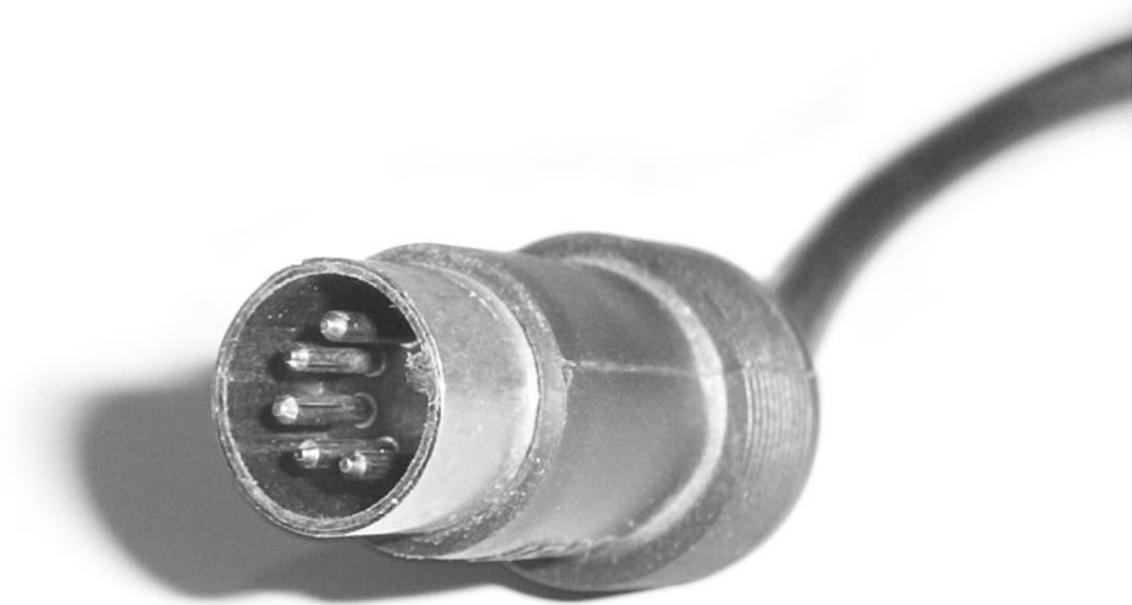
- Fly RC magazine: Connectors Connection describes most or all of the connectors used by RC users.
- There are a number of similar design PC board power connectors, including Molex Mini-Fit SR, Molex Mini-fit jr., MOLEX MICROFIT and Molex SABRE connectors, and AMP DUAC connectors that look similar to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

In Australia, a T-configuration socket is used for DC power outlets, such as in stand-alone power systems (SAPS) or on boats. For this use, the horizontal slot is on top and is positive. This is also used for temporary equipment in emergency vehicles. In Victoria

the top of the T is taken to look like a minus sign, and is therefore negative. Outside Victoria the vertical pin is meant to be earth/chassis ground, consistent with Australian Standards for Type I 240 volt outlets; therefore, the top of the T is positive on a negative-earth vehicle. Older positive-earth vehicles are still in service, so actual polarity at the outlet can be random.

## Chapter 7

# DIN Connector



Five-pin male 180° DIN connector

A **DIN connector** is a connector that was originally standardized by the *Deutsches Institut für Normung* (DIN), the German national standards organization. There are DIN standards for a large number of different connectors, therefore the term "DIN connector" alone does not unambiguously identify any particular type of connector unless the document number of the relevant DIN standard is added (e.g., "DIN 41524 connector"). In the context of consumer electronics, the term "DIN connector" commonly refers to a member of a family of circular connectors that were initially standardized by DIN for analog audio signals. Some of these connectors have also been used in analog video applications and for digital interfaces such as MIDI or the IBM AT computer keyboard (later PS/2 connectors for keyboard and mouse are Mini-DIN connectors). The original DIN standards for these connectors are no longer in print and have been replaced with the equivalent international standard IEC 60130-9.

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

### ***Circular connectors***

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



The plugs consist of a circular shielding metal skirt protecting a number of straight round pins. The skirt is keyed to ensure that the plug is inserted with the correct orientation and to prevent damage to the pins. The basic design also ensures that the shielding is connected between socket and plug prior to any signal path connection being made. However, as the keying is consistent across all connectors, it does not prevent incompatible connectors from mating, which can lead to damage; this is changed in Mini-DIN, which keys different connectors.

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

Screw-locking versions of this connector have also been used in instrumentation, process control and professional audio. In North America this variant is often called a "small Tuchel" connector after one of the major manufacturers. Tuchel is now a division of Amphenol. The pin and socket inserts are nearly identical to those used in non-locking connectors, and in some cases locking and non-locking connectors can be mated. Additional configurations up to 24 pins are also offered in the same shell size. A bayonet-locking version was also used on portable tape recorders and dictation machines through the 1980s.

## **Loudspeaker connector**



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

A polarised two-pin unshielded connector, designed for connecting a loudspeaker to a power amplifier (or other device; many of the earlier shoebox style tape recorders used them), is known as the DIN 41529 loudspeaker connector. It exists as a panel-mounting female version, and line-mounted male and female versions. The male version has a central flat pin, and circular pin mounted off-centre. The circular pin should be connected to the positive line (red) while the spade should be connected to the negative line (black).

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

## **Applications**

### **Analog audio**

The 3/180° and 5/180° connectors were originally standardized and widely used in Germany, Czech republic, and, later, in USSR and Comecon countries for interconnecting analog audio equipment, for example a stereo tape recorder to a stereo amplifier or preamplifier, using the five pins for the four signal connections plus ground.

The cord used for this has a connector on each end, and the pins are connected pin for pin, that is, pin 1 to pin 1, 2 to 2, etc. Pins on male connectors are numbered (from right to left, viewed from outside of the connector, with the 5 pins upwards, and facing them): 1-4-2-5-3. Holes on female connectors are also numbered 1-4-2-5-3, but from left to right (facing the holes). A four-channel cord wired in this way is sometimes simply called a *DIN cord*, a *DIN lead* or a *DIN cable*. For mono interconnections, the 3/180° plugs are sufficient. When a mono plug is inserted into a stereo socket, it mates with the left channel. This interface was rare in the U.S. market, and has progressively disappeared on new equipment, both in Germany and worldwide, since the 1980s, in favour of RCA connectors.

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

### Other uses

The 5/180° connectors are commonly used for the

- SYNC interface for electronic musical instruments,
- MIDI interfaces for electronic musical instruments,
- serial ports in the original Apple IIc personal computer,
- in the original IBM PC and PC/AT, as well as the Amiga, for the computer keyboard cable (this connector fell out of use in the mid nineties as the ATX Form Factor used the PS/2 connector instead).
- Audio in the original HME wireless communicators, it is the headset connector for (Tx&Rx) Inbound and Outbound audio for Drive Through Restaurants
- Controlling tilt of UMTS Antennas (Antenna Interface Standards Group)
- Connecting two controllers for radio controlled model aircraft together for training purposes.

The DIN connector saw several other uses outside of audio. The AT keyboard uses a 5-pin DIN connector; the TurboGrafx-16 game console used a 5-pin DIN for its A/V output. Oddly, the Atari XEGS as well as Commodore C64 and Elektronika BK used a DIN connector for their AC Adapter. Also, early C64s that only supported composite video out used a 5-pin DIN for A/V - however, the newer C64s that supported chroma/luma output used 8-pin DIN to carry the extra signals. The Sega Genesis, Neo Geo and Neo Geo CD used an 8-pin DIN for their composite, RGB video and mono audio outputs, also providing +5V for using an RF modulator. The Dragon 32 also used 4 5-pin DIN connectors for joysticks, tape connection and monitor outputs. The TRS-80

Model I used three identical 5-pin DIN connectors for its AC adapter, video output, and tape recorder, making it easy to destroy the unit if the plugs were confused. Almost the same could be seen on Soviet Elektronika BK home computers, where four 5-pin DIN connectors were used for tape recorder, B/W video output, RGB video output and AC adapter. The Geneve 9640 uses an 8 pin DIN for it's composite video, analog RGB, audio, and +12Volt for an RF modulator.

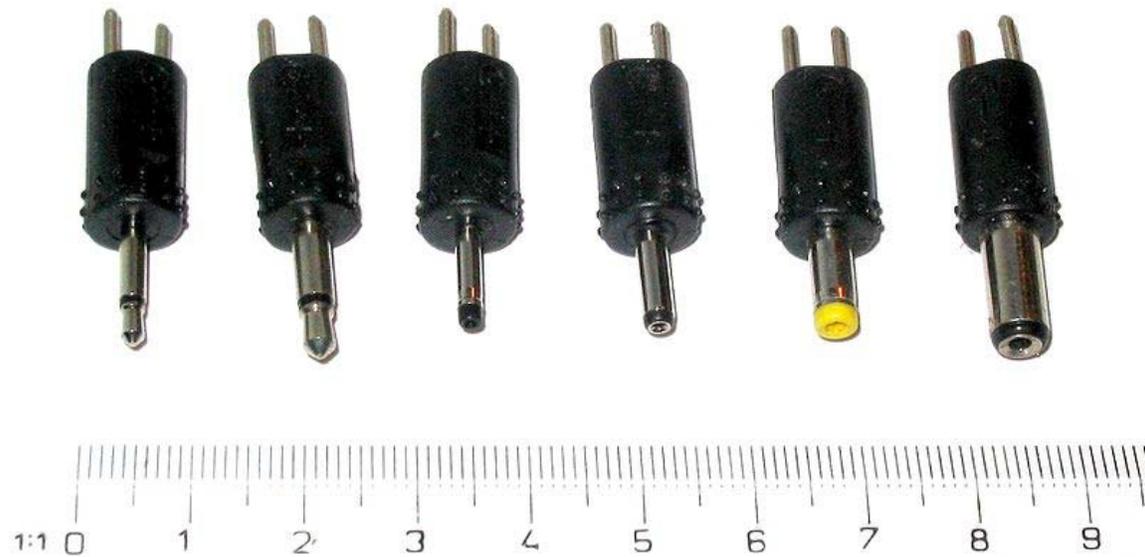
In the Soviet Union, 3-pin and 5-pin DIN connectors named OHIQ-BГ, could be seen on many pieces of equipment, as well as factory-made audio equipment. Radio amateurs and small cooperatives quickly discovered these reliable connectors and began to put them into almost every low frequency signal device,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

## Chapter 8

# Coaxial Power Connector



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



Common DC power connectors

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

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

### ***Connector construction and terminology***

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

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

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

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

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

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

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

### ***Many different sizes***

There are many different sizes of coaxial power connectors

Contact ratings vary from unspecified (and probably less than 1 A in practice) up to 5 A, with 2 A typical. Voltage is again often unspecified, up to 48 V with 12 V typical. The smaller types usually have lower ratings, both for current and voltage.

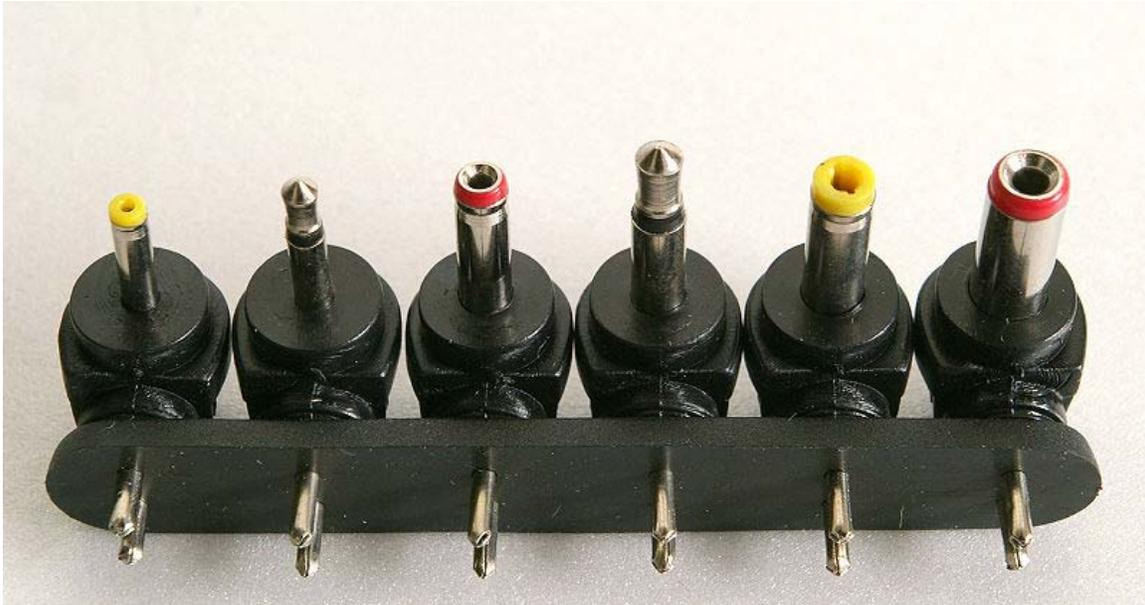
It is quite possible that new sizes will continue to appear and disappear. The most likely reason for a new size is that a particular manufacturer wishes to discourage use of third-party power supplies, either for technical reasons or to promote use of their own products, or both.

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

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

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

### ***Common sizes and interchangeability***



Some common DC power connectors

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

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

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

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

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

### ***Locking and retention features***

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

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

An alternate design, the even rarer **lock-tab DC coaxial connector** (also called **bayonet lock**) offers a compromise that resists unplugging, but which *will* disengage when pulled hard enough. This connector uses small metal tab protrusions on the connector barrel to lock the plug in place, requiring a special push-and-rotate motion to engage the locks. This is a mechanical way to provide a "safe breakaway" feature somewhat like the magnetic latch used in the Apple Inc. proprietary MagSafe design. Kobiconn and Lumberg have offered some lock-tab variants, and there may be other manufacturers as well.

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

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

## **Standards**



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

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

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

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

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

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

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

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

### ***EIAJ power connectors***

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

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

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

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

### ***DIN 45323 power connectors***

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

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

- 6.00 mm OD, 1.98 mm ID

### ***Universal power supplies***



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

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

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

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

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

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

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

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

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

### ***Guidelines for power connector selection***

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

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

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

## ***Comprehensive listing of DC coaxial connectors***

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

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

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

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

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

There are a number of sizes listed below that appear to be quite similar, and while the tolerances of these connectors are typically indicated as  $\pm 0.05$  or  $\pm 0.03$  mm by the manufacturers, there is still ambiguity as to whether two sizes differing by only 0.05 mm

(or where the specification is only given to the nearest 0.10 mm) warrants listing them separately here. Also, there are minor tolerancing and measuring variations and discrepancies in the dimensions given; further work should be done to determine the original specifications for size, and then to list the similar sizes that are intended to be compatible.

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

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

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

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

## **RadioShack Adaptaplug conversion matrix**

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

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

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

## Chapter 9

# Cigarette Lighter Receptacle



12 volt cigar lighter plug.



Metal and plastic sockets

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

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

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

### ***History***

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

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

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

## *Use as a lighter*



Car cigar lighter

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

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

### ***Use as an electrical outlet***

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

### **Technical details**

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

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

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

12V Sockets normally comply with SAE standard J563.

6-volt cigar lighter receptacle and plug

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

12-volt cigar lighter receptacle and plug, size A

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

12-volt cigar lighter receptacle and plug, size B

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

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

## **Design considerations**

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

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

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

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

## Chapter 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.

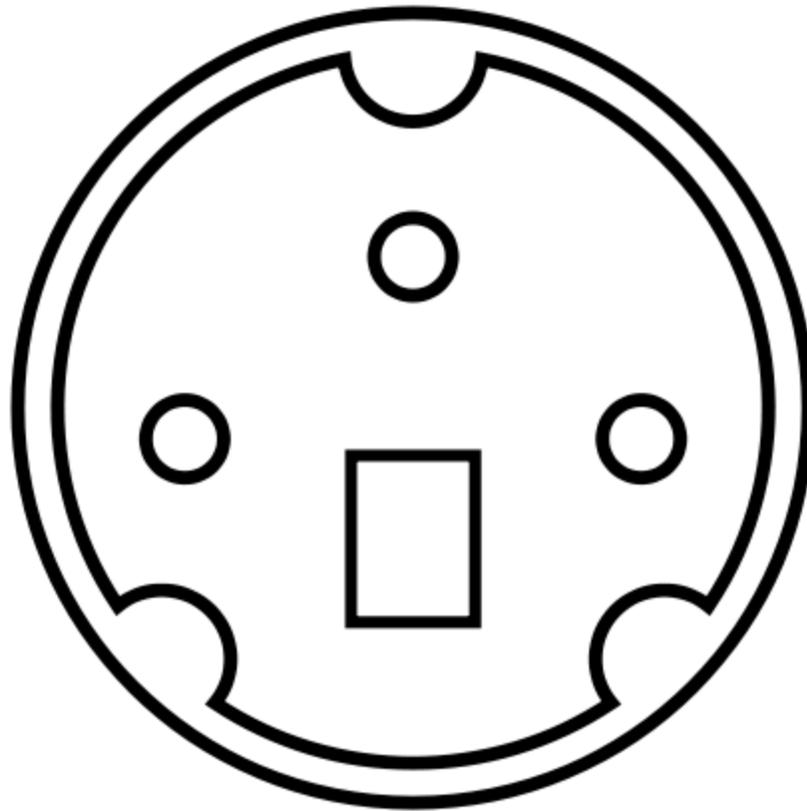


*(The plug or male connectors shown, as visible when unplugged looking into the connector.)*

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

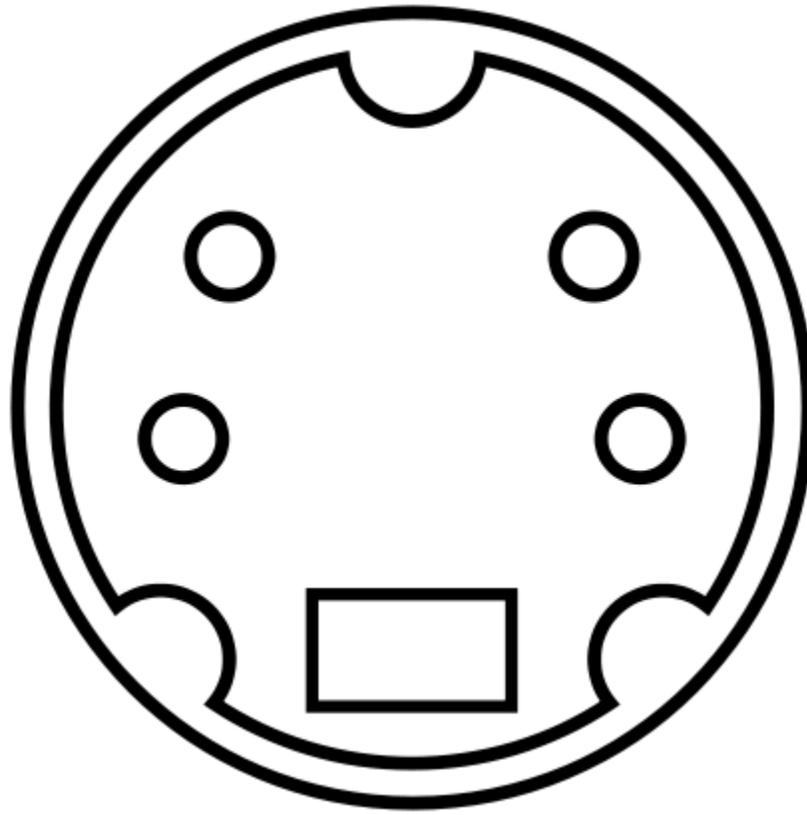


- Apple LocalTalk Network
- VESA Stereo
- SGI StereoView (pinout diagram)
- Behringer Mixer Power Supplies
- Optoma EH1020 Projector
- TOPFIELD TF5400 PVR Combo Receiver

4-pin

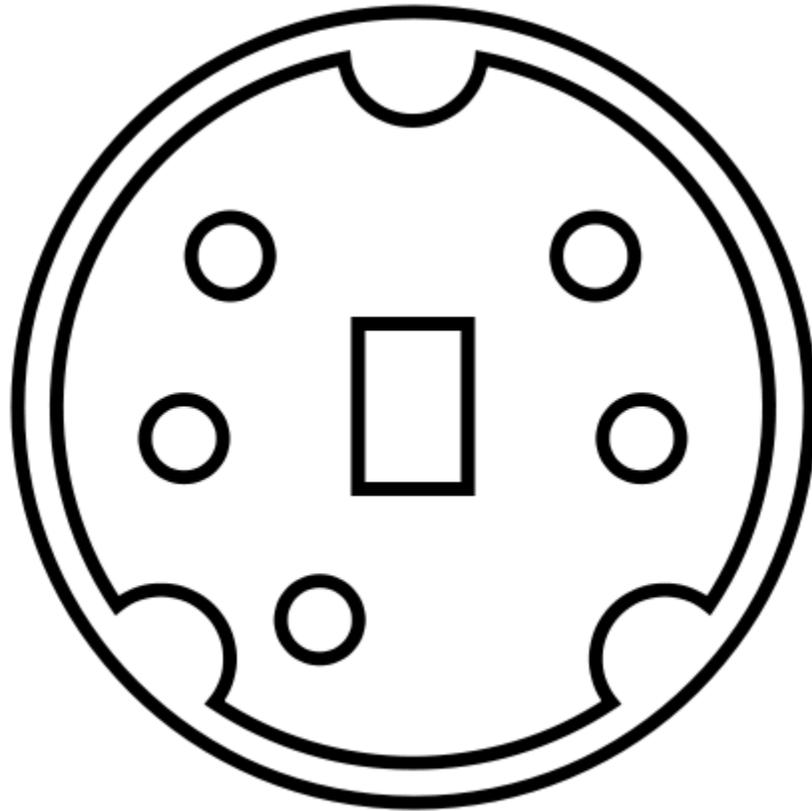


4 pin mini-DIN for S-Video



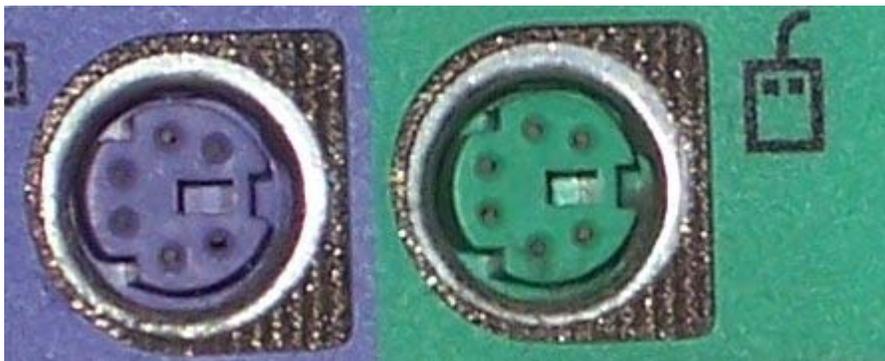
- Apple Desktop Bus (Pinout diagram)
- S-Video (Pinout diagram)
- Thomson SpeedTouch 605 Console Serial Port / DSL Router (pinout diagram)
- Low voltage power supplies like the Seagate Pushbutton External Drive Power Supply

## 5-pin

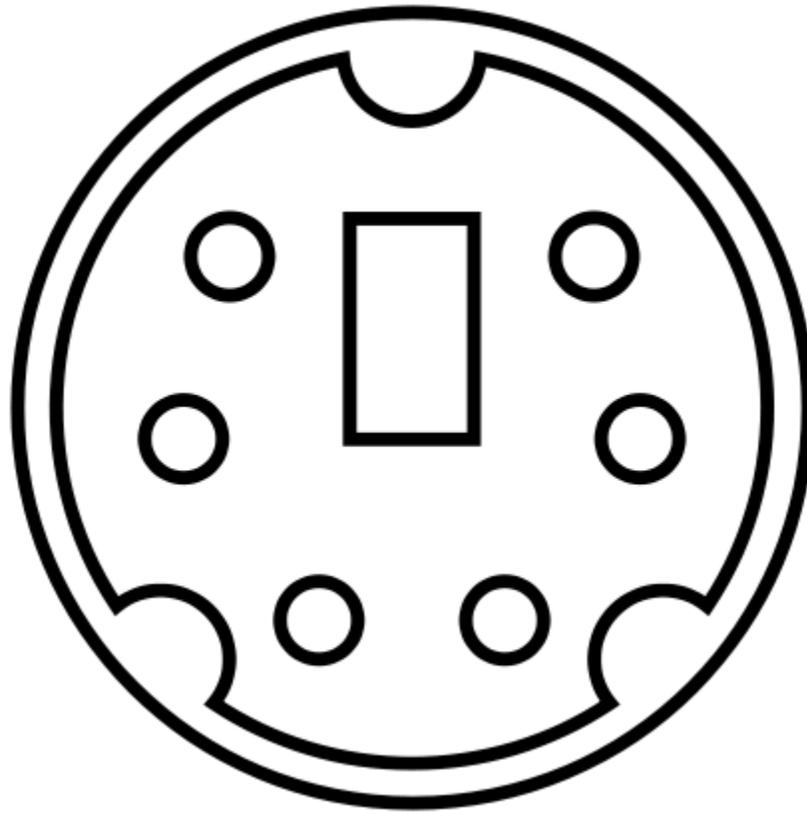


- Low-voltage power supply input connector on various pieces of equipment
- SONY LANC camcorder control interface (Pinout diagram)
- 5-pin MIDI input and output connectors used by the Creative Technology Sound Blaster X-Fi Front I/O Panel and the Creative LivedriveII (pinout diagram)
- Altec Lansing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

## 6-pin



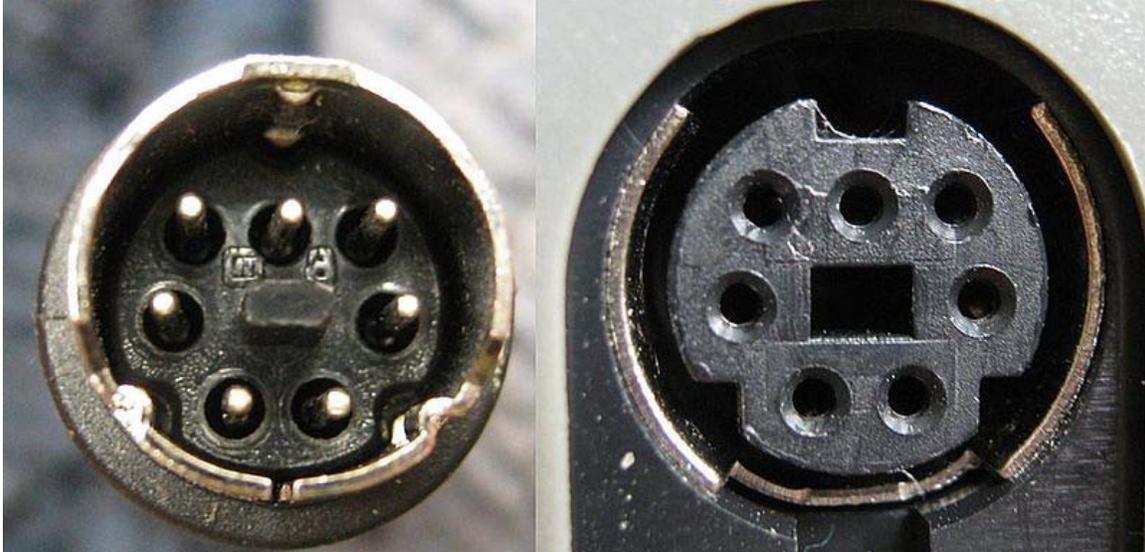
The color-coded PS/2 connection ports (purple for keyboards and green for mice)



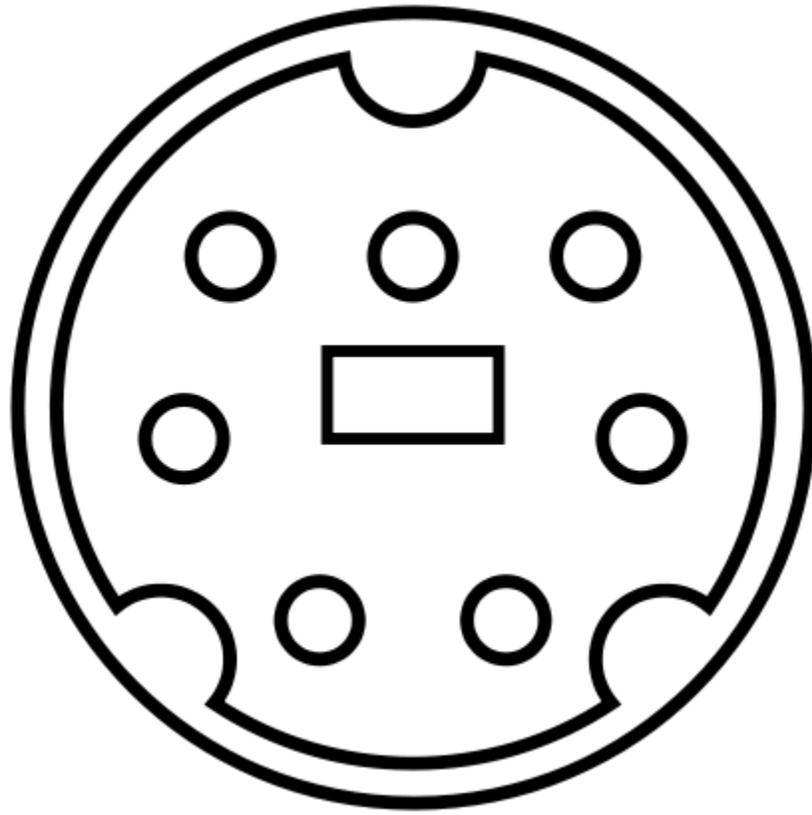
- IBM PC compatible PS/2 keyboard/mouse connector
- Amateur radio TNC modem-radio interface
- Power supply DC output for some electronic devices
- Acorn Archimedes keyboard
- Blitz DVD screen for cars
- Klipsch 2.1 channel audio system (2 speakers/1 subwoofer)
- Leadtek and VisionTek GeForce2 Ti cards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

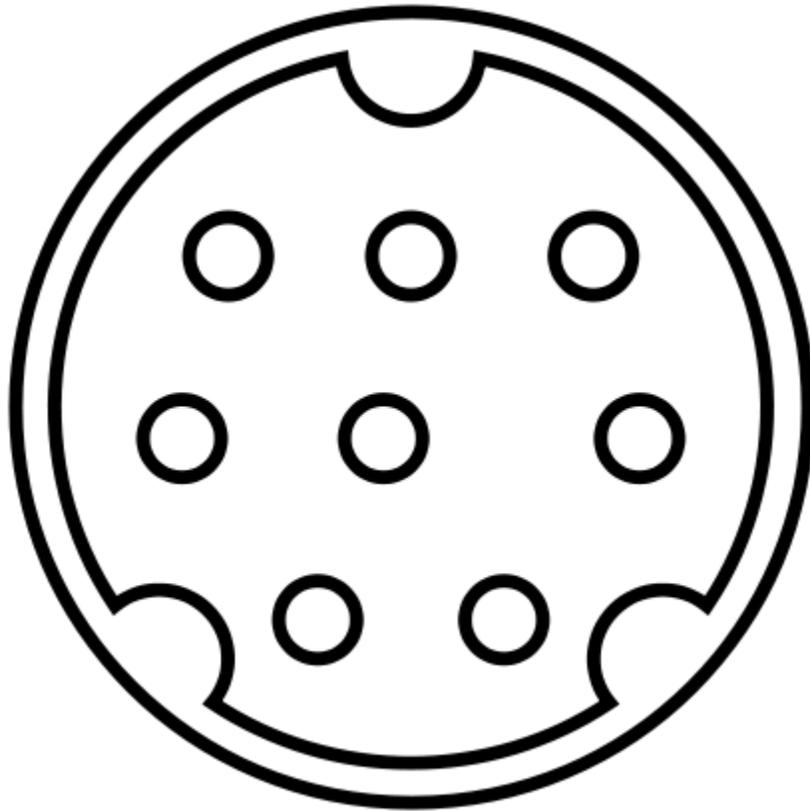


Example of the standard 7 pin mini-DIN connectors. These are from a Commodore 1531 datasette and its adapter.



- 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

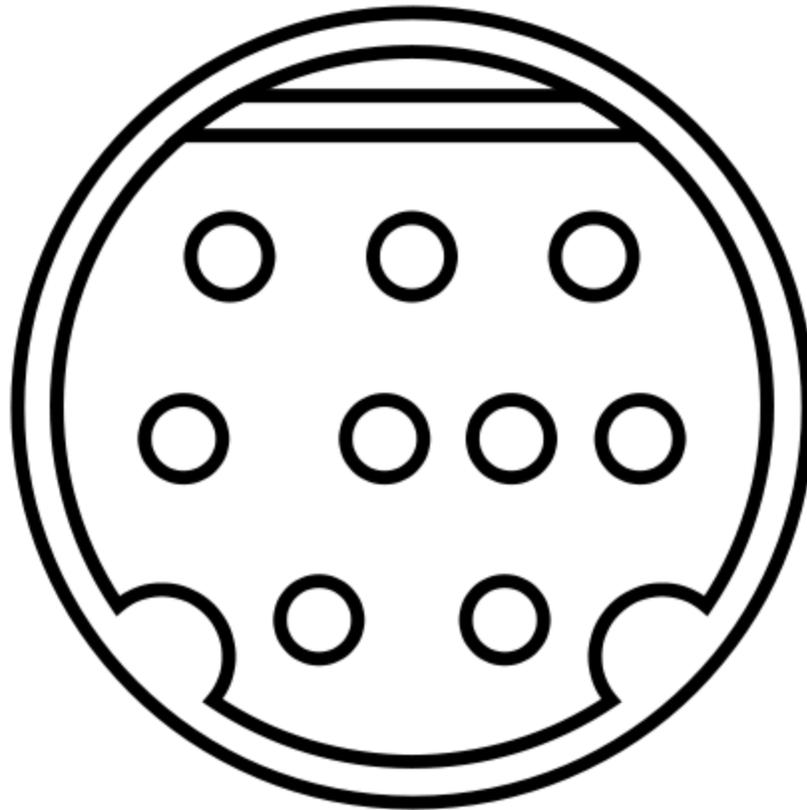
## 8-pin



- 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***

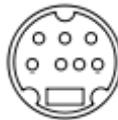
Several non-standard sockets are designed to mate with standard mini-DIN plugs. These connectors provide extra conductors, and are used to save space by combining functions in one connector that would otherwise require two standard connectors.

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

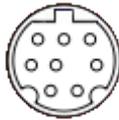
- Aspenhome iPod Dock
- Hauppauge WinTV
- Samsung X20 notebook

## 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.)

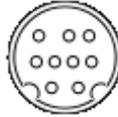
- 9-pin Apple GeoPort connector

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.

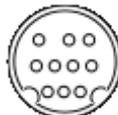
- This connector is close enough in specification to an Altec Lansing right speaker connection to be replaced with this connector plug.

### 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

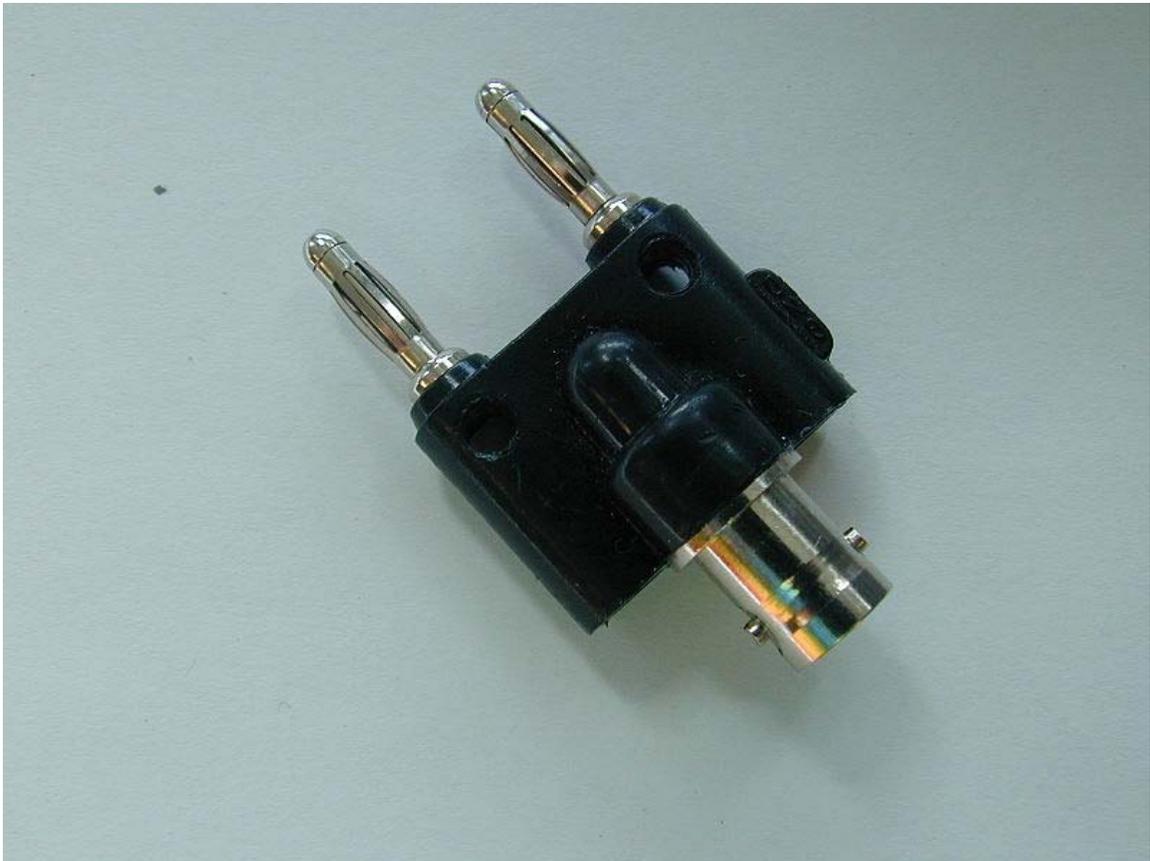
### **Other non-standard connectors**

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

## Chapter 11

# Banana Connector & Molex Connector

## Banana Connector



Adapter between a female BNC connector and banana plugs



Typical banana plugs connected to loudspeaker

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

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

### ***Design***

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

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

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

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

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

### ***Derived plugs***

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

US-style double banana (pictured): A plastic housing containing two banana plugs, allowing simultaneous connection of a signal line and a ground (earth) line. The housing may allow the connection of individual wires, a permanently attached coaxial cable providing both signal and ground, or a coaxial connector such as the BNC connector shown in the photo. By convention, multiple full-sized banana connectors are spaced on 3/4 inch centers.

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

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

### ***Miniature connectors***

A miniaturized version of the banana connector was also produced. About 1/3 the size of the standard connector, these were useful in high-density applications but never achieved the same sort of popularity as the larger banana connectors. They are substantially more fragile than the larger connectors. Multiple miniature banana connectors are usually spaced on 1/2 inch centers.

## **Electrical safety**

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

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



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

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

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

## Molex Connector



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

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

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

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

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

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

### **Desktop PC use**

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

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

### **Motherboard power connector (Molex Mini-fit Jr.)**

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

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

Standard pinout:

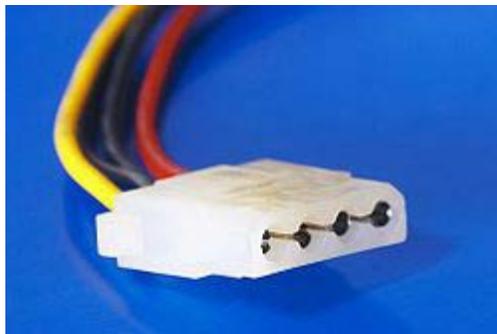
24-pin ATX12V 2.x power supply connector  
(20-pin omits the last four: 11, 12, 23 and 24)

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

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

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

## Molex 8981 Series



Molex 8981 Power connector (female)

**Type** Electrical power connector

### Production history

**Designer** Molex

### General specifications

<b>Width</b>	21 mm	
<b>Height</b>	6 mm	
<b>Pins</b>	4	
<b>Electrical</b>		
<b>Signal</b>	Yes	
<b>Max. voltage</b>	12 V	
<b>Max. current</b>	11 A/pin (30 °C rise)	
<b>Pin out</b>		
<b>Pin</b>	<b>Color</b>	<b>Type</b>
<b>Pin 1</b>	Yellow	+12 V
<b>Pin 2</b>	Black	Ground
<b>Pin 3</b>	Black	Ground
<b>Pin 4</b>	Red	+5 V

18 AWG wire is typically used.

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

### Disk drive connector (Molex 8981 Series Power Connector)

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

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

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

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

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

## Chapter 12

# MagSafe & Battery Terminal

## MagSafe

### MagSafe



The MagSafe power adapter on a MacBook.

<b>Type</b>	Computer power connector
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#### Production history

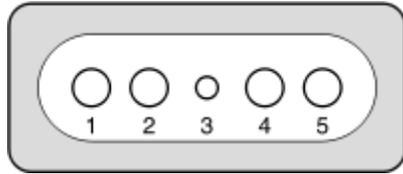
<b>Manufacturer</b>	Apple Inc.
<b>Produced</b>	2006
<b>Superseded</b>	Apple Power Connector

#### General specifications

<b>Hot pluggable</b>	Yes
<b>External</b>	Yes

**Pins**                    5

**Pin out**



Male connector, front view

<b>Pin 1</b>	Ground
<b>Pin 2</b>	V+ @ 16.5 VDC
<b>Pin 3</b>	Charge control pin
<b>Pin 4</b>	V+ @ 16.5 VDC
<b>Pin 5</b>	Ground

Grey area indicates magnetic connector

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

## Features



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

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

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

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

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

## ***Pinout***

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

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

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

## ***Criticisms and defects***



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

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

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

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

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

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

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

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

## ***Prior power systems***



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



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



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

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

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

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

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

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

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

## Battery Terminal

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



Common battery contacts and terminals



Battery holders with pressure contacts

### ***Automotive battery terminals***

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

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

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

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

## ***Marine battery terminals***

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

## ***Zinc battery terminals***

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

## ***SLA battery terminals***

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

## ***UPS battery terminals***

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

## ***Dry battery terminals***

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

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

Nine-volt batteries have snap-on connectors.