Fuse (electrical)

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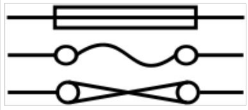
In electronics and electrical engineering a **fuse** (short for *fusible link*) is a type of overcurrent protection device. Its essential component is a metal wire or strip that melts when too much current flows, which breaks the circuit in which it is connected, thus protecting the circuit's other components from damage due to excessive current.

200 A Industrial fuse. 80 kA breaking capacity.


Electronic symbols for a fuse. IEC (upper) and American (lower two) versions.

A practical fuse was one of the essential features of Thomas Edison's electrical power distribution system.

Fuses (and other overcurrent devices) are an essential part of a power distribution system to prevent fire or damage. When too much current flows through a wire, it may overheat and be damaged, or even start a fire. Wiring regulations give the maximum rating of a fuse for protection of a particular circuit. Local authorities will incorporate national wiring regulations as part of law. Fuses are selected to allow passage of normal currents, but to quickly interrupt a short circuit or overload condition.

Contents

Characteristic parameters

Rated current I_N This is the maximum current that the fuse can continuously pass without interruption to the circuit, or harmful effects on its surroundings.

Speed The speed at which a fuse operates depends on how much current flows through it and the material of which the fuse is made. In addition, temperature influences the resistance of the fuse. Manufacturers of fuses plot a time-current characteristic curve, which shows the time required to melt the fuse and the time required to clear the circuit for any given level of overload current.

Fuses are often characterized as "fast-blow", "slow-blow" or "time-delay", according to the time they take to respond to an overcurrent condition. The selection of the characteristic depends on what equipment is being protected. Semiconductor devices may need a fast or *ultrafast* fuse for protection since semiconductors may have little capacity to withstand even a momentary overload. Fuses applied on motor circuits may have a time-delay characteristic, since the surge of current required at motor start soon decreases and is harmless to wiring and the motor.

The I^2t value This is a measure of the energy required to blow the fuse element and is an important characteristic of the fuse. It is an indication of the "let-through" energy passed by the fuse which downstream circuit elements must withstand before the fuse opens the circuit.

Voltage drop The values of the voltage drop across a fuse are usually given by the manufacturer. A fuse may become hot due to the energy dissipation in the fuse element at rated current conditions. The voltage drop should be taken into account particularly when using a fuse in low-voltage applications.

Breaking capacity The breaking capacity is the maximum current that can safely be interrupted by the fuse. Generally this should be higher than the maximum prospective short circuit current. Miniature fuses may have an interrupting rating only 10 times their rated current. Some fuses are designated High Rupture Capacity (HRC) and are usually filled with sand or a similar material. Fuses for small low-voltage wiring systems are commonly rated to interrupt 10,000 amperes. Fuses for larger power systems must have higher interrupting ratings, with some low-voltage current-limiting HRC fuses rated for 300,000 amperes. Fuses for high-voltage equipment, up to 115,000 volts, are rated by the total apparent power (megavolt-amperes, MVA) of the fault level on the circuit.

Rated voltage The voltage rating of a fuse should always be greater than or equal to the circuit voltage. For example, glass tube fuses rated 32 volts should never be used in line-operated (mains-operated) equipment even if the fuse physically can fit the fuseholder. Fuses carrying a 250 V rating may be safely used in a 125 V circuit, but the reverse is not true as the fuse may not be capable of safely interrupting the arc in a circuit of a higher voltage. Low-voltage fuses can generally be used at any voltage up to their rating.

Medium-voltage fuses rated for a few thousand volts are never used on low voltage circuits, due to their expense and because they cannot properly clear the circuit when operating at very low voltages.

Markings

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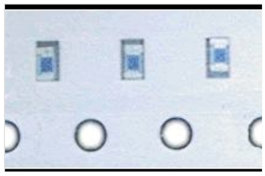
Most fuses are marked on the body, or end caps to markings show their ratings. Surface mount technology "chip type" fuses feature little or no markings making identification very difficult.

A sample of the many markings that can be found on a fuse.

When replacing a fuse, it is important to interpret these markings correctly as fuses that may look the same, could be designed for very different applications. Fuse markings[1] will generally convey the following information;

- Ampere rating of the fuse
- Voltage rating of the fuse
- Time-current characteristic ie. element speed
- Approvals
- Manufacturer / Part Number / Series
- Breaking capacity



Surface Mount Fuses on 8 mm tape. Each fuse measures 1.6 mm x 0.79 mm and has no markings.

Approvals

The majority of fuse manufacturers build products that comply with a set of guidelines and standards, based upon the application of the fuse. These requirements are devised by many different Government agencies and certification authorities. Once a fuse has been tested and proven to meet the required standard, it may then carry the approval marking of the certifying agency.

Packages

Fuses come in a vast array of sizes & styles to cater for the immense number of applications in which they are used. While many are manufactured in standardised package layouts to make them easily interchangeable, a large number of new styles are released into the marketplace every year. Fuse bodies may be made of ceramic, glass, plastic, fiberglass, Molded Mica Laminates, or molded compressed fibre depending on application and voltage class.

Cartridge (ferrule) fuses have a cylindrical body terminated with metal end caps. Some cartridge fuses are manufactured with end caps of different sizes to prevent accidental insertion of the wrong fuse rating in a holder. An example of such a fuse range is the 'bottle fuse', which in appearance resembles the shape of a bottle.

Fuses designed for soldering to a printed circuit board have radial or axial wire leads. Surface mount fuses have solder pads instead of leads.

Fuses used in circuits rated 200-600 volts and between about 10 and several thousand amperes, as used for industrial applications such as protection of electric motors, commonly have metal blades located on each end of the fuse. Fuses may be held by a spring loaded clip or the blades may be held by screws. Blade type fuses often require the use of a special purpose extractor tool to remove them from the fuse holder.

Semi-enclosed fuses are fuse wire carriers in which the fusible wire itself can be replaced. These are used in consumer units in some parts of the world, but are becoming less common.

Materials

While glass fuses have the advantage of a fuse element visible for inspection purposes, they have a low breaking capacity which generally restricts them to applications of 15 A or less at 250 V_{AC}. Ceramic fuses have the advantage of a higher breaking capacity facilitating their use in higher voltage/ampere circuits. Filling a fuse body with sand provides additional protection against arcing in an overcurrent situation.

Dimensions

Cartridge fuses are generally measured as the overall length and diameter of the fuse. Due to the large variety of cartridge fuses available, fuse identification relies on accurate measurements as fuses can differ by only a few millimeters between types. 'Bottle style' cartridge fuses also require the measurement of the cap diameter as this varies between ampere ratings.

Other fuse packages can require a variety of measurements such as;

- body (width x height x depth)
- blade or tag (width x height x depth)
- overall length of the fuse (when the fuse features blades or tags)
- overall width of the fuse (when the fuse features 2 bodies)
- width of the mounting holes (when the fuse features tags)
- distance between blades (when radially configured)
- fixing centre (when the fuse features tags - see below)

Fuses fitted with tags require the fixing centre measurement. This measurement is the distance between the tag mounting holes on either end of the fuse as measured from the centre of each mounting hole.

Special features

Glass cartridge and plug fuses allow direct inspection of the fusible element. Other fuses have other indication methods including:

- Indicating pin or striker pin: extends out of the fuse cap when the element is blown.
- Indicating disc: a coloured disc (flush mounted in the end cap of the fuse) falls out when the element is blown.
- Element window: a small window built into the fuse body to provide visual indication of a blown element.
- Flag: an external sprung arm that is released to an extended position once the element is blown.
- External trip indicator: similar function to striker pin, but can be externally attached (using clips) to a compatible fuse.
- Some fuses allow a special purpose microswitch or relay unit to be fixed to the fuse body. When the fuse element blows, the indicating pin extends to activate the micro switch or relay which in turn triggers an event.

Automotive fuses

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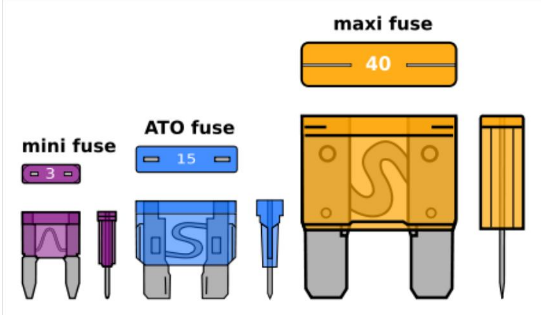
Automotive fuses protect the wiring and electrical equipment for vehicles. They are generally rated for circuits no higher than 24 volts direct current, but there exists brands of mini[2] and maxi[3] fuses that are modifed to be able to work in the 42 volt environment.



Plug-in type fuses come in three physical sizes: mini, ATO and maxi

Blade type

Plug-in fuses (also called blade or spade fuses), with a plastic body and two prongs that fit into sockets, are mostly used in automobiles. These types of fuses come in three different physical dimensions: mini (or minifuse), ATO (or ATC) and maxi (or maxifuse).
The physical dimensions, including the connector, of the fuses are as follows (LxWxH) (ampere ratings in the parenthesis):

- mini: 10.9x3.6x16.3 mm (2A, 3A, 4A, 5A, 7.5A, 10A, 15A, 20A, 25A, 30A)
- ATO (Automotive Technology Organization): 19.1x5.1x18.5 mm (1A, 2A, 3A, 4A, 5A, 7.5A, 10A, 15A, 20A, 25A, 30A, 40A)
- maxi: 29.2x8.5x34.3 mm (20A, 30A, 40A, 50A, 60A, 70A, 80A)

It is possible to replace[4] an ATO-type plug-in fuse with a circuit breaker that has been designed to fit in the socket of an ATO-sized fuse holder. These circuit protectors are more expensive than a regular fuse.

Color-coding

Blade fuses use a color-coding standard. [5] The Mini and ATO style fuses use the same color-coding system, while the larger maxi fuses use a different system, with only some colors representing the same current ratings.

Mini and ATO Color-coding:

Color	Current (A)
black*	1
grey	2
violet	3
pink	4
orange/tan	5
brown	7.5
red	10
aqua/blue	15
yellow	20
clear/natural	25
green	30
blue green*	35
amber*	40

* = available in ATO fuses only

Maxi Color-coding:

Color	Current (A)
yellow	20
grey	25
green	30
brown	35
orange	40
red	50
blue/aqua	60
tan	70
clear/natural	80

Bosch type

Bosch type fuses are used in old (often European) automobiles. The physical dimension of this type of fuse is 6x25 mm with conical ends. Bosch type fuses usually use the same color coding for the rated current. The DIN standard is 72581/1


Bosch type fuse (used in older cars)

Color	Ampere
yellow	5A
white	8A
red	16A
blue	25A

Lucas type

Lucas type fuses are used in old British made or assembled automobiles. The physical length of this type of fuse is either 1" or 1.25" with conical ends. Lucas type fuses usually use the same color coding for the rated current. Lucas fuses have three ratings; the continuous current they are designed to carry, the instantaneous current at which they will fuse, and the continuous current at which they will also fuse as well. The figure found on Lucas fuses is the continuous fusing current which is twice the continuous amp rating that the system should be using; this can be a source of confusion when replacing Lucas fuses with non Lucas fuses.

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Color	Continuous amps	Instantaneous fusing amps	Continuous fusing amps
Blue	1.5A	3.5A	3A
Yellow	2.25A	5A	4.5A
Red on Yellow	2.5A	6A	5A
Green	3A	7A	6A
Nut Brown	4A	10A	8A
Red on Green	5A	12A	10A
Green on Black	5A	12A	10A
Red on Brown	6A	14A	12A
Light Brown	7.5A	18A	15A
Pink	12.5A	30A	25A
White	17.5A	40A	35A
Purple on Yellow	25A	60A	50A
Yellow on Red	30A	75A	60A

80A

High voltage fuses

Fuses are used on power systems up to 115,000 volts AC. High-voltage fuses are used to protect instrument transformers used for electricity metering, or for small power transformers where the expense of a circuit breaker is not warranted. For example, in distribution systems, a power fuse may be used to protect a transformer serving 1-3 houses. A circuit breaker at 115 kV may cost up to five times as much as a set of power fuses, so the resulting saving can be tens of thousands of dollars. Pole-mounted distribution transformers are nearly always protected by a fusible cutout, which can have the fuse element replaced using live-line maintenance tools.

Large power fuses use fusible elements made of silver, copper or tin to provide stable and predictable performance. High voltage *expulsion fuses* surround the fusible link with gas-evolving substances, such as boric acid. When the fuse blows, heat from the arc causes the boric acid to evolve large volumes of gases. The associated high pressure (often greater than 100 atmospheres) and cooling gases rapidly extinguish (quench) the resulting arc. The hot gases are then explosively expelled out of the end(s) of the fuse. Other special High Rupturing Capacity (HRC) fuses surround one or more parallel connected fusible links with an energy absorbing material, typically silicon dioxide sand. When the fusible link blows, the sand absorbs energy from the arc, rapidly quenching it, creating an artificial fulgurite in the process.

Fuses compared with circuit breakers

Fuses have the advantages of often being less costly and simpler than a circuit breaker for similar ratings. The blown fuse must be replaced with a new device which is less convenient than simply resetting a breaker and therefore likely to discourage people from ignoring faults. On the other hand replacing a fuse without isolating the circuit first (most building wiring designs do not provide individual isolation switches for each fuse) can be dangerous in itself, particularly if the fault is a short circuit.

High rupturing capacity fuses can be rated to safely interrupt up to 300,000 amperes at 600 V AC. Special current-limiting fuses are applied ahead of some molded-case breakers to protect the breakers in low-voltage power circuits with high short-circuit levels.

"Current-limiting" fuses operate so quickly that they limit the total "let-through" energy that passes into the circuit, helping to protect downstream equipment from damage. These fuses clear the fault in less than one cycle of the AC power frequency. Circuit breakers cannot offer similar rapid protection.

Circuit breakers which have interrupted a severe fault should be removed from service and inspected and replaced if damaged.

Circuit breakers must be maintained on a regular basis to ensure their mechanical operation during an interruption. This is not the case with fuses, in which no mechanical operation is required for the fuse to operate under fault conditions.

In a multi-phase power circuit, if only one fuse opens, the remaining phases will have higher than normal currents, and unbalanced voltages, with possible damage to motors. Fuses only sense overcurrent, or to a degree, over-temperature, and cannot usually be used independently with protective relaying to provide more advanced protective functions, for example, ground fault detection.

Some manufacturers of medium-voltage distribution fuses combine the overcurrent protection characteristics of the fusible element with the flexibility of relay protection by adding a pyrotechnic device to the fuse operated by external protection relays.

Fuse Boxes

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rewirable fuses

MEM rewirable fuse box

MEM rewirable fuse holders (30A & 15A)

Wylex fuse box

fuse wire as sold to UK consumers

In the UK, older electrical consumer units (also called fuse boxes) are fitted either with semi-enclosed (rewirable) fuses (BS 3036) or cartridge fuses (BS 1361). (Fuse wire is commonly supplied to consumers as short lengths of 5A-, 15A- and 30A-rated wire wound on a piece of cardboard.) Modern consumer units usually contain miniature circuit breakers (MCBs) instead of fuses, though cartridge fuses are sometimes still used, as MCBs are rather prone to nuisance tripping.

Renewable fuses (rewirable or cartridge) allow user replacement, but this can be hazardous as it is easy to put a higher-rated or double fuse element (link or wire) into the holder ("overfusing"), or simply fitting it with copper wire or even a totally different type of conducting object (hairpins, paper clips, nails etc.) to the existing carrier. Such tampering will not be visible without full inspection of the fuse. Fuse wire was never used in North America for this reason, although renewable fuses continue to be made for distribution boards.

The fuse boxes pictured in this section are (right) a MEM consumer unit with four rewirable fuse holders (two 30A & two 15A) installed c.1957 (cover removed); a "Wylex standard" unit with eight rewirable fuse holders; and (below) two modern distribution boards, the first of which has MCBs installed.

The "Wylex standard" consumer unit was very popular in the United Kingdom until the wiring regulations started demanding Residual-Current Devices (RCDs) for sockets that could feasibly supply equipment outside the equipotential zone. The design does not allow for fitting of RCDs or RCBOs. Some Wylex standard models were made with an RCD instead of the main switch, but (for consumer units supplying the entire installation) this is no longer compliant with the wiring regulations as alarm systems should **not** be RCD-protected. There are two styles of fuse base that can be screwed into these units — one designed for rewirable fusewire carriers and one designed for cartridge fuse carriers. Over the years MCBs have been made for both styles of base. In both cases, higher rated carriers had wider pins, so a carrier couldn't be changed for a higher rated one without also changing the base.

In North America, fuse boxes were formerly used in buildings wired before about 1950. These used screw-in "plug" type (not to be confused with what the British call plug fuses), in screw-thread holders similar to Edison-base incandescent lamps, with ratings of 5, 10, 15, 20, 25, and 30 amperes. To prevent installation of fuses with too high a current rating for the circuit, later fuse boxes included rejection features in the fuseholder socket. Some installations have resettable miniature thermal circuit breakers which screw into the fuse socket. One form of abuse of the fuse box was to put a penny in the socket, which defeated the overcurrent protection function and resulted in a dangerous condition. Plug fuses are no longer used for branch circuit protection in new residential or industrial construction.

a modern "fuse box" - a distribution board using MCBs, next to a box with an embedded power meter

British plug fuse

The BS 1363 13 A plug has a BS 1362 cartridge fuse inside. This allows the use of 30 A/32 A (30 A was the original size; 32 A is the closest European harmonised size) socket circuits safely. In order to keep cable sizes manageable these are usually wired in ring mains. It also provides better protection for small appliances with thin flex as a variety of fuse ratings (1 A, 2 A, 3 A, 5 A, 7 A, 10 A 13 A with 3, 5 and 13 being the most common) are available and a suitable fuse should be fitted to allow the normal operating current while protecting the appliance and its cord as well as possible. With some loads it is normal to use a slightly higher rated fuse than the normal operating current. For example on 500 W halogen floodlights it is normal to use a 5 A fuse even though a 3 A would carry the normal operating current. This is because halogen lights draw a significant surge of current at switch on as their cold resistance is far lower than their resistance at operating temperature.

a distribution board being installed

In most other wiring practices the wires in a flexible cord are considered to be protected by the branch circuit overcurrent device, usually rated at around 15 amperes, so a plug-mounted fuse is not used. Small electronic apparatus often includes a fuseholder on or in the equipment, to protect internal components only.

The rating on a BS1362 fuse specifies the maximum current the fuse can pass 'indefinitely' under standard conditions. The fuse will pass higher currents than the rated value for significant periods, depending on how high the overload is. Fuse manufacturers publish tables or graphs of fuse characteristics to allow electrical system designers to specify the correct fuse for the conditions under which it will be expected to operate. One example is the table published by Cooper-Bussmann for their BS1362 fuses[6]. In this table it can be seen that the fuse is specified to be able to carry its rated current for a minimum of 1,000 hours; 1.6 times its rated current for a minimum of 30 minutes; and 1.9 times its rated current for a maximum of 30 minutes. Thus, this BS1362 13A fuse is only rated to break its circuit after carrying 24.7 Amps for 30 minutes.

Coordination of fuses in series

20 mm 200 mA glass cartridge fuse used inside equipment and 1 inch 13 A ceramic British plug fuse.

Where several fuses are connected in series at the various levels of a power distribution system, it is very desirable to clear only the fuse (or other overcurrent devices) electrically closest to the fault. This process is called "coordination" and may require the time-current characteristics of two fuses to be plotted on a common current basis. Fuses are then selected so that the minor, branch, fuse clears its circuit well before the supplying, major, fuse starts to melt. In this way only the faulty circuits are interrupted and minimal disturbance occurs to other circuits fed by the supplying fuse.

Where the fuses in a system are of similar types, simple rule-of-thumb ratios between ratings of the fuse closest to the load and the next fuse towards the source can be used.

Other fuse types

Resetable fuses

main article:Resettable fuse

So-called "self-resetting" fuses use a thermoplastic conductive element known as a Polymeric Positive Temperature Coefficient (or PPTC) thermistor that impedes the circuit during an overcurrent condition (through increasing the device resistance). The PPTC thermistor is self-resetting in that when the overcurrent condition is removed, the device will revert back to low resistance, allowing the circuit to operate normally again. These devices are often used in aerospace/nuclear applications where replacement is difficult.

Thermal fuses

A "thermal fuse" is often found in consumer equipment such as coffee makers or hair dryers or transformers powering small consumer electronics devices. They contain a fusible, temperature-sensitive alloy which holds a spring contact mechanism normally closed. When the surrounding temperature gets too high, the alloy melts and allows the spring contact mechanism to break the circuit. The device can be used to prevent a fire in a hair dryer for example, by cutting off the power supply to the heater elements when the air flow is interrupted (e.g. the blower motor stops or the air intake becomes accidentally blocked). Thermal fuses are a 'one shot', non-resettable device which must be replaced once they have been activated.

See also

- Antifuse
- Autorecloser
- Electronic Components
- Semiconductor fuse
- Protective Device Coordination

Notes

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1. ^ http://www.thefusewarehouse.com/pages/product_markings.htm
2. ^ https://www1.elfa.se/data1/wwwroot/webroot/Z_DATA/623e2b00-75a4-11dc-b309-005056c00008.pdf Elfa.se: datasheet of mini type fuse
3. ^ https://www1.elfa.se/data1/wwwroot/webroot/Z_DATA/7fac31f0-75a4-11dc-b309-005056c00008.pdf Elfa.se: datasheet of maxi type fuse>
4. ^ ELFA - Electronics supplier of Northern Europe (http://www.elfa.se/en/)
5. ^ Electrical System: Fuses & Circuit Breakers (http://www.carcare.org/Electrical/fuses_breakers.shtml)
6. ^ "British Plug Top Fuse TDC180 (http://www.bussmann.com/library/bifs/2042.PDF) ". Retrieved on 2007-11-28.

References

- IEC 60269-1 - Low-voltage fuses - Part 1: General requirements
- IEC 60269-2 - Low-voltage fuses - Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) - Examples of standardized systems of fuses A to I
- IEC 60269-3 - Low-voltage fuses - Part 3: Supplementary requirements for fuses for use by unskilled persons (fuses mainly for household and similar applications) - Examples of standardized systems of fuses A to F
- IEC 60269-4 - Low-voltage fuses - Part 4: Supplementary requirements for fuse-links for the protection of semiconductor devices

External links

- [1] (http://www.littelfuse.com/data/en/Product_Catalogs/EC101-J_V052505.pdf) Information on circuit protection, surface mount fuses, axial lead & cartridge fuses, blade terminal & special mount fuses, fuseholders, fuse blocks & clips and military fuses and fuseholders
- [2] (http://www.bussmann.com/2/ApplicationTools.html) for the Bussmann manual of fuse selection
- Fuses vs MCBs (http://www.wiki.diyfaq.org.uk/index.php?title=MCB#Comparison_with_Fuses)
- [3] (http://www.swecheck.com.au/pages/product_catalog.htm) Technical information on circuit protection, fuses, fuse holders, clips, blocks & accessories

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