

# Circuit Breaker Operation & its load calculations

## Abstract

Circuit breaker is very effective protection device in any lighting application. Improper loading of MCB might lead to “Nuisance Tripping”, damage the application or damage the circuit breaker and even cause fire breakout. This document will drive you through the brief introduction of circuit breaker, its operation and load calculations.

## Miniature Circuit Breaker (MCB)

A circuit breaker is a protective device to protect the application during an overcurrent condition. MCB is a resettable protective device that protects against situations like Overload and Short Circuit.

In other words: Under normal condition the device will carry the load current and during the fault/abnormal condition the device will automatically break and automatically reset as the fault condition is eliminated

### a. Cross Sectional Diagram

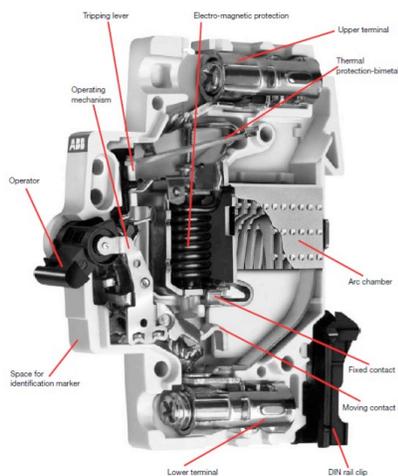


Fig 1. Cross Sectional view of a MCB

### b. Modes of Operation

#### Thermal and Magnetic trip definition

MCB uses an electromechanical trip unit to open the contacts during an overcurrent condition. The thermal



trip unit is temperature sensitive and the magnetic trip unit is current sensitive. These thermal and magnetic trip units are independent and act mechanically with the MCB trip mechanism to open the MCB contacts.

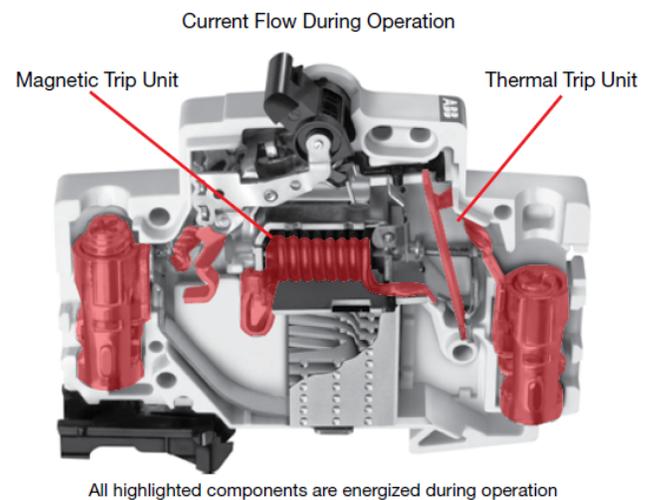


Figure 2. Cross Sectional view to show Magnetic and Thermal Trip functions

#### Thermal / Overload protection:

During continuous overload condition thermal trip unit gets activated and protects the circuit. The thermal unit is comprised of a bimetal lever located behind the MCB trip bar and is in the direct current carrying path. During overload, the increased current flow heats the bimetal lever causing it to bend. As the lever bends it pulls the tripping element which opens the MCB contacts.

The overload current and time required for the bimetal to bend and trip the breaker are inversely proportional. Hence, as current increases the tripping time reduces.

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## Magnetic / short circuit protection:

A short circuit current activates the magnetic trip function. The magnetic trip unit is comprised of an electromagnet coil, an armature and movable contact.

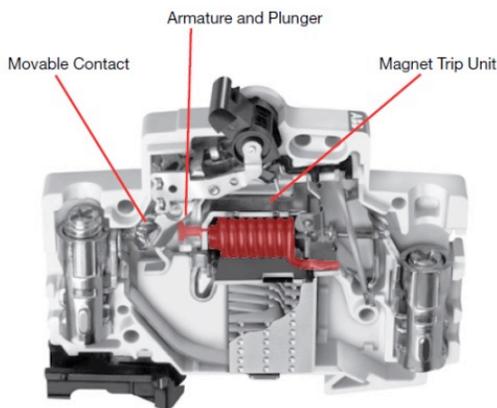


Figure 3. Cross Sectional view to show Magnetic Trip functions

With short circuit condition, a high magnitude of current passes through the coils creating a magnetic field that attracts the movable armature towards the fixed armature. The tripping lever is pushed against the movable contact and the contacts are opened.

## Manual Protection:

User can manually control the Circuit On/Off Conditions, by dropping the operator control switch.

### c. Trip Curves:

The tripping characteristic of MCB is plotted as tripping time Vs. current level. The curve shows the amount of time required for a MCB to trip at a given overcurrent or short circuit condition.

As per IEC 60898-2, Electrical accessories – Circuit-breakers for overcurrent protection for household and similar installations, Part 2: Circuit-breakers for AC and DC operation. The trip curve plotted as below,

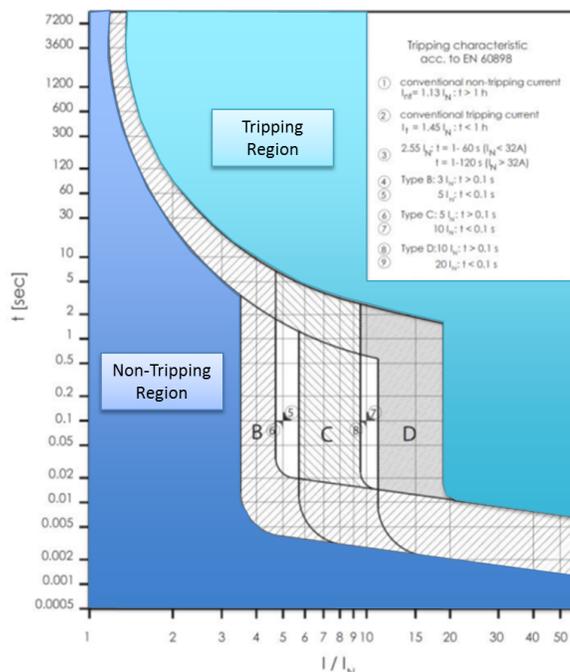


Figure 4. Trip Curve as per IEC 60898-2

The above picture defines tripping and non-tripping region. If the In-rush falls under tripping region, the MCB will trip instantaneously and Inrush current under non tripping region is safe for operation.

### d. MCB Types:

- **TYPE B:** The tripping limits are between 3 and 5 times the current rating of the MCB. Example: 10A MCB will trip between 30A and 50A in an overcurrent condition.
- **TYPE C:** The tripping limits are between 5 and 10 times the current rating of the MCB. Example: 10A MCB will trip between 50A and 100A in an overcurrent condition.
- **TYPE D:** The tripping limits are between 10 and 50 times the current rating of the MCB. Here applications are with products generating very high inrush currents. Such as Heavy Motors and Solenoids

\*Limits as per IEC/EN 60898

\*\*Electrician's usually consider Type B for Household lighting and Type C for commercial lighting application

## Inrush Current

Input current of short duration during initial start-up that is much greater than the operating or steady state current. We can say that during start-up LED driver draw higher than normal operating current for a short duration. This current occurs because of various capacitors distributed throughout the design. These capacitors perform different functions in the design like limit electromagnetic interference, filter switching noise, and/or store energy. By and large the greatest contributors to inrush are the energy storage capacitors.

Simply put, a capacitance value times the change in voltage across it divided by the time it takes for that voltage to change causes a current pulse to flow that is of the same time duration as the voltage change. This is given in the equation below.

$$C \times \Delta V(t) / t = \Delta i(t)$$

So if the capacitor value and voltage change are large but occur in a very short amount of time, there is a large current flow through the capacitor. That current drawn from the AC line is inrush.

### a. Waveform:

LED Drivers powered by the AC line see a sinusoidal waveform (as in the figure below). There are 360° to one complete AC line cycle, just as a circle or a compass has 360°. When a LED Driver is energized (start-up) by the power line, it occurs (turn-on) at approximately 1° of the 360° line cycle. In real life and with manual switches you never know what degree that turn-on will occur; but it matters. A sine wave has a peak and a trough at 90° and 270°. These degrees are where the varying magnitude sine wave respectively reaches its maximum and minimum peak voltage values. Also, the 0°, 180°, and 360° points are where the sine wave voltage is exactly zero.

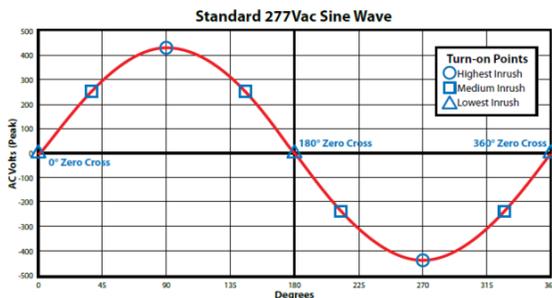


Figure 5. Standard Sine Wave

A turn-on at zero voltage is relatively soft. The change in capacitor voltage can be muted. In this case the inrush current is drawn during the normal change of the line voltage in the appropriate line cycle time and/or with any additional circuitry that may try to push a higher voltage in a shorter amount of time across internal capacitors; however, here the inrush will be much less than if turn-on is at 90° or 270°. Of course, turn-on at the 90° maximum or 270° minimum means the change in the capacitor voltage expected is near instantaneous; hence, a large positive (at maximum) or negative (at minimum) current spike must occur that is more or less superimposed upon that which would have occurred if turn-on was at the zero voltage crossing.

The inrush current spike itself has a magnitude and a width. It's normally characterized for its peak and time width (the time at which 10% magnitude occurs). It's also measured at some source impedance, the highest nominal AC line voltage of specified driver operation, full load, a nominal 25°C temperature, and a time at which it has not been recently switched on. The source impedance is a standard value given in NEMA 410.

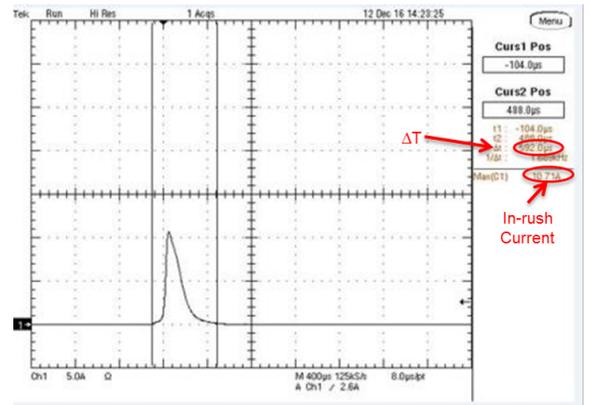


Figure 6. Inrush current waveform of ESS020W-0700-24

### b. Effects of high inrush current:

High inrush current can create potential negative effects. NEMA 410 defines limits of acceptable inrush currents to prevent this. Usually drivers are designed to stay within the limits. The highest nominal voltage on a universal driver would be 277 Vac, this will obviously vary for drivers with other operating voltages. Full load is the normal test load. A 25°C cold start is considered worst case. Lastly, you want all the internal capacitors to be fully discharged so that no residual voltages present.

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Unacceptable inrush can potentially damage relays. Standard relays can switch anywhere in a standard line cycle. As discussed above, switching at certain parts of the line cycle will allow for a maximum inrush. This can cause damage by degrading relay contacts and sometimes welding them closed, due to arcing at the contact. Standard component analysis techniques must be employed to determine the load derating to use on a relay, as well as the kind of inrush it can accept.

### c. Relation of Inrush Current to MCB Trip Curve:

Under high inrush current circumstances MCB can be a utilized as a protection device, it can open the circuit instantaneously and later can be returned to nominal operating condition without causing any damage to the application, once the circuit recovers from overcurrent condition.

For LED lighting application, usually user prefers type B, as per Fig 4 for instantaneous pick up trip point time is less than 0.002S. if the LED driver inrush current lower than 100A ( $\Delta T = 0.002S$ ). Then you can neglect considering the inrush current for the MCB load calculations.

## MCB Load Calculation

Considering as example ERP LED driver model ESS020W-0700-24, below are listed parameters

- Nominal Input Voltage: 230 Vac
- Input Current: 0.083 A
- Inrush Current: 10.71 A (as per Picture. 6)
- $\Delta T$  (Inrush current): 0.0006S
- MCB Type: 10A rated current, Type B
- Check if the inrush current is less than 0.002S, if yes proceed as below
- Non tripping current of 10A, Type B, MCB (Int):
  - 1.13 x MCB rated current
  - 1.13 x 10 = 11.3 A
- Number of load per MCB = Int / Input current
  - 11.3 / 0.083 = 136.1
  - 136 units per MCB (100% load)
- 80% MCB load calculation = Int x 0.8 (Considering the safety factor of 20% and not loading the MCB to its 100%)
  - 11.3 x 0.8 = 9.04 A
  - 9.04 / 0.083 = 108.9
  - 109 units per MCB

- Concluding on 109 units per 10A, Type B MCB

In case of inrush current higher than 100A with  $\Delta T \geq 0.002 S$ , then follow procedure as below,

- Correlate the  $\Delta T$  with I/IN from Fig 4
- Compute the Multiplication factor for the MCB Current rating
- Divide the value by In-rush current
- Final value will be the No. of units per MCB

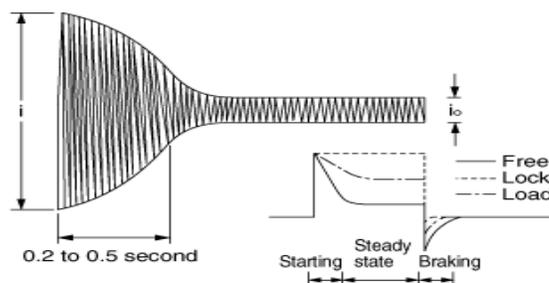
For example, consider inrush 120 A with  $\Delta T$  of 0.1 S, MCB Load calculation would be as below,

Correlating above value from Fig 4, at  $\Delta T = 0.1 S$  10A, type B MCB will trip between 30 to 50 A load current, hence the example application, will instantaneously trip on turn on.

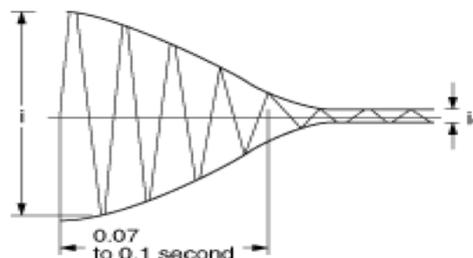
So selecting 32 A, Type C MCB will trip between 160 to 320A load current, hence user can load max of 1 unit on this MCB

## High inrush current application examples

### Inrush Current of a Motor



### Inrush Current of a Solenoid



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- Here you can observe from the above, that the peak current remains for a longer duration, then stabilizes over time
- Hence selection of Circuit Breaker depends on the Inrush current, else it might lead to “Nuisance Tripping”

## Effects of improper MCB loading

- **Danger of fire:** if the MCB is oversized and the wire gauge used in the electrical system is not appropriate, the MCB will not trip and lead to fire breakout
- **Nuisance Tripping:** This might be due to “High Inrush Current” and result of not considering for MCB load calculation
- Damage the MCB
- Damage the application circuit

## Summary

Consider inrush current of the device or equipment, while selecting MCB type and its load. Inrush current with  $\Delta T \leq 0.002S$  can be neglected for MCB load calculation. Compute the MCB load considering the continuous input current. For higher inrush current applications, correlate the inrush current with the MCB trip curve and conclude the MCB load.

## References

- ABB – Miniature Circuit Breaker, Application Guide
- Schneider Electric - Circuit Breaker Characteristic Trip Curves and Coordination – Data Bulletin # 0600DB0105
- MK by Honeywell – Sentry Technical – Circuit Protection
- Thomas Research Products – Inrush white paper

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