# CB – FAQ

## Answers to frequently asked questions about circuit breakers (CB)

Version 1

# Contents

## Definitions and Terms



## Circuit Breaker for Equipment

## Applications, Notes



## Cables and Conductors

# Definitions and Terms

**What do the abbreviations TCP, TMC(P), and EC(P) stand for with respect to circuit breakers?**

TCP Thermal Circuit breaker Pluggable
TMC(P) Thermal Magnetic Circuit breaker (Pluggable)
EC(P) Electronic Circuit breaker (Pluggable)

**What does ‘temperature behavior’ mean?**

Temperature behavior refers to how the ambient temperature affects the load capacity and trip curve of a circuit breaker. The time/current curve is normally based on an ambient temperature of 23 °C. Most thermal and thermal-magnetic circuit breakers are not temperature compensated, which means the trip times for a thermal release are shorter at higher ambient temperatures and longer at lower ambient temperatures. The time/current curve will therefore automatically adjust itself to the thermal load capacity of numerous power consumers.

**What is a short circuit current?**

A short circuit current is an overcurrent that occurs due to an error with low impedance between two points that have different potentials during normal operation. A short circuit can be caused by an error or a faulty connection.

**What does the ‘operation’ of a circuit breaker refer to?**

‘Operation’ in this sense is when the moving contact switches from the open position to the closed position or vice versa. Note that a distinction is made between a switch operation (in terms of switching the power on or off) and a mechanical operation (closing and opening).

**What does ‘trip time’ refer to?**

Trip time refers to the time measured from the moment the trip current in the main circuit begins to flow to the moment that current is interrupted in each pole (i.e., reaches zero).

**What does a ‘release’ mean?**
A release is a component that serves as a mechanical switching mechanism. It disengages the locking mechanism and allows the contacts to open automatically. An overcurrent release (e.g., bimetallic strip or magnetic coil) is activated when the current exceeds a predefined threshold.

**What is an intrinsically safe circuit?**
If there is no risk of explosion in an electrical device, even when electrical sparks occur, then the device is considered ‘intrinsically safe.’ Intrinsic safety in this regard means that the maximum potential energy in a circuit is limited to such a degree that any resulting electrical sparks or arcs do not give off enough energy to ignite the explosive fuel–air mixtures that may occur in the chemical or mining industry.

**What is a circuit breaker with a cycling trip-free release?**
In this type of circuit breaker, the contacts move to the open position when the overcurrent release activates. When the device cools down, the contacts will close again automatically, even if manual operation is blocked. This process is repeated (i.e., the contacts alternate between opened and closed) until the overcurrent is cleared.

**What is an auxiliary contact?**
An auxiliary contact is a contact that is electrically isolated from the main contact (even though its position is determined by the position of the main contact) and is used to connect alarm and sequential circuits. Auxiliary contacts can be used to control a central monitoring device, trigger a local alarm, or send a signal to a computer-controlled system.

**What is a homogeneous electric field?**
An electric field is called homogeneous when the potential gradients between the electrodes are constant (i.e., the distance between the field lines that are formed remains constant). This type of field arises between two spherical electrodes whose radius is greater than their distance to each other. An exact homogeneous field is achieved using a special border shape in circular plate electrodes. These electrodes are also referred to as Rogowski electrodes.

**What is applied voltage?**
Applied voltage is the voltage that is applied to the terminals of a circuit breaker pole immediately before the power is switched on and immediately after the power is switched off.

**What is galvanic isolation?**
Galvanic isolation refers to the principle of isolating electrically charged parts with different potentials using insulating material or air paths. More specifically, it means preventing the flow of electrically charged particles between two electrodes.

**What is a tease-free (positively) trip-free mechanism?**
To achieve a stable switching behavior, many circuit breakers feature a trip-free mechanism that cannot be influenced by external conditions. This type of trip-free mechanism is used to safely switch off the power consumer as soon as an overcurrent is detected, even if the actuator (tilt lever, rocker, push button, etc.) itself is blocked.

**What does ‘selectivity’ mean?**
Selectivity means that, when a short circuit occurs, only the protection device located directly upstream from the defective area will interrupt the current, while the other parts of the system continue to operate unhindered. Selectivity minimizes the impact of a fault and helps avoid machine downtime costs.

**How are the terms rated current and overcurrent defined?**
The rated current refers to the circuit breaker current that is specified for a specific operating condition by the manufacturer of an electrical device. Any current that exceeds the rated current is called an overcurrent.

# Circuit Breaker for Equipment

**What is a circuit breaker for equipment (CBE)?**
A circuit breaker for equipment is a circuit breaker that is specifically designed to protect equipment such as motors, transformers, etc.

**What are the different types of CBEs and what are their abbreviations?**
There are basically three different types of circuit breakers for equipment:
- A thermal circuit breaker (TCP), which is specifically used to protect an electrical consumer from overloads.
- A thermal-magnetic circuit breaker (TMC), which features standard trip curves with short circuit and overload protection.
- An electronic circuit breaker, which detects, analyzes, and limits the current via electronics. The circuit is isolated either by a power semiconductor or through galvanic isolation via a mechanical contact plus drive. Long wires with high damping and input capacities of up to 20,000 µF can also be used safely.

**When should a thermal-magnetic circuit breaker (TMC) be used?**
In thermal-magnetic circuit breakers, the protective function is triggered by a combination of current heat and magnetic force. The thermal part uses a time delay to protect the consumer from overloads, while the magnetic part responds to high overload currents and short-circuit currents without a time delay.
The defective circuit is then switched off within milliseconds. TMCs are ideally suited for information and communication devices and for applications that require the utmost precision given the risk of overloads.

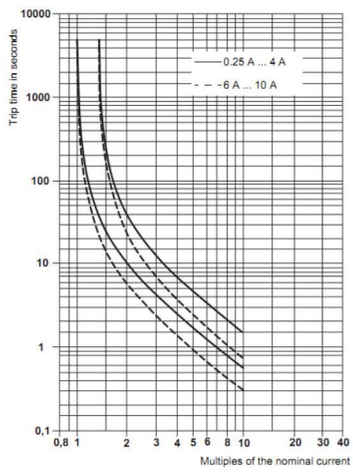
**Which characteristic curves are applicable and what are the differences between them?**

Thermal curves

| TCP… | TCP…/DC32V |
|---|---|

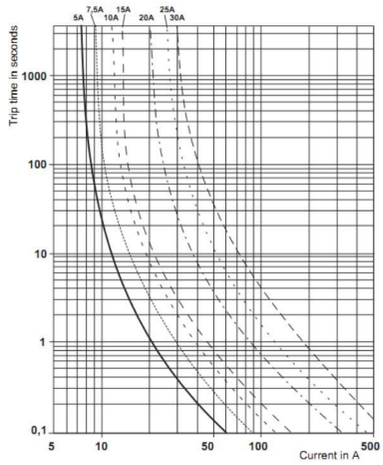
**Time/Current Characteristic Curve**

Total interruption period for nominal current, ambient temperature 23°C

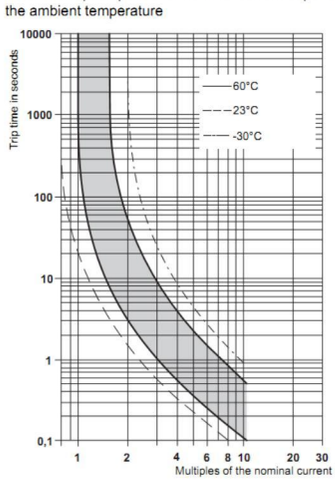



**Time/Current Characteristic Curve**

Total interruption period for nominal current



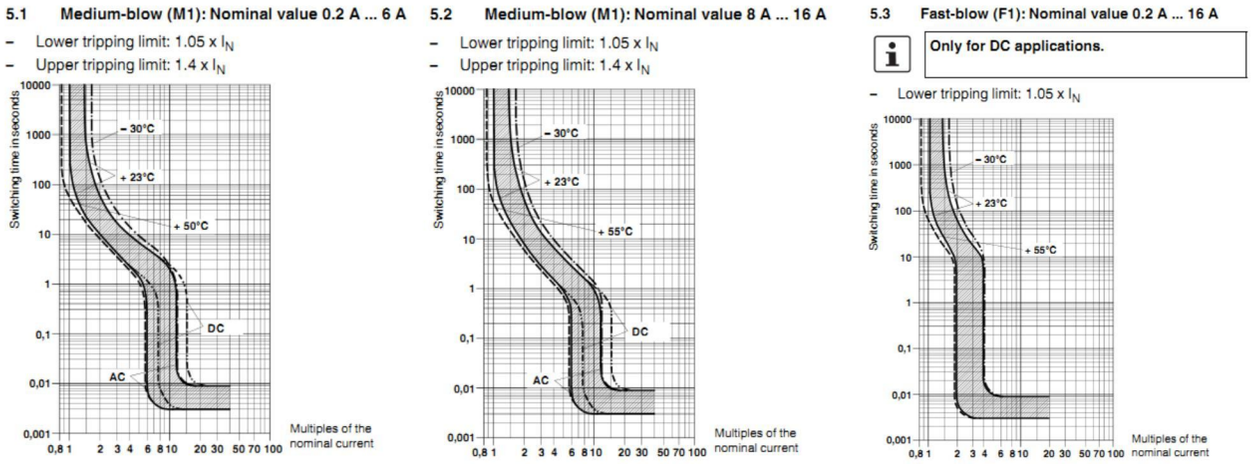

Total interruption period for nominal current dependent on the ambient temperature




Due to the thermal inertia of the bimetallic strips, the characteristic curve slopes downward slowly. As a result, thermal circuit breakers are suitable only for overload currents and not suitable for short-circuit currents.

Thermal-magnetic curve

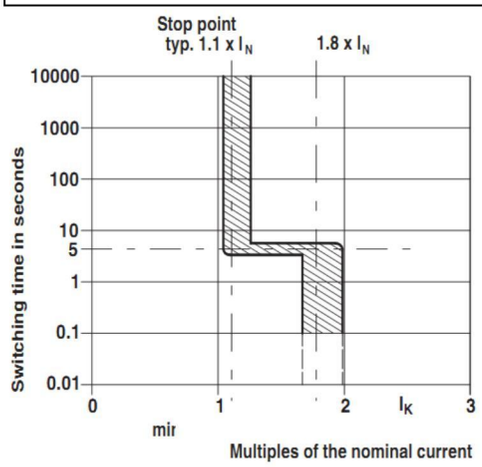
TMC (P)…




Whereas the slight decline at the top of the curve is due to the slow thermal heating of the bimetallic strips, the steep decline in the curve is caused by the magnetic short-circuit release.

Electronic curve

EC(P)…




The electronically defined trigger thresholds result in a curve with very steep sides. The switch-off point begins at 1.1 x IN. If this is exceeded for more than 3–5 seconds, the device will be switched off. The current is actively limited at max. 1.8 x IN.

**What is the difference between a circuit breaker and an overcurrent release?**
The overcurrent release is a component of a circuit breaker that is used to disengage the switching mechanism so that the contacts can open.
According to EN 60934, a fuse is a device that opens a connected circuit when one or more of its elements melts. A current that exceeds a specific threshold for a sufficient period of time will be switched off by this device. Once a fuse is triggered and melts, it cannot be reused.
In summary: A melted fuse cannot be reset. Note, however, that a “resettable” fuse in this case refers to a circuit breaker and not the fuse described above!
Based on the international IEC standard and European standard EN 60934: A circuit breaker is a mechanical switching device capable of making, carrying, and breaking currents under normal circuit conditions and also for making, carrying for a specified time, and breaking currents under specified abnormal conditions such as a short circuit.

**What is to be observed when serially mounting circuit breakers?**
When circuit breakers are serially mounted and multiple adjacently mounted devices are under simultaneous load, a reciprocal thermal influence arises. This effect, which leads to an increase in the ambient temperature, depends on the rated current, the number of devices, the distance between the devices, the coincidence factor when devices are under load, and the level of ventilation. Given serial mounting and a coincidence factor of 1, only 80% of the rated current can be applied to the devices. The reason for this lies in the higher ambient temperature for each device mounted in this manner. If a 10 A automatic fuse is used, for example, then the trigger threshold would already be reached at 8 A.

**What is a circuit breaker pole?**
A pole is a part of the circuit breaker that is assigned exclusively to an electrically isolated current path in the main circuit and is equipped with contacts to connect and disconnect the main circuit (without the parts used to attach and activate the pole).

**How does a thermal-magnetic circuit breaker (TMC) work?**
The protective function offered by thermal-magnetic circuit breakers is triggered by the temperature and magnetic force. The thermal part (e.g., bimetallic strips) of the circuit breaker protects against overloads using a time-delayed release. The magnetic part (e.g., coil and plunger or swivel armature) responds to high overload currents and short-circuit currents without a time delay and switches off the defective circuit within milliseconds.
For this reason circuit breakers with a thermal-magnetic release are well suited for devices and systems based on information and communication technology as well as for process control and other applications that required a high degree of safety given the risk of overloads and short circuits. Compared to thermal circuit breakers, however, they are more sensitive to input surge currents.

**How does a thermal circuit breaker (TCP) work?**
Thermal circuit breakers are triggered by a heating element that current flows through (e.g., thermal bimetallic strips). They are and remain one of the simplest, most reliable, and cost-effective protection devices available. Thermal bimetallic strips can either be bimetallic strips with a latching device and a separate spring-loaded contact mechanism or a snap-in plate with a contact attached to it. Due to their design, circuit breakers with snap-in plates are cheaper and have somewhat better fast-acting characteristics than circuit breakers with bimetallic strips.

Another thermal principle, the expansion wire, uses the extremely high expansion coefficient of special metals to open contacts. A wire made from such material is located between two springs and heated by a current. The wire will then elongate until a predefined temperature limit is reached, whereupon the element switches from the operating position to the interrupt position. A thermal curve with very fast-acting characteristics can be achieved using this principle.

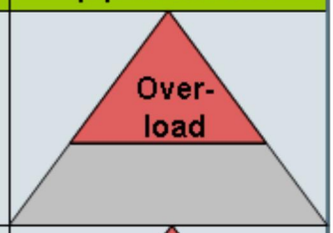
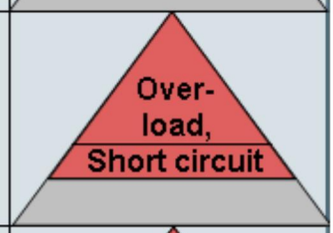
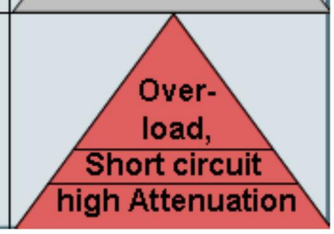
Thermal circuit breakers are ideally suited for protecting a wide array of components and systems ranging from motors and transformers to the electrical systems used in air, land, and sea vehicles.

These applications all require the ability to differentiate between short input surge currents and harmful long-term overcurrents. Thermal circuit breakers are not triggered by current peaks that occur when switching on a lamp or motor, for example. If a motor is blocked, however, these circuit breakers will interrupt the circuit to prevent any damage to the motor coil.

**What is the exact definition of a circuit breaker?**
“A circuit breaker is a mechanical switching device capable of making, carrying, and breaking currents under normal circuit conditions and also for making, carrying for a specified time, and breaking currents under specified abnormal conditions,” such as a short circuit. (As defined in EN 60934.)

**How is the trip time measured?**
The trip time is measured from the time the current in the first closing pole of the main circuit begins to flow to the time the current in the last opening pole of the main circuit reaches zero.

**Which circuit breaker is suitable for which application?**

| | Overload | Short Circuit | Application |
|---|---|---|---|
| Thermal |  |  |   |
| Thermal & magnetic |  |  |   |
| Electronic |  1.8 x $I_N$ |  1.8 x $I_N$ |   |

## Regulations and Standards

**What does UL stand for?**
Similar to the VDE in Germany, UL is the American registration office for circuit breakers and other electrical products. UL stands for Underwriters Laboratories Inc. UL testing and certification laboratories are found not only in the USA, but in many other countries as well.

**What do Icn breaking capacity as per EN 60934 and UL 1077 breaking capacity mean?**
Icn breaking capacity as per EN 60934 refers to a current that can be safely interrupted at least three times, i.e., switched off once when an error occurs and then switched on twice when the error persists. The circuit breaker is required to still have limited functionality after three interrupts.
If UL1077 breaking capacity is indicated, then the circuit breaker may stop working after the current is switched off, although it must still meet the ‘fail-safe’ requirement when combined with a backup fuse (i.e., no damage may occur to neighboring parts).
The breaking capacity is always based on the prospective short circuit current, i.e., the current that would flow in the circuit if the circuit breaker had been replaced by a conductor with negligible impedance.

**Where can I find information on the various protection classes for electrical equipment?**
In DIN EN 60 529 /VDE 0479, Section 1 (same as the German version of IEC 60 529).
The protection class is normally indicated with the letters IP and two reference numbers. The first number refers to the degree of protection against contact and foreign bodies while the second number refers to the degree of water protection.

# Insulation Coordination

**What is the difference between reinforced insulation and double insulation?**
A distinction is generally made between the following insulation systems:

- Functional insulation (VDE 0110-1:1997, Section 1.3.17.1; formerly: operational insulation): Insulation that is required for the proper operation of electrical equipment. This insulation does not insulate against electric shocks and may be applied as a layer of paint, for example.
- Base insulation (VDE 0110-1:1997, Section 1.3.17.2): Insulation of voltage-carrying parts that offers basic protection against electric shocks.
- Additional insulation (VDE 0110-1:1997, Section 1.3.17.3): Separate insulation in addition to base insulation that offers protection against electric shock in the event the base insulation fails.
- Double insulation (VDE 0110-1:1997, Section 1.3.17.4): Insulation that consists of a base insulation and an additional layer of insulation.
- Reinforced insulation (VDE 0110-1:1997, Section 1.3.17.5): A single layer of insulation for voltage-carrying parts that offers the same level of protection against electric shocks as double insulation in accordance with the relevant standard.

**What is the purpose of an air path?**
Air path L (VDE 0110-1:1997, Section 1.3.2): Shortest distance in the air between two conductive parts. It serves to protect against transient overvoltages generated from an external or internal source (overvoltage category).
Category: 3

**What is a leakage path or leakage current?**
Leakage path K (VDE 0110-1:1997, Section 1.3.3): Shortest distance between two conductive parts as measured along the surface of the insulating material (IEV 151-03-37). It helps prevent leakage paths from forming due to contamination or weak leakage currents. Leakage current refers to any current that flows between the two conductive parts as a result of conductive contaminants.

## Protection Categories

**Why are two protection classes indicated for each circuit breaker?**
Because the operation and connection areas have different requirements. Regarding the connection area, the need for a compact and easy-to-access design dictates a low protection class. Given that this area is normally only accessible during installation (with power switched off), a higher protection class is considered unnecessary.

The operation area, on the other hand, must always be accessible when the system or machine is running. To protect anyone who comes into contact with voltage-carrying parts, the automatic fuses offer protection class IP30 or higher.
What requirements are necessary to achieve the IP30 rating for the operation area?
The number ‘3’indicates protection against the penetration of foreign objects ≥ 2.5 mm. Consequently, touching the voltage-carrying parts with your hand or finger or any tool with a diameter ≥ 2.5 mm is not possible.

If functionality requires openings of < 1 mm, then the protection class goes up to IP40.
Which protection class should I choose if I need protection against splash water?
IP54 is the right choice for very moist environments. The second number ‘4’ indicates ‘splash water protection’ and the number ‘5’ indicates ‘protection against dust deposits.’

**What should I know if I intend to use my device under all weather conditions?**
For all-weather needs, the protection classes intended for the marine environments—IP65 or IP66—are the best choice. Protection against jets of water (second number ‘5’) or even strong jets of water (second number ‘6’) may be required depending on the installation site. The first number ‘6’ indicates additional protection against the ingress of dust.

**What does protection class IP67 offer?**
Protection class IP67 indicates that the device is protected from the effects of immersion in water under defined pressure and time conditions (number ‘7’). It also offers total protection against the ingress of dust and contact with electrically charged parts (number ‘6’).
What requirements does a design with IP20 fulfill?
The number ‘2’ indicates protection against medium foreign objects ≥ 12.5 mm. This means you will not be able to touch voltage-carrying parts with your hand or finger. This design does not offer any significant water protection (number ‘0’).

## Personal Protection

**What is a residual current?**
A residual current refers to a current that flows through an insulation fault between conductive parts and the ground. The electrical connection between the fault location and the ground normally has high resistance, which in turn brings the residual current into the mA range. To detect such residual currents, an FI circuit breaker (new Residual protective Current Device, RCD) is used which includes a balance transformer to measure the difference between the supply currents and the return currents. If this difference does not equal zero, then a residual current is present.

**What is an undervoltage release?**
An undervoltage release or undervoltage module causes the circuit breaker to move to the Off position if the voltage at the connections of the module falls below a predefined threshold. The undervoltage release prevents machines from automatically restarting when the voltage returns after a power interruption or failure.

**What is a short-circuit protection device (SCPD)?**
An SCPD is an overvoltage protection device that automatically interrupts the circuit or parts of the circuit to protect against short-circuit currents.
How can you protect against residual current?
With RCDs, or Residual Current protective Devices. The RCDs disconnect an electrical system from the power grid if a residual current flows through grounded and conductive parts of the system that are not part of the operating circuit, or through a human body. As a result, the difference between the supply flow and the return flow in the circuit no longer equals zero.

## Applications, Notes

**What are the rated values indicated on the circuit breaker and what do they mean?**
The electrical operating limits of a circuit breaker are determined by the characteristic current and voltage values. These are referred to as rated values and represent the maximum values that the system can achieve according to the data sheet. This means that the data sheet values also apply if devices are operated at lower rated values. The rated operating voltage (Ue) of a CB is the voltage on which the rated short circuit breaking capacity (Icn) is based. This voltage is indicated on the device for both AC and DC connections.
The rated current (In) of a CB indicates the maximum current value that the CB can carry without interruption under the environmental conditions specified in the data sheet. The main contacts, however, are not necessarily suitable for carrying very small currents in the mA range. If this applies to you, our specialists will be happy to answer any of your questions.

**Do voltage fluctuations affect the trigger capacity of the circuit breaker?**
Depending on circuit impedance as defined under Ohm's Law, any change in the voltage generates a change in the current unless the consumer is powered by a regulated power source. Increasing the current beyond the threshold values will cause the circuit breaker to trigger so as to prevent any damage to the consumer (e.g., due to overheating).
Note that this is not always caused by a high voltage. A motor that operates in a delta connection, for example, can also trigger the circuit breaker given that its startup phase draws three times as much current as a regular star connection.

**Do I need to consider the voltage rating when selecting a circuit breaker?**
Yes, the voltage should not exceed the maximum tolerance of the rated voltage for the circuit breaker type in question. Operating at lower voltages such as 12 V instead of 24 V is permitted and does not impair functionality.

**Why are different currents specified for the breaking capacity with respect to DC and AC voltages?**
The greater breaking capacity for alternating currents is due to the fact that arcs are extinguished every time the current crosses the zero point. As a result, high short circuit currents can be controlled in the same manner as for direct currents, which must be forced to cross the zero point using additional measures such as a special arcing chamber. If no additional arc extinguishing measures are provided for direct currents, then the design layout is generally the same as for alternating currents.

**I intend to use a switch-mode power supply instead of a transformer power supply because of its higher efficiency rating. Can I still implement the safety concept if I use fast-acting circuit breakers?**
Doing so may indeed prevent reverse currents flowing to the power supply and hence any other consumers connected to that power supply. The circuit breaker, however, will be unable to differentiate between a short circuit and a capacitive load and will thus immediately cause the consumer to switch off due to the relatively high surge of charging current. This can be remedied by using an electronic circuit breaker whose interrupting capacity complies with the characteristics of the switch-mode power supply.

**Is a circuit breaker better than a fuse for my intended use?**
Although fuses offer cheap circuit protection, the cost savings must be compared with the low overall costs of a circuit breaker over its entire service life. The ability to switch back on after being triggered due to an error is a significant advantage of circuit breakers. The downtime until the device can be restarted is therefore minimized. Circuit breakers also prevent the intentional or accidental use of fuses with the wrong current rating, which would otherwise jeopardize the protection of all connected consumers.

Moreover, the trigger behavior of a circuit breaker will remain stable for its entire service life. Fuses, on the other hand, will wear out over time, which may lead to changes in their characteristics that cause the fuse wire to melt after a specific period of use, even when the rated current is maintained.

Circuit breakers offer more flexibility when it comes to designing an electrical system. Auxiliary contacts can be used to indicate the operating status. Combined switch/circuit breakers lead to lower space requirements and installation time and costs. Unlike fuses, circuit breakers offer a wide range of variation depending on type and trigger characteristics. They can therefore be adapted to the consumer and the operating conditions in a much more precise manner. Another important disadvantage is that fuses cannot be tested without destroying them in the process.

**How can I avoid false trips when input current or transient operating current peaks occur?**
Many electricians regard a high current rating as a necessity. Although a high current rating prevents the circuit breaker from tripping when input current or transient operating current peaks occur, it does not offer protection in the case of persistent overloads. Motors, magnet coils, or transformers are subject to increased thermal loads that negatively impact their reliability and service life.

**Why are thermal circuit breakers the most commonly used solution?**
Thermal circuit breakers are robust and cost-effective due to their simple and proven design. Thanks to the heat capacity of the bimetallic strips, they are capable of withstanding excessive input currents while reliably protecting the power consumer from overloads and short circuits.

**Parts of my electrical system can only briefly withstand large currents without incurring damage. Nonetheless, higher input surge currents will likely occur. What solutions are available for this problem?**
Thermal-magnetic protection made of bimetallic strips and coils are typically used for this purpose. An alternative is to use an electrical circuit breaker that actively limits the input current.

# Cables and Conductors

**What does ‘AWG’ mean for conductor cross sections?**
AWG stands for American Wire Gauge, which is a system for coding wires established in 1857 by the American company Brown & Sharpe. Each number represents a specific conductor or wire cross-sectional area. The numbers may appear random at first given that they are inversely related to the size of the area. There is however a historical explanation for this in the manufacturing process – the process of wire drawing. The wires are initially “thick” and then incrementally drawn out to the desired diameter. This process changes the surface area size by approx. 26 % from one AWG number to the next. A thinner wire therefore has a larger AWG number. The range begins at AWG 40 (equals 0.005 mm2) to AWG 1 and ends at AWG 0000 (also written as AWG 4/0).
An increase of 3 AWG steps, e.g., from AWG 1 (42.4 mm2) to AWG 4 (21.2 mm2), divides the cross-sectional area in two. This in turn doubles the electrical resistance of the conductor. Conversely, a decrease of 3 AWG steps leads to a doubling of cross-sectional area and weight. An increase of 6 AWG steps (e.g., AWG 4 to AWG 10) halves the diameter. Conversely, a decrease of 6 AWG steps reduces the diameter by half. According to this system, a copper wire with a cross-section of AWG 10 has a diameter of 2.54 mm and thus a resistance of 1.0 ohms over 304.8 m of length.

**AWG in changing times: Is this unit of measurement still used today?**
Wire drawing technology has changed over the past 150 years. Thanks to advances in material science, a lower number of wire drawing procedures is now required. Moreover, the AWG system is based on inches, which means it has to be converted to the metric system in Europe or even forces the manufacturers of wires or plug connectors to produce special US versions. As long as the USA continues to use the AWG system, this unit of measurement remains current, especially considering that the US market is one of the most important markets in the world.

**Up to which diameter are AWG numbers used?**
The American National Electrical Code (NEC) specifies AWG numbers for wire cross sections up to AWG 0000 or AWG 4/0 (107.2 mm2). For larger cross sections, the surface area is indicated in circular mils (cmil) or in kilo circular mils (kcmil). Since 1 cmil only equals 1.273 x 10-6 square inches, kcmil or MCM units of measure are typically used. 1000 circular mils equals 1 kcmil or 1 MCM = 0.5067 mm2. As a result, the aforementioned limit of AWG 4/0 would equal 212 MSM. Note that, unlike the AWG number, the MCM number is positively related to the wire cross section (i.e., the larger the number the larger the cross section).