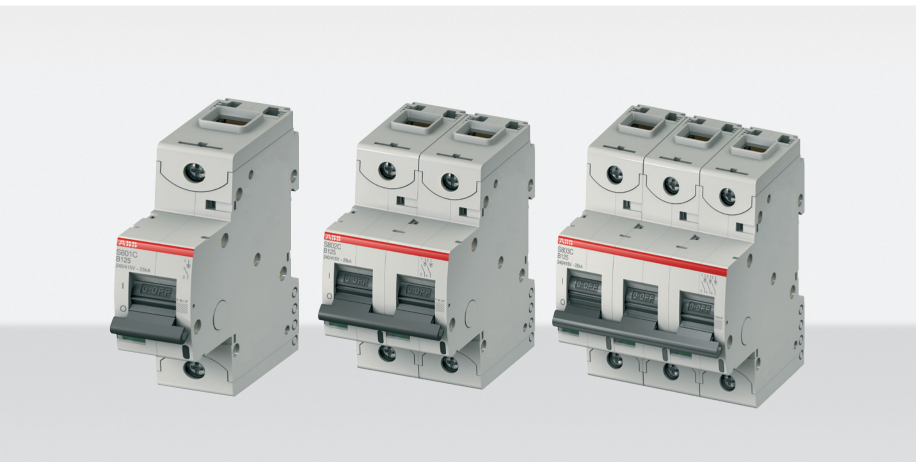
WHITE PAPER

Circuit protection characteristics of UL 489

Miniature Circuit Breakers (branch circuit protective devices)



Miniature Circuit Breakers (MCBs) are available with different tripping characteristics, or trip curves, which allow selection of the best protection of cables and different types of loads in different applications. This white paper explains the design and technology of modern, current-limiting MCBs and their trip curves.

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This paper does not cover non-current limiting MCBs ("zero-point crossing" MCBs).

Modern, current-limiting MCBs are typically used for protecting cables/conductors and loads up to 100 A using a combination of thermal and magnetic trip units. The thermal trip unit is based on a bi-metal strip while the magnetic one is based on a solenoid.

Current-limiting MCBs are similar in function to their larger siblings, molded case circuit breakers, with one significant difference: their trip units usually cannot be adjusted. Therefore, MCBs are available with different tripping characteristics, or trip curves, which allow options for the best protection of cables and different types of loads in different applications.

Trip curves are standardized according to IEC standards 60898-1 and 60947-2. Modern UL 489 MCBs usually come in three different trip curves—Z, C, and K—though some manufacturers offer B and D trip curves instead of Z and K, respectively. The UL 489 standard describes the tripping/protection requirements for a circuit breaker as follows:

- 7.1.2.3 135 percent calibration test
- 7.1.2.3.1 A circuit breaker carrying 135 percent of its rated current … shall trip within 1 hour for a device rated at 50 A or less, and within 2 hours for a device rated at more than 50 A. Unless otherwise directed, the test sample shall be at the ambient temperature indicated.
- 7.1.2.4 100 percent calibration test
- 7.1.2.4.1 A circuit breaker shall be capable of carrying 100 percent of its rated current without tripping.

The thermal trip unit of the MCB satisfies the requirements of UL 489.

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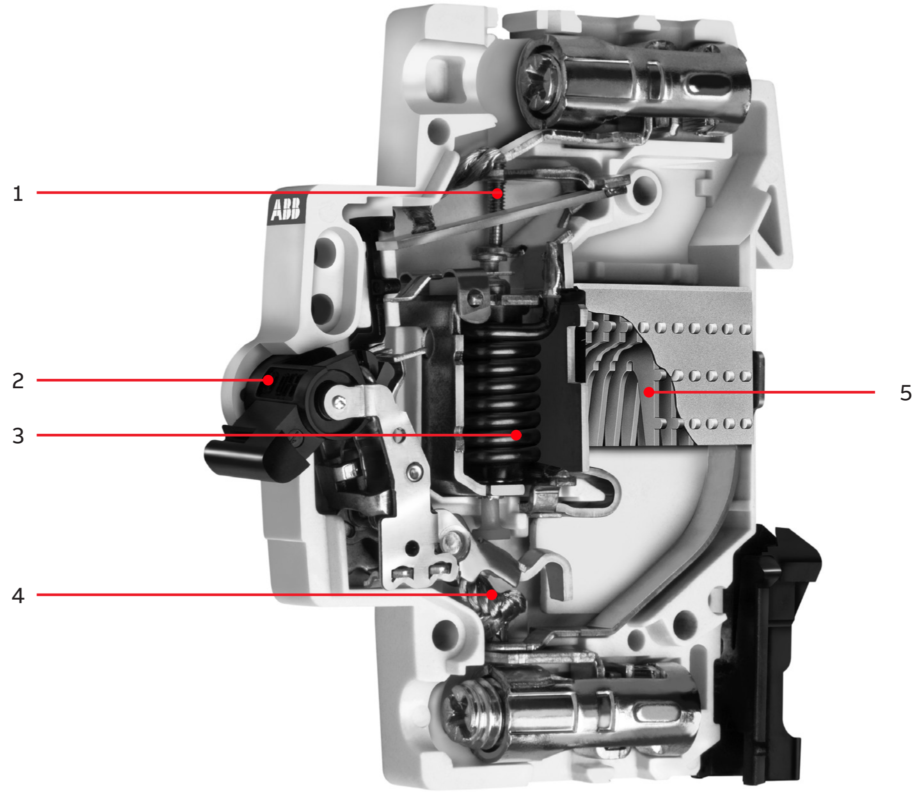
Figure 1: Typical current-limiting MCB



Design

Figure 1 shows the components of a typical current-limiting MCB. The thermal trip unit consists of a bi-metal strip, which bends under the thermal influence of overcurrent (overload) until it opens the contacts through the switching mechanism.

The electromagnetic instantaneous trip unit consists of a solenoid with a core that releases a pin (hammer trip) that opens the contacts by direct impact, bypassing the switching mechanism. By virtue of its design the electromagnetic trip unit acts much faster than the thermal trip unit, typically within milli-seconds.

1. Bi-metal (thermal) trip unit (overload)
2. Toggle
3. Electromagnetic trip unit (short circuit)
4. Switching mechanism + contacts
5. Arc extinguishing chamber

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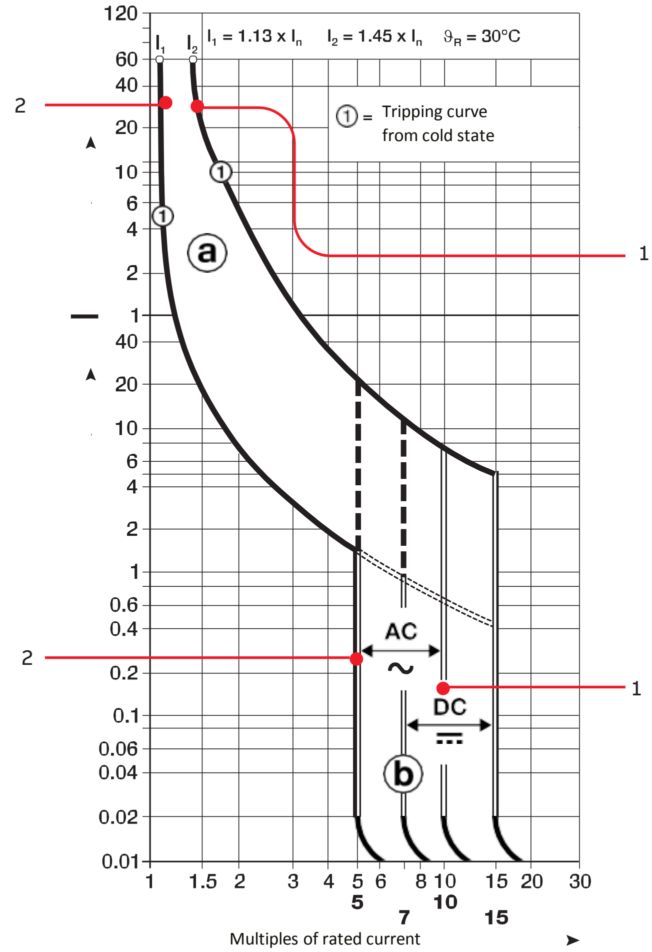
Figure 2: trip curve graph



1. **No-trip threshold**
   The breaker is not allowed to trip before this point
2. **Tripping threshold**
   The breaker must trip at this point at the latest

Tripping characteristic (trip curve)
Figure 2 shows the general graph of a trip curve, a C curve. Generally, the graph of a trip curve shows the (over)current/time range (basically, the tolerance band) within which a breaker must trip according to the standard. It has lower and upper thresholds which define the width of this range/tolerance band.

Corresponding to the thermal and the magnetic trip units of an MCB, the graph of a trip curve has two zones, the zone of thermal tripping (zone “a”, the upper/left curved part) and the zone of magnetic tripping (zone “b”, the lower/right part).

Zone of thermal tripping (overload)
The thermal tripping characteristics of a breaker must comply with the requirements of UL 489 as well as the corresponding IEC standards. UL describes the required tripping as mentioned earlier, and IEC specifies dedicated value points, depicted in the curve/graph shown above.

The thermal trip curve depends on ambient temperature. Therefore, the manufacturer needs to show the calibration temperature of the trip curve. According to UL 489, the manufacturer can choose between 25°C (68°F) and 40°C (104°F) for the trip curve calibration temperature. At higher ambient temperature, the curve moves to the left (earlier tripping), and at lower temperatures, it moves to the right (delayed tripping). The two curves shown in the graph are the limits of the range within which the MCB is required to trip.

The breaker may not trip before the (over)current reaches a value beyond the left curve (no-trip threshold). According to UL, this value is 100% of the breaker rating. The breaker also must trip before the overcurrent reaches a value beyond the right curve (tripping threshold). Manufacturers can calibrate the thermal tripping unit at any point between these two thresholds.

— Figure 3: IEC trip curves

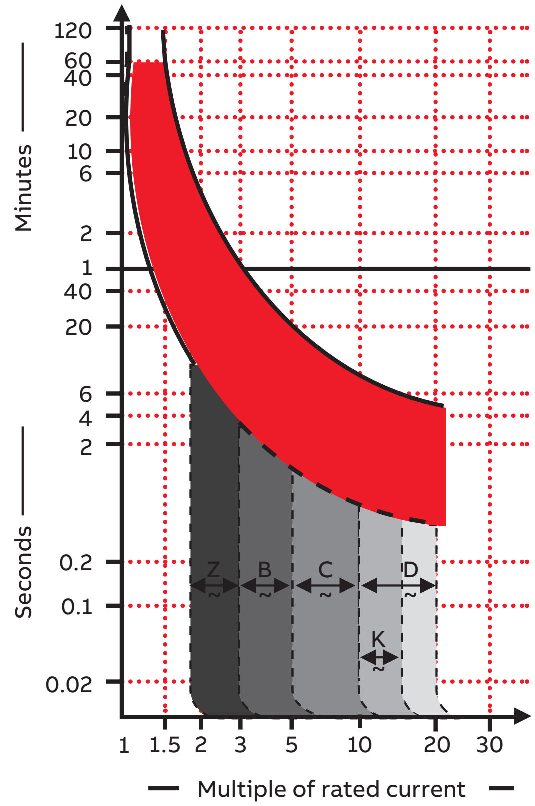
Zone of magnetic tripping (short circuit)
This characteristic of the trip curve has no counterpart on the UL side. At a certain level of (over) current the magnetic trip unit kicks in and overrides the thermal trip unit. The magnetic trip unit is an instantaneous trip unit, meaning as soon as it is triggered by a corresponding value of (over)current it will open the breaker contacts immediately through direct intervention.

In the example of the C-curve, the breaker can't trip until the overcurrent reaches a value of five times the rated current, and it must trip before the current reaches ten times the rated level. The magnetic tripping time depends on the frequency of the supply voltage, typically 50/60 Hz. At higher frequencies, or for DC voltage, tripping is delayed up to 1.5 times the value at 50/60 Hz.

As previously mentioned, the graph of a trip curve shows the tolerance band within which manufacturers can set the individual tripping point of their breakers and calibrate them accordingly. Because of tolerances in production, most manufacturers calibrate their breakers at a tripping point (for the thermal part of the graph) in the middle of the tolerance band given by the standard. For the magnetic part of the C-curve example, this would be 7.5 times the rated current.

With regard to the D curve, it is common practice to calibrate magnetic tripping at a point of 12 to 13 times the rated current. This tripping point calibration improves protection of a motor with a blocked rotor. Therefore that breakers with D curve and breakers with K curve have equal or at least similar calibration points.

The graph in figure 3 below shows a comparison of all IEC trip curves.



Understanding trip curves and being able to identify the differences among them based on the MCB functionality will facilitate the selection of the right trip curve. Selecting the correct trip curve for an MCB can potentially enhance the protection and lifetime of connected loads.

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1TQC2039E0001 WP REV.A NOV. 2020