Circuit breaker

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An air circuit breaker for low voltage (less than 1000 volts) power distribution switchgear





A 2 pole miniature circuit breaker





Four 1 pole circuit breakers

A **circuit breaker** is an automatically operated [electrical](http://en.wikipedia.org/wiki/Electricity) [switch](http://en.wikipedia.org/wiki/Switch) designed to protect an [electrical circuit](http://en.wikipedia.org/wiki/Electrical_network) from damage caused by [overload](http://en.wikipedia.org/wiki/Overcurrent) or[short circuit](http://en.wikipedia.org/wiki/Short_circuit). Its basic function is to detect a fault condition and, by interrupting continuity, to immediately discontinue electrical flow. Unlike a[fuse](http://en.wikipedia.org/wiki/Fuse_%28electrical%29), which operates once and then has to be replaced, a circuit breaker can be reset (either manually or automatically) to resume normal operation. Circuit breakers are made in varying sizes, from small devices that protect an individual household appliance up to large [switchgear](http://en.wikipedia.org/wiki/Switchgear) designed to protect high voltage circuits feeding an entire city.

editOrigins

Inspired by the works of American scientist [Joseph Henry](http://en.wikipedia.org/wiki/Joseph_Henry) and English scientist [Michael Faraday](http://en.wikipedia.org/wiki/Michael_Faraday), the circuit breaker was invented in 1836 by an American, [Charles Grafton Page](http://en.wikipedia.org/wiki/Charles_Grafton_Page).[[1]](http://en.wikipedia.org/wiki/Circuit_breaker#cite_note-0)

An early form of circuit breaker was described by [Thomas Alva Edison](http://en.wikipedia.org/wiki/Thomas_Alva_Edison) in an 1879 patent application, although his commercial power distribution system used [fuses](http://en.wikipedia.org/wiki/Fuse_%28electrical%29).[[2]](http://en.wikipedia.org/wiki/Circuit_breaker#cite_note-1) Its purpose was to protect lighting circuit wiring from accidental short-circuits and overloads. A modern miniature circuit breaker similar to the ones now in use was patented by [Brown, Boveri & Cie](http://en.wikipedia.org/wiki/Brown%2C_Boveri_%26_Cie) in 1924. Hugo Stotz, an engineer who had sold his company, [Stotz-Kontakt](http://de.wikipedia.org/wiki/ABB_Stotz-Kontakt%22%20%5Co%20%22de%3AABB%20Stotz-Kontakt), to BBC, was credited as the inventor on DRP (*Deutsches Reichspatent*) 458329.[[3]](http://en.wikipedia.org/wiki/Circuit_breaker#cite_note-2) Stotz's invention was the forerunner of the modern thermal-magnetic breaker commonly used in household load centers to this day.

editOperation

All circuit breakers have common features in their operation, although details vary substantially depending on the voltage class, current rating and type of the circuit breaker.

The circuit breaker must detect a fault condition; in low-voltage circuit breakers this is usually done within the breaker enclosure. Circuit breakers for large currents or high voltages are usually arranged with [pilot devices](http://en.wikipedia.org/wiki/Relay) to sense a fault current and to operate the trip opening mechanism. The trip [solenoid](http://en.wikipedia.org/wiki/Solenoid) that releases the latch is usually energized by a separate battery, although some high-voltage circuit breakers are self-contained with current transformers, protection relays, and an internal control power source.

Once a fault is detected, contacts within the circuit breaker must open to interrupt the circuit; some mechanically-stored energy (using something such as springs or compressed air) contained within the breaker is used to separate the contacts, although some of the energy required may be obtained from the fault current itself. Small circuit breakers may be manually operated; larger units have [solenoids](http://en.wikipedia.org/wiki/Solenoid) to trip the mechanism, and electric motors to restore energy to the springs.

The circuit breaker contacts must carry the load current without excessive heating, and must also withstand the heat of the arc produced when interrupting (opening) the circuit. Contacts are made of copper or copper alloys, silver alloys, and other highly conductive materials. Service life of the contacts is limited by the erosion of contact material due to arcing while interrupting the current. Miniature and molded case circuit breakers are usually discarded when the contacts have worn, but power circuit breakers and high-voltage circuit breakers have replaceable contacts.

When a current is interrupted, an [arc](http://en.wikipedia.org/wiki/Electric_arc) is generated. This arc must be contained, cooled, and extinguished in a controlled way, so that the gap between the contacts can again withstand the voltage in the circuit. Different circuit breakers use [vacuum](http://en.wikipedia.org/wiki/Vacuum), air, [insulating gas](http://en.wikipedia.org/wiki/Insulating_gas), or [oil](http://en.wikipedia.org/wiki/Transformer_oil) as the medium in which the arc forms. Different techniques are used to extinguish the arc including:

* Lengthening / deflection of the arc
* Intensive cooling (in jet chambers)
* Division into partial arcs
* Zero point quenching (Contacts open at the zero current time crossing of the AC waveform, effectively breaking no load current at the time of opening. The zero crossing occurs at twice the line frequency i.e. 100 times per second for 50 Hz and 120 times per second for 60 Hz AC)
* Connecting [capacitors](http://en.wikipedia.org/wiki/Capacitor) in parallel with contacts in DC circuits

Finally, once the fault condition has been cleared, the contacts must again be closed to restore power to the interrupted circuit.

editArc interruption

Miniature low-voltage circuit breakers use air alone to extinguish the arc. Larger ratings will have metal plates or non-metallic arc chutes to divide and cool the arc. [Magnetic blowout](http://en.wikipedia.org/wiki/Magnetic_blowout) coils or [permanent magnets](http://en.wikipedia.org/wiki/Permanent_magnets) deflect the arc into the arc chute.

In larger ratings, oil circuit breakers rely upon vaporization of some of the oil to blast a jet of oil through the arc.[[4]](http://en.wikipedia.org/wiki/Circuit_breaker#cite_note-3)

Gas (usually [sulfur hexafluoride](http://en.wikipedia.org/wiki/Sulfur_hexafluoride)) circuit breakers sometimes stretch the arc using a magnetic field, and then rely upon the [dielectric strength](http://en.wikipedia.org/wiki/Dielectric_strength) of the sulfur hexafluoride (SF6) to quench the stretched arc.

[Vacuum](http://en.wikipedia.org/wiki/Vacuum) circuit breakers have minimal arcing (as there is nothing to ionize other than the contact material), so the arc quenches when it is stretched a very small amount (<2–3 mm). Vacuum circuit breakers are frequently used in modern medium-voltage switchgear to 35,000 volts.

Air circuit breakers may use [compressed air](http://en.wikipedia.org/wiki/Compressed_air) to blow out the arc, or alternatively, the contacts are rapidly swung into a small sealed chamber, the escaping of the displaced air thus blowing out the arc.

Circuit breakers are usually able to terminate all current very quickly: typically the arc is extinguished between 30 ms and 150 ms after the mechanism has been tripped, depending upon age and construction of the device.

editShort-circuit current

Circuit breakers are rated both by the normal current that they are expected to carry, and the maximum short-circuit current that they can safely interrupt.

Under short-circuit conditions, a current many times greater than normal can exist (see [maximum prospective short circuit current](http://en.wikipedia.org/wiki/Maximum_prospective_short_circuit_current)). When electrical contacts open to interrupt a large current, there is a tendency for an [arc](http://en.wikipedia.org/wiki/Electric_arc) to form between the opened contacts, which would allow the current to continue. This condition can create conductive ionized gases and molten or vaporized metal which can cause further continuation of the arc, or creation of additional short circuits, potentially resulting in the explosion of the circuit breaker and the equipment that it is installed in. Therefore, circuit breakers must incorporate various features to divide and extinguish the arc.

In air-insulated and miniature breakers an *arc chute* structure consisting (often) of metal plates or ceramic ridges cools the arc, and [magnetic blowout](http://en.wikipedia.org/wiki/Magnetic_blowout) coils deflect the arc into the arc chute. Larger circuit breakers such as those used in electrical [power distribution](http://en.wikipedia.org/wiki/Power_distribution) may use [vacuum](http://en.wikipedia.org/wiki/Vacuum), an [inert](http://en.wikipedia.org/wiki/Inert) [gas](http://en.wikipedia.org/wiki/Gas) such as [sulphur hexafluoride](http://en.wikipedia.org/wiki/Sulphur_hexafluoride%22%20%5Co%20%22Sulphur%20hexafluoride) or have contacts immersed in [oil](http://en.wikipedia.org/wiki/Oil) to suppress the arc.

The maximum short-circuit current that a breaker can interrupt is determined by testing. Application of a breaker in a circuit with a prospective short-circuit current higher than the breaker's interrupting capacity rating may result in failure of the breaker to safely interrupt a fault. In a worst-case scenario the breaker may successfully interrupt the fault, only to explode when reset.

Miniature circuit breakers used to protect control circuits or small appliances may not have sufficient interrupting capacity to use at a panelboard; these circuit breakers are called "supplemental circuit protectors" to distinguish them from distribution-type circuit breakers.

editStandard current ratings

[International Standard](http://en.wikipedia.org/wiki/International_Standard) IEC 60898-1 and [European Standard](http://en.wikipedia.org/wiki/European_Standard) EN 60898-1 define the *rated current* *I*n of a circuit breaker for low voltage distribution applications as the maximum current that the breaker is designed to carry continuously (at an ambient air temperature of 30 °C). The commonly-available preferred values for the rated current are 6 A, 10 A, 13 A, 16 A, 20 A, 25 A, 32 A, 40 A, 50 A, 63 A, 80 A, 100 A[[5]](http://en.wikipedia.org/wiki/Circuit_breaker#cite_note-4), and 125A ([Renard series](http://en.wikipedia.org/wiki/Renard_series%22%20%5Co%20%22Renard%20series), slightly modified to include current limit of British [BS 1363](http://en.wikipedia.org/wiki/BS_1363) sockets). The circuit breaker is labeled with the rated current in [amperes](http://en.wikipedia.org/wiki/Ampere), but without the unit symbol "A". Instead, the ampere figure is preceded by a letter "B", "C" or "D" that indicates the *instantaneous tripping current*, that is the minimum value of current that causes the circuit-breaker to trip without intentional time delay (i.e., in less than 100 ms), expressed in terms of *I*n:

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| **Type** | **Instantaneous tripping current** |
| B | above 3 *I*n up to and including 5 *I*n |
| C | above 5 *I*n up to and including 10 *I*n |
| D | above 10 *I*n up to and including 20 *I*n |
| K | above 8 *I*n up to and including 12 *I*nFor the protection of loads that cause frequent short duration (approximately 400 ms to 2 s) current peaks in normal operation. |
| Z | above 2 *I*n up to and including 3 *I*n for periods in the order of tens of seconds.For the protection of loads such as semiconductor devices or measuring circuits using current transformers. |

In the United States, [Underwriters Laboratories](http://en.wikipedia.org/wiki/Underwriters_Laboratories) (UL) certifies equipment ratings, called Series Ratings (or “integrated equipment ratings”), using a two-tier rating. For example, a 22/10 rating. This rating means that the meter pack has a 22 kAIC tenant breaker, feeding a 10 kAIC loadcenter with 10 kAIC branches, where kAIC stands for “Thousand Ampere Interrupting Capacity.” Common meter pack ratings are 22/10, 42/10 and 100/10.[[6]](http://en.wikipedia.org/wiki/Circuit_breaker#cite_note-5)

editTypes of circuit breakers





Front panel of a 1250 A air circuit breaker manufactured by ABB. This low voltage power circuit breaker can be withdrawn from its housing for servicing. Trip characteristics are configurable via [DIP switches](http://en.wikipedia.org/wiki/DIP_switch) on the front panel.

Many different classifications of circuit breakers can be made, based on their features such as voltage class, construction type, interrupting type, and structural features.

edit**Low voltage circuit breakers**

Low voltage (less than 1000 VAC) types are common in domestic, commercial and industrial application, and include:

* MCB (Miniature Circuit Breaker)—rated current not more than 100 A. Trip characteristics normally not adjustable. Thermal or thermal-magnetic operation. Breakers illustrated above are in this category.
* MCCB (Molded Case Circuit Breaker)—rated current up to 2500 A. Thermal or thermal-magnetic operation. Trip current may be adjustable in larger ratings.
* Low voltage power circuit breakers can be mounted in multi-tiers in low-voltage switchboards or [switchgear](http://en.wikipedia.org/wiki/Switchgear) cabinets.

The characteristics of Low Voltage circuit breakers are given by international standards such as IEC 947. These circuit breakers are often installed in draw-out enclosures that allow removal and interchange without dismantling the switchgear.

Large low-voltage molded case and power circuit breakers may have electrical motor operators, allowing them to be tripped (opened) and closed under remote control. These may form part of an [automatic transfer switch](http://en.wikipedia.org/wiki/Automatic_transfer_switch) system for standby power.

Low-voltage circuit breakers are also made for direct-current (DC) applications, for example DC supplied for subway lines. Special breakers are required for direct current because the arc does not have a natural tendency to go out on each half cycle as for alternating current. A direct current circuit breaker will have blow-out coils which generate a magnetic field that rapidly stretches the arc when interrupting direct current.

Small circuit breakers are either installed directly in equipment, or are arranged in a [breaker panel](http://en.wikipedia.org/wiki/Circuit_breaker_panel).





Photo of inside of a circuit breaker

The 10 ampere [DIN rail](http://en.wikipedia.org/wiki/DIN_rail)-mounted thermal-magnetic miniature circuit breaker is the most common style in modern domestic [consumer units](http://en.wikipedia.org/wiki/Consumer_unit) and commercial electrical [distribution boards](http://en.wikipedia.org/wiki/Distribution_board) throughout [Europe](http://en.wikipedia.org/wiki/Europe). The design includes the following components:

1. Actuator [lever](http://en.wikipedia.org/wiki/Lever) - used to manually trip and reset the circuit breaker. Also indicates the status of the circuit breaker (On or Off/tripped). Most breakers are designed so they can still trip even if the lever is held or locked in the "on" position. This is sometimes referred to as "free trip" or "positive trip" operation.
2. Actuator mechanism - forces the contacts together or apart.
3. Contacts - Allow current when touching and break the current when moved apart.
4. Terminals
5. Bimetallic strip.
6. Calibration [screw](http://en.wikipedia.org/wiki/Screw) - allows the [manufacturer](http://en.wikipedia.org/wiki/Manufacturer) to precisely adjust the trip current of the device after assembly.
7. Solenoid
8. Arc divider/extinguisher

edit**Magnetic circuit breakers**

*Magnetic circuit breakers* use a [solenoid](http://en.wikipedia.org/wiki/Solenoid) ([electromagnet](http://en.wikipedia.org/wiki/Electromagnet)) whose pulling force increases with the [current](http://en.wikipedia.org/wiki/Current_%28electricity%29). Certain designs utilize electromagnetic forces in addition to those of the solenoid. The circuit breaker contacts are held closed by a latch. As the current in the solenoid increases beyond the rating of the circuit breaker, the solenoid's pull releases the latch which then allows the contacts to open by spring action. Some types of magnetic breakers incorporate a hydraulic time delay feature using a viscous fluid. The core is restrained by a spring until the current exceeds the breaker rating. During an overload, the speed of the solenoid motion is restricted by the fluid. The delay permits brief current surges beyond normal running current for motor starting, energizing equipment, etc. Short circuit currents provide sufficient solenoid force to release the latch regardless of core position thus bypassing the delay feature. Ambient temperature affects the time delay but does not affect the current rating of a magnetic breaker

edit**Thermal magnetic circuit breakers**

*Thermal magnetic circuit breakers*, which are the type found in most [distribution boards](http://en.wikipedia.org/wiki/Distribution_board), incorporate both techniques with the electromagnet responding instantaneously to large surges in current (short circuits) and the bimetallic strip responding to less extreme but longer-term over-current conditions. The thermal portion of the circuit breaker provides an "inverse time" response feature which provides faster or slower response for larger or smaller over currents respectively.

edit**Common trip breakers**





Three pole common trip breaker for supplying a three-phase device. This breaker has a 2 A rating

When supplying a branch circuit with more than one live conductor, each live conductor must be protected by a breaker pole. To ensure that all live conductors are interrupted when any pole trips, a "common trip" breaker must be used. These may either contain two or three tripping mechanisms within one case, or for small breakers, may externally tie the poles together via their operating handles. Two pole common trip breakers are common on 120/240 volt systems where 240 volt loads (including [major appliances](http://en.wikipedia.org/wiki/Major_appliance) or further distribution boards) span the two live wires. Three-pole common trip breakers are typically used to supply [three-phase electric power](http://en.wikipedia.org/wiki/Three-phase_electric_power) to large motors or further distribution boards.

Two and four pole breakers are used when there is a need to disconnect the neutral wire, to be sure that no current can flow back through the neutral wire from other loads connected to the same network when people need to touch the wires for maintenance. Separate circuit breakers must never be used for disconnecting live and neutral, because if the neutral gets disconnected while the live conductor stays connected, a dangerous condition arises: the circuit will appear de-energized (appliances will not work), but wires will stay live and [RCDs](http://en.wikipedia.org/wiki/Residual-current_device) will not trip if someone touches the live wire (because RCDs need power to trip). This is why only common trip breakers must be used when switching of the neutral wire is needed

edit**Medium-voltage circuit breakers**

Medium-voltage circuit breakers rated between 1 and 72 kV may be assembled into metal-enclosed switchgear line ups for indoor use, or may be individual components installed outdoors in a [substation](http://en.wikipedia.org/wiki/Electrical_substation). Air-break circuit breakers replaced oil-filled units for indoor applications, but are now themselves being replaced by vacuum circuit breakers (up to about 35 kV). Like the high voltage circuit breakers described below, these are also operated by current sensing protective [relays](http://en.wikipedia.org/wiki/Relay) operated through [current transformers](http://en.wikipedia.org/wiki/Current_transformer). The characteristics of MV breakers are given by international standards such as IEC 62271. Medium-voltage circuit breakers nearly always use separate current sensors and [protective relays](http://en.wikipedia.org/wiki/Protective_relay), instead of relying on built-in thermal or magnetic overcurrent sensors.

Medium-voltage circuit breakers can be classified by the medium used to extinguish the arc:

* Vacuum circuit breakers—With rated current up to 3000 A, these breakers interrupt the current by creating and extinguishing the arc in a vacuum container. These are generally applied for voltages up to about 35,000 V,[[7]](http://en.wikipedia.org/wiki/Circuit_breaker%22%20%5Cl%20%22cite_note-6) which corresponds roughly to the medium-voltage range of power systems. Vacuum circuit breakers tend to have longer life expectancies between overhaul than do air circuit breakers.
* Air circuit breakers—Rated current up to 10,000 A. Trip characteristics are often fully adjustable including configurable trip thresholds and delays. Usually electronically controlled, though some models are [microprocessor](http://en.wikipedia.org/wiki/Microprocessor) controlled via an integral electronic trip unit. Often used for main power distribution in large industrial plant, where the breakers are arranged in draw-out enclosures for ease of maintenance.
* SF6 circuit breakers extinguish the arc in a chamber filled with sulfur hexafluoride gas.

Medium-voltage circuit breakers may be connected into the circuit by bolted connections to bus bars or wires, especially in outdoor switchyards. Medium-voltage circuit breakers in switchgear line-ups are often built with draw-out construction, allowing the breaker to be removed without disturbing the power circuit connections, using a motor-operated or hand-cranked mechanism to separate the breaker from its enclosure.

edit**High-voltage circuit breakers**

*Main article:*[*High-voltage switchgear*](http://en.wikipedia.org/wiki/High-voltage_switchgear)





Russian 110 kV oil circuit breaker





115 kV bulk oil circuit breaker





400 kV SF6 live tank circuit breakers

Electrical [power transmission](http://en.wikipedia.org/wiki/Power_transmission) networks are protected and controlled by high-voltage breakers. The definition of *high voltage* varies but in power transmission work is usually thought to be 72.5 kV or higher, according to a recent definition by the [International Electrotechnical Commission](http://en.wikipedia.org/wiki/International_Electrotechnical_Commission) (IEC). High-voltage breakers are nearly always [solenoid](http://en.wikipedia.org/wiki/Solenoid)-operated, with current sensing [protective relays](http://en.wikipedia.org/wiki/Protective_relay)operated through [current transformers](http://en.wikipedia.org/wiki/Current_transformer). In [substations](http://en.wikipedia.org/wiki/Electrical_substation) the protective relay scheme can be complex, protecting equipment and buses from various types of overload or ground/earth fault.

High-voltage breakers are broadly classified by the medium used to extinguish the arc.

* Bulk oil
* Minimum oil
* Air blast
* Vacuum
* [SF6](http://en.wikipedia.org/wiki/Sulfur_hexafluoride)

Some of the manufacturers are [ABB](http://en.wikipedia.org/wiki/ABB_Group), [GE (General Electric)](http://en.wikipedia.org/wiki/General_electric) , [Tavrida Electric](http://en.wikipedia.org/w/index.php?title=Tavrida_Electric&action=edit&redlink=1" \o "Tavrida Electric (page does not exist)), [Alstom](http://en.wikipedia.org/wiki/Alstom), Mitsubishi Electric, Pennsylvania Breaker, [Siemens](http://en.wikipedia.org/wiki/Siemens), [Toshiba](http://en.wikipedia.org/wiki/Toshiba), Končar HVS, BHEL, CGL, Square D (Schneider Electric).

Due to environmental and cost concerns over insulating oil spills, most new breakers use SF6 gas to quench the arc.

Circuit breakers can be classified as *live tank*, where the enclosure that contains the breaking mechanism is at line potential, or *dead tank* with the enclosure at earth potential. High-voltage AC circuit breakers are routinely available with ratings up to 765 kV. 1200kV breakers were launched by Siemens in November 2011.[[8]](http://en.wikipedia.org/wiki/Circuit_breaker#cite_note-7)

High-voltage circuit breakers used on transmission systems may be arranged to allow a single pole of a three-phase line to trip, instead of tripping all three poles; for some classes of faults this improves the system stability and availability.

edit**Sulfur hexafluoride (SF6) high-voltage circuit-breakers**

*Main article:*[*Sulfur hexafluoride circuit breaker*](http://en.wikipedia.org/wiki/Sulfur_hexafluoride_circuit_breaker)

A sulfur hexafluoride circuit breaker uses contacts surrounded by sulfur hexafluoride gas to quench the arc. They are most often used for transmission-level voltages and may be incorporated into compact gas-insulated switchgear. In cold climates, supplemental heating or de-rating of the circuit breakers may be required due to liquefaction of the SF6 gas.

Other breakers

The following types are described in separate articles.

* Breakers for protections against earth faults too small to trip an over-current device:
	+ [Residual-current device](http://en.wikipedia.org/wiki/Residual-current_device) (RCD, formerly known as a *residual current circuit breaker*) — detects current imbalance, but does not provide over-current protection.
	+ [Residual current breaker with over-current protection](http://en.wikipedia.org/wiki/Residual-current_device) (RCBO) — combines the functions of an RCD and an MCB in one package. In the [United States](http://en.wikipedia.org/wiki/United_States) and Canada, panel-mounted devices that combine ground (earth) fault detection and over-current protection are called Ground Fault Interrupter (GFI) breakers; a wall mounted outlet device or separately enclosed plug-in device providing ground fault detection and interruption only (no overload protection) is called a Ground Fault Circuit Interrupter (GFCI).
	+ [Earth leakage circuit breaker](http://en.wikipedia.org/wiki/ELCB) (ELCB) — This detects earth current directly rather than detecting imbalance. They are no longer seen in new installations for various reasons.
* [Autorecloser](http://en.wikipedia.org/wiki/Autorecloser) — A type of circuit breaker which closes again after a delay. These are used on overhead [power distribution](http://en.wikipedia.org/wiki/Power_distribution) systems, to prevent short duration faults from causing sustained outages.
* [Polyswitch](http://en.wikipedia.org/wiki/Polyswitch) (polyfuse) — A small device commonly described as an automatically resetting fuse rather than a circuit breaker.