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POWER SUPPLIES

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White Paper
Circuit Breaker

Rev00

Created:		Checked:	
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1 INDEX

2 INTRODUCTION

This document describes the behaviour of a thermal-magnetic circuit breaker. Furthermore, it indicates how to select a suitable circuit breaker for our DC/DC-converters.

Circuit breakers are designed to protect an electrical circuit from damage caused by excess current from an overload or short circuit. If a circuit breaker detects such a fault, it switches automatically off to interrupt the current flow.
The most used ones are the thermal magnetic circuit breakers. They have two different tripping (switch-off) mechanisms:

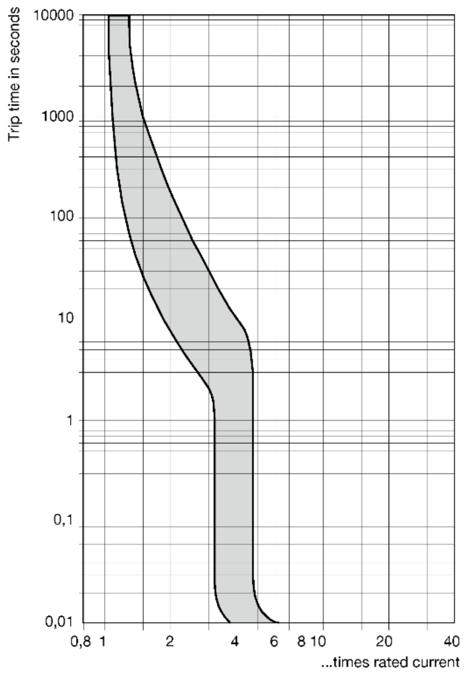
1) Magnetic tripping: Fast tripping caused by large peak-currents. Only current dependent. Used for short-circuit protection.
2) Thermal tripping: Slow tripping caused by temperature rise, responding to less extreme but longer-term over-current conditions. Current and time dependent. Used for protection against overload.

Combining the thermal and magnetic tripping results in the overall time-current tripping curves below. The circuit breaker must be chosen adequately, based on expected peak-loads and average loads of the application, which both must pass and not trip the circuit breaker. At the same time a disconnection must be ensured in the event an overload or short-circuit event.
Various tripping characteristics are therefore available for circuit-breakers: characteristic B, C and D according to the standard IEC/EN 60898-1.

3 TRIPPING CURVES

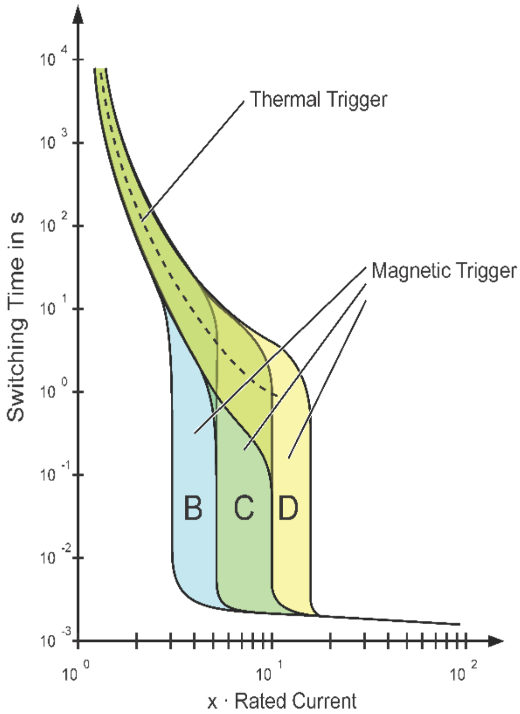
In most datasheets of the circuit breakers, the magnetic tripping current curve is only specified down to 10 ms (source E-T-A):

Curve B / 1...63 A



Magnetic tripping currents are increased by 30 % on DC supplies.
Ambient temperature 30 °C

General tripping curves extend it to shorter tripping times:



From above curves, two important points can be observed:

1) For short times below 20 ms, the tripping current reaches higher levels. At 10 ms, the curve indicates approximately 4 to 6 times the nominal current instead of 3 to 5 times specified for magnetic release.
   For current-peaks < 10 ms, the tripping current increases further and reaches very high levels for events in the range of 1 to 2 ms.
2) The magnetic tripping current is by 30 % higher for DC-applications than for AC-application (see note in first curve). For the instantaneous tripping current, the standard specifies a range of 4 up to 7 times the nominal current I_n instead of 3 up to 5 times for AC-applications.
   This is also defined by the standard EN 60898-2 (Circuit-breakers for overcurrent protection for household and similar installations - Part 2: Circuit-breakers for AC and DC operation):

Table 2 – Ranges of instantaneous tripping

Type	Ranges for alternating current	Ranges for direct current
B	Above 3 I_n up to and including 5 I_n	Above 4 I_n up to and including 7 I_n
C	Above 5 I_n up to and including 10 I_n	Above 7 I_n up to and including 15 I_n

For the two reasons outlined above, it is not necessary to over-specify the circuit breaker for short events like the inrush-current.

4 SELECTING THE CIRCUIT BREAKER

The selection of the correct circuit breaker is not an easy task and depends on various factors:

- **Input voltage:** The circuit breaker must be rated for the maximum applied DC-or AC-input-voltage. Be aware that the allowed DC-voltage rating of a circuit breaker is much lower than its AC-voltage rating.
- **Input current:** The circuit breaker must be rated for the maximum continuous input current at the minimum input-voltage and the maximum load, taking into account the efficiency of the converter.
- **Ambient temperature:** The maximum operating current of the circuit breaker is depending on the ambient temperature and has a derating for ambient temperatures > 30 °C.

In the datasheets of our intreXis Boardnet Converter-series, we recommend suitable circuit breakers for the maximum output load.

If you have a special application which is not covered by our circuit breaker recommendation in the datasheet (for instant with low continuous load and high dynamic loads), please contact intreXis AG for advice. Based on your detailed application-parameters, we can select a suitable circuit breaker for you.

5 TYPICAL INRUSH-CURRENT BEHAVIOUR OF INTREXIS BOARDNET CONVERTERS

In all of our intreXis Boardnet Converters, the inrush-current behaviour is very similar and can be divided in four phases:

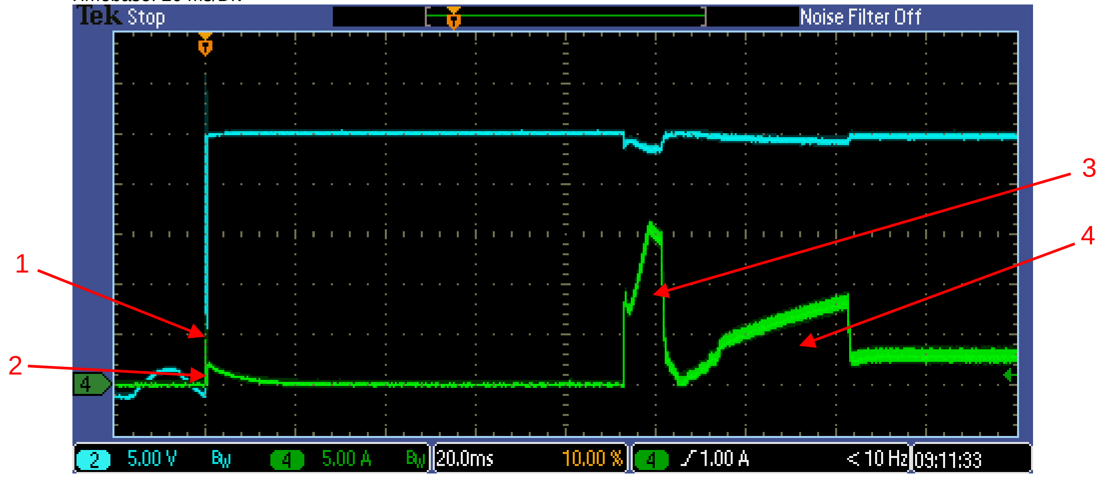
1) **Charging current of the EMC-filtering capacitors:** A very short current peak (<10 us). Our active inrush-current limiter does not limit this peak-current, because the EMC-filtering capacitors must be located directly at the input connector. However, the duration and the energy of this peak-current is very low and does not trip any external fuses or circuit breakers.
2) **Charging current of the input capacitors**: This current charges the bulk input capacitors of the converter, is limited by our active inrush-current limiter and decays exponentially.
3) **Charging current of the intermediate voltage capacitors:** This current charges the capacitors of the intermediate circuit voltage. This charging current is only present in our two-stage converters from 75 – 1000 W for input-voltages <110 VDC. For input voltages ≥110 VDC and in our 50 W-converter, this current is not present.
4) **Charging of the output- and load-capacitors**: This current charges the output- and load-capacitors to the nominal output voltage. It depends also on the applied load.

Phase 2) and phase 3) determine the inrush-current energy I_{inrush}^2t and, in addition to the load, is an important parameter for the proper selection of the external circuit breaker.

For better understanding, we measured the inrush-current on our 150 W-converter and indicated the phases 1-4 with red arrows:

Measurement: typical inrush current at nominal load @ 24 Vin:

CH2 blue: Input voltage 5 V/Div,
CH4 green: Input current 5 A/Div,
Timebase: 20 ms/Div



Measurement: typical inrush current at nominal load @ 110 Vin (phase 3 not present):

CH2 blue: Input voltage 20 V/Div,
CH4 green: Input current 5 A/Div,
Timebase: 20 ms/Div