intreXis®
POWER SUPPLIES

intreXis AG
Tobelraastrasse 4
CH-8212 Neuhausen am Rheinfall
SWITZERLAND

Tel +41 (0)525111190 www.intrexis.ch
Fax +41 (0)525111199 info@intrexis.ch

White Paper

New intreXis Boardnet Converter with Power Boost: Behaviour in case of short circuit and tripping of circuit breakers

Written by:		Checked by:	
Ch.Carlen	28.03.2019	T.Schiegg	28.03.2019
			

1. INTRODUCTION

In railway-applications, a DC/DC-converter has to power frequently various load-branches. These load branches are often individually protected with circuit breakers, to isolate them selectively in case of a fault. In case of such a fault (short-circuit), the DC/DC-converter must be able to source enough current to trip the circuit breaker reasonably. For this purpose, the overload and short-circuit behaviour of the DC/DC-converter is vitally important.

All DC/DC-converters of our intreXis Boardnet Converter Platform are continuously overload and short-circuit proof. No overheating or damage will occur to our DC/DC-converters during any overload or short-circuit event.

This white paper describes the overload and short-circuit behaviour of our newest 500 W DC/DC-converters, which have a new power-boost, which can:

- Source up to twice the nominal output current during startup: satisfies high peak current absorption of demanding loads during startup.
- Source up to twice the nominal output current during a short-circuit event: trips circuit breakers reliably.
- Source 1.5 time the nominal output power (750 W) for peak-loads up to 100 ms.

Test and measurements were carried out with the 500 W DC/DC-converter, 24 V output voltage (IC303_1), to confirm the peak-power capability and tripping of various circuit-breakers.

2. IC30X_1: OVERLOAD AND SHORT-CIRCUIT BEHAVIOUR

For our newest 500 W DC/DC-converters IC303_1 and IC304_1, we designed a very innovative power-boost feature for overload and short-circuit events.

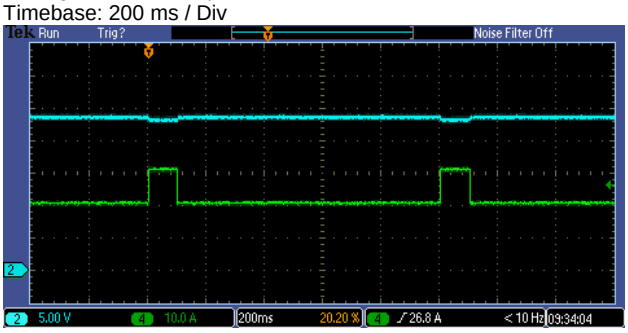
This new power boost feature of the IC30X_1-converters has following advantages:

- Up to 750 W (1.5 times nominal output power) for 100 ms can be sourced without limitation, the output voltage remains stable. Therefore, the customer can choose a DC/DC-converter based on peak load requirements (average power often much lower), which results in a smaller, lighter and more cost-efficient solution.
- Up to twice the nominal output current can be sourced during start-up. This feature satisfies high peak current absorption of demanding loads and ensures proper start-up.
  Startup-current: 40 A typ (IC303_1), 20 A typ (IC304_1)
- Up to twice the nominal output current (40 A_{pk} for IC303_1, 20 A_{pk} for IC304_1) can be sourced during a short-circuit event. This ensures reliable and fast (magnetical) tripping of circuit breakers in only a few milliseconds.
- Low average and RMS-current (<10 A_{rms} for IC303_1, <5.0 A_{rms} for IC304_1) during short-circuit event. This protects connectors and load wiring from overheating.

Output overloaded:

Short overloads:
Up to 750 W (1.5 times nominal output power) for 100 ms: no limitation, output voltage remains stable.

Measurement on IC303_1: 500 W for 900 ms, 750 W for 100 ms:
CH2, blue trace: output voltage 5 V / Div
CH4, green trace: output current 10 A / Div
Timebase: 200 ms / Div



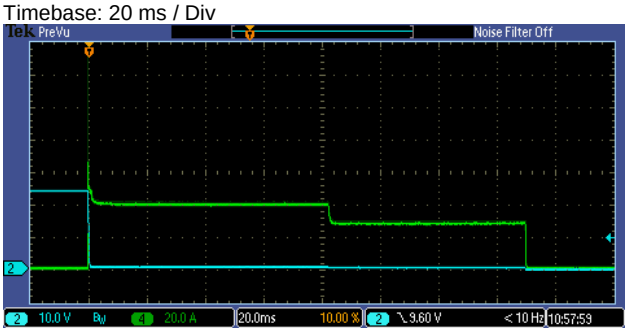
Longer/Higher overloads:
>100 ms or >750 W: the converter switches off and retries like in a short-circuit event (hiccup-mode: see below).

Short circuit:

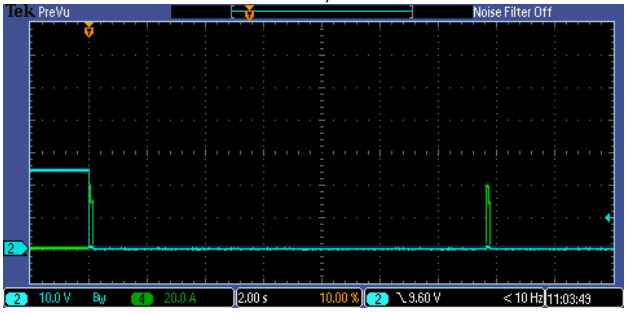
The converter goes into Hiccup-Mode:
The converter switches off and tries periodically to switch on again, each 14 seconds for 150 ms. If the short-circuit is still present, the converter switches off again and tries again periodically. If the short-circuit is removed, the converter switches on at the next switch-on attempt.

Measurement on IC303_1: Short-circuit event
If the output is shorted, the IC303_1 supplies twice the nominal output current (40 A instead of 20 A) for roughly 80 ms, then 1.5 times the nominal current (30 A) for another 70 ms.

CH2, blue trace: output voltage 10 V / Div
CH4, green trace: output current 20 A / Div
Timebase: 20 ms / Div



After this power-boost-time of 150 ms, the converter switches off and tries periodically to switch on again, every 14 seconds for 150 ms. If the short-circuit is still present, the converter switches off and tries again. If the short-circuit is removed, the converter switches on at the next switch-on attempt.

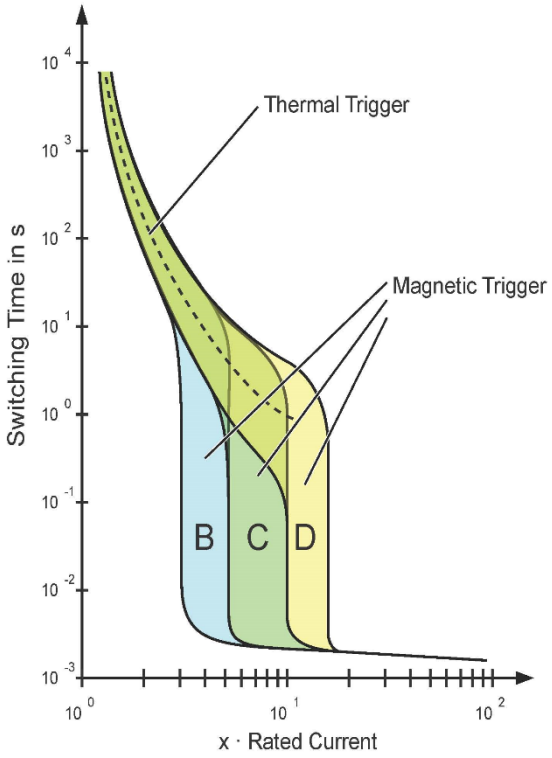


3. CIRCUIT BREAKERS

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.



4. IC303_1 TEST WITH CIRCUIT BREAKERS

Various circuit breakers (10 – 20 A, characteristic B and C) were tested under following conditions:

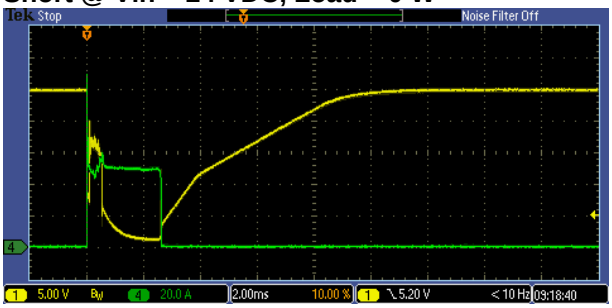
- Input Voltage Vin: 24 VDC and 110 VDC.
- Load: 0 W or 80 % load: 400 W with 1x IC303_1, 800 W with 2x IC303_1.
- Converter: 1x IC303_1 or 2x IC303_1 paralleled.

For all following measurements:
- CH1, yellow trace: Vout, 5 V/Div
- CH4, green trace: Iout, 20 A/Div
- Timebase: 2 ms/Div

4.1 Circuit Breaker: 10 A, characteristic C

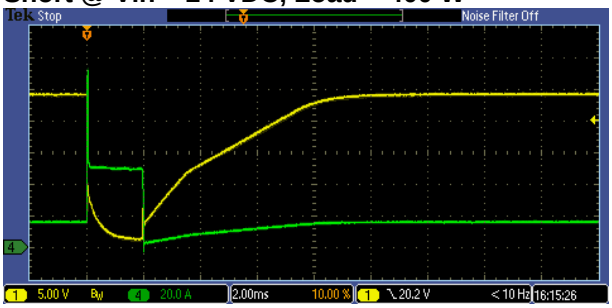
Tests with 1x IC303_1:

Short @ Vin = 24 VDC, Load = 0 W



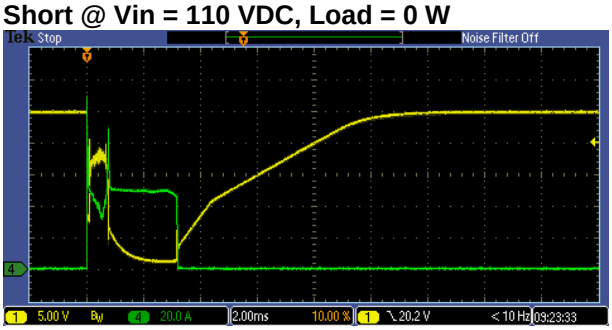
Circuit breaker trips after 2.6 ms

Short @ Vin = 24 VDC, Load = 400 W



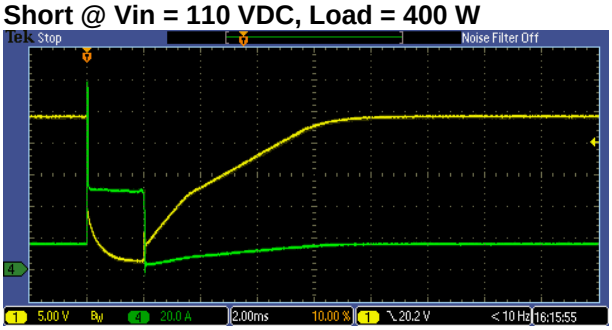
Circuit breaker trips after 2.0 ms

Short @ Vin = 110 VDC, Load = 0 W



Circuit breaker trips after 3.2 ms

Short @ Vin = 110 VDC, Load = 400 W



Circuit breaker trips after 2.0 ms

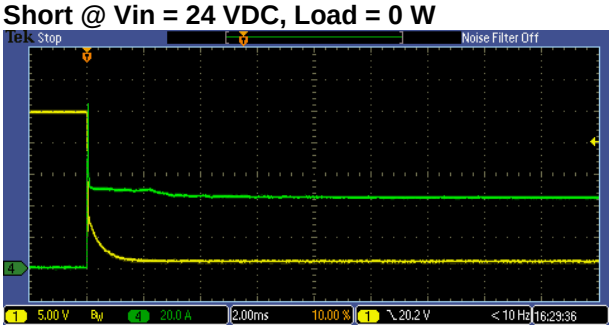
The circuit breaker 10A with characteristic C tripped under all conditions within 4 ms.
Already one IC303_1 is sufficient to trip this circuit breaker reliably.

Tests with two paralleled IC303_1 showed the same results: reliable tripping of the circuit breaker.

4.2 Circuit Breaker: 13 A, characteristic C

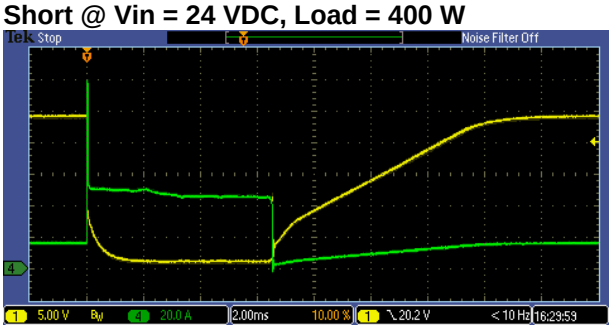
Tests with 1x IC303_1:

Short @ Vin = 24 VDC, Load = 0 W



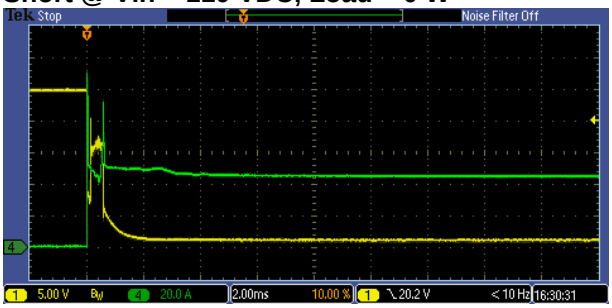
Circuit breaker does not trip

Short @ Vin = 24 VDC, Load = 400 W



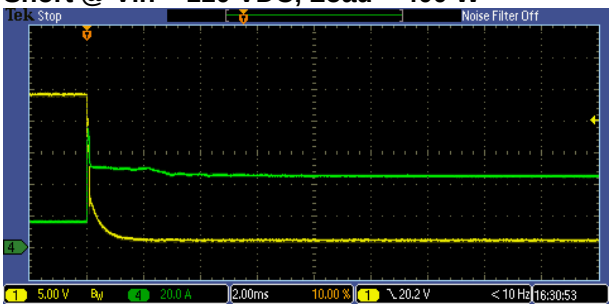
Circuit breaker trips after 6.6 ms

Short @ Vin = 110 VDC, Load = 0 W



Circuit breaker does not trip

Short @ Vin = 110 VDC, Load = 400 W

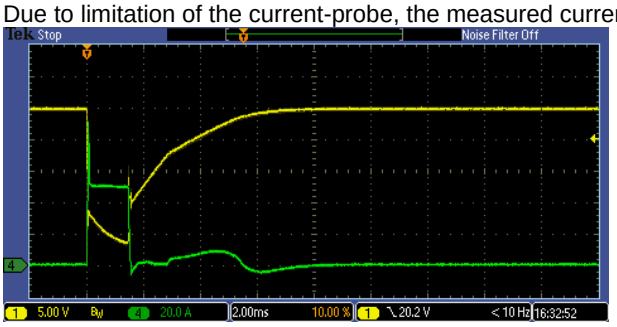


Circuit breaker does not trip

Tests with 2x IC303_1 paralleled:

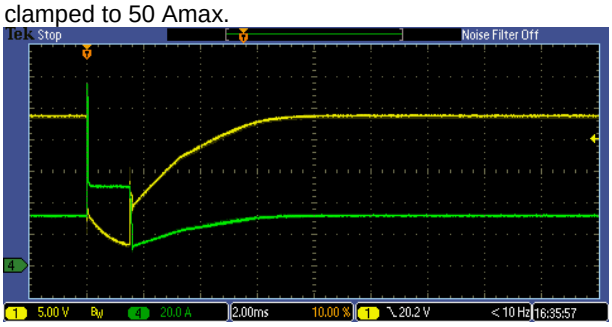
Short @ Vin = 24 VDC, Load = 0 W

Due to limitation of the current-probe, the measured current is clamped to 50 Amax.



Circuit breaker trips after 1.4 ms

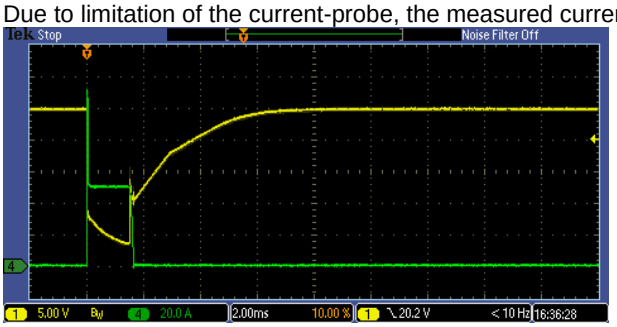
Short @ Vin = 24 VDC, Load = 800 W



Circuit breaker trips after 1.6 ms

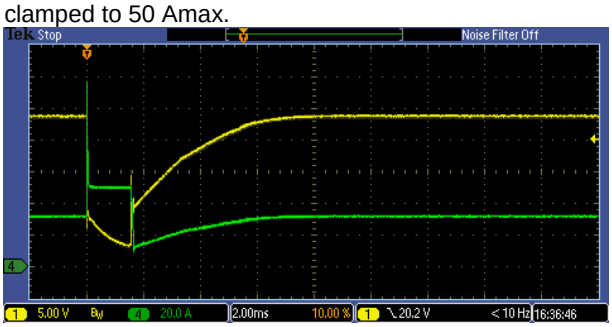
Short @ Vin = 110 VDC, Load = 0 W

Due to limitation of the current-probe, the measured current is clamped to 50 Amax.



Circuit breaker trips after 1.6 ms

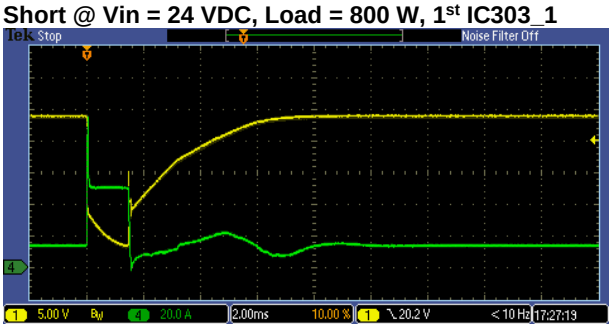
Short @ Vin = 110 VDC, Load = 800 W



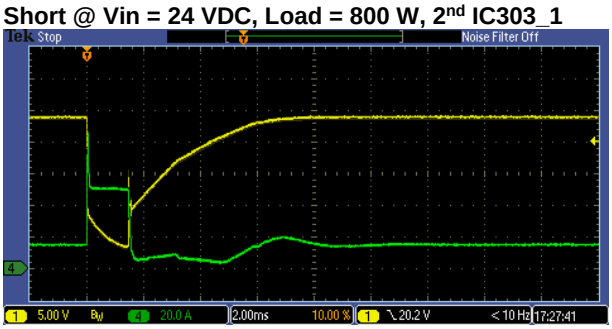
Circuit breaker trips after 1.6 ms

Current was measured for each single IC303_1 separately to verify current sharing.
The total current is 100 A:

Short @ Vin = 24 VDC, Load = 800 W, 1st IC303_1



Short @ Vin = 24 VDC, Load = 800 W, 2nd IC303_1

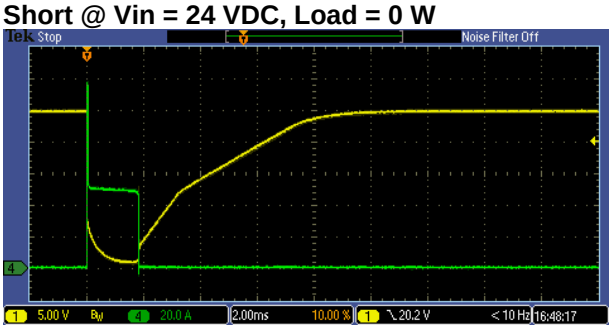


With one IC303_1, the circuit breaker 13A with characteristic C does not always trip.
With two paralleled IC303_1, the circuit breaker 13A with characteristic C tripped under all conditions within 2 ms.
Two paralleled IC303_1 are sufficient to trip this circuit breaker reliably.

4.3 Circuit Breaker: 16 A, characteristic B

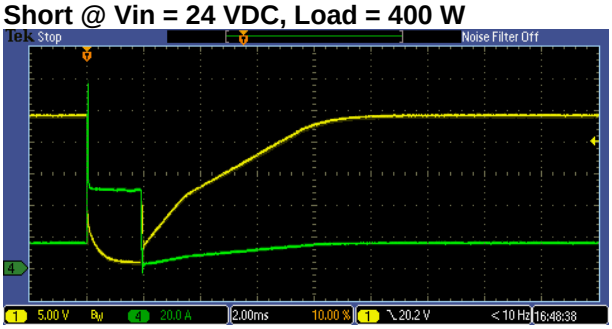
Tests with 1x IC303_1:

Short @ Vin = 24 VDC, Load = 0 W



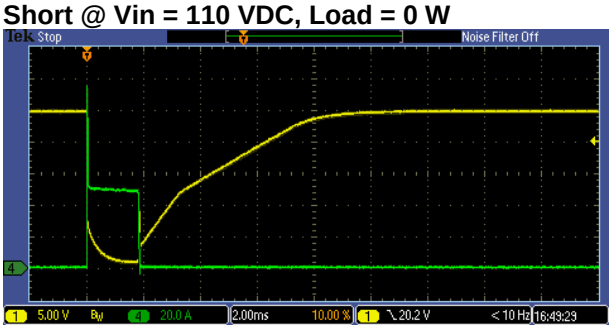
Circuit breaker trips after 1.8 ms

Short @ Vin = 24 VDC, Load = 400 W



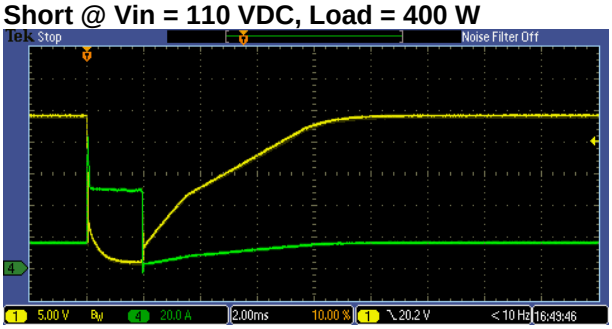
Circuit breaker trips after 2.0 ms

Short @ Vin = 110 VDC, Load = 0 W



Circuit breaker trips after 1.8 ms

Short @ Vin = 110 VDC, Load = 400 W



Circuit breaker trips after 2.0 ms

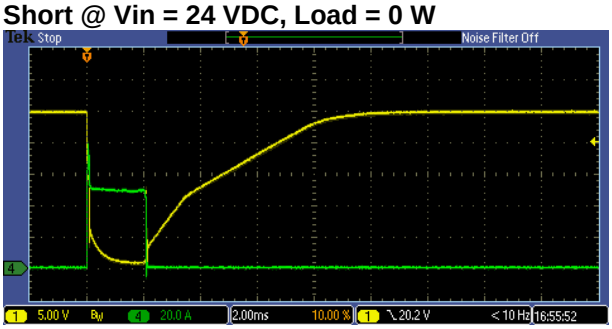
The circuit breaker 16A with characteristic B tripped under all conditions within 3 ms.
Already one IC303_1 is sufficient to trip this circuit breaker reliably.

Tests with two paralleled IC303_1 showed the same results: reliable tripping of the circuit breaker.

4.4 Circuit Breaker: 20 A, characteristic B

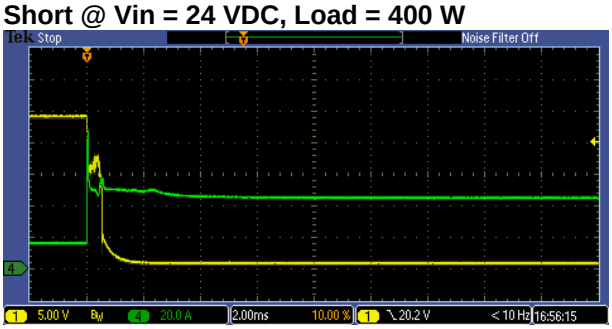
Tests with 1x IC303_1:

Short @ Vin = 24 VDC, Load = 0 W



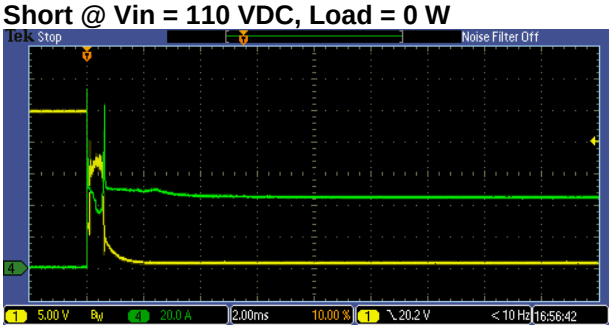
Circuit breaker trips after 2.1 ms

Short @ Vin = 24 VDC, Load = 400 W



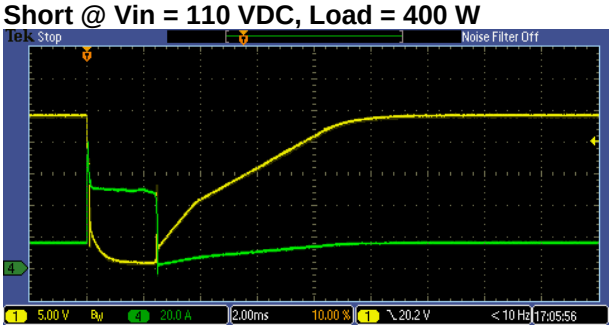
Circuit breaker does not trip

Short @ Vin = 110 VDC, Load = 0 W



Circuit breaker does not trip

Short @ Vin = 110 VDC, Load = 400 W

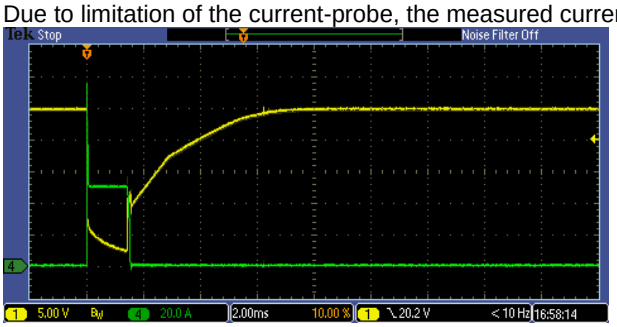


Circuit breaker trips after 2.4 ms

Tests with 2x IC303_1 paralleled:

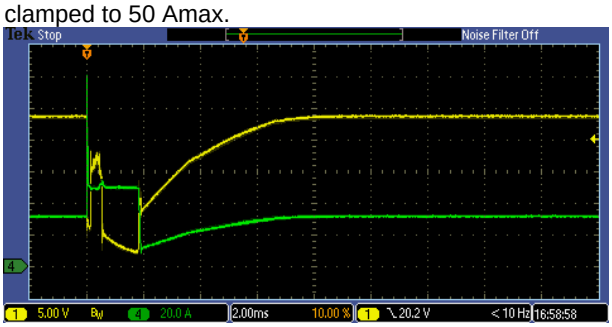
Short @ Vin = 24 VDC, Load = 0 W

Due to limitation of the current-probe, the measured current is clamped to 50 Amax.



Circuit breaker trips after 1.4 ms

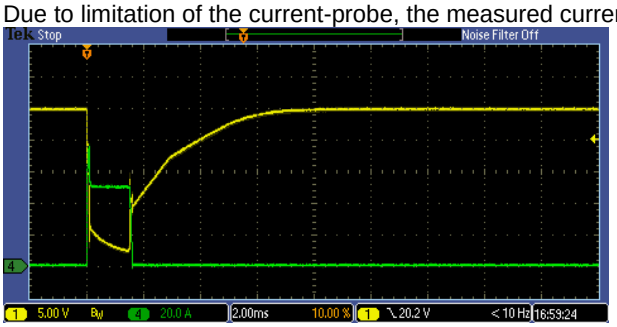
Short @ Vin = 24 VDC, Load = 800 W



Circuit breaker trips after 1.8 ms

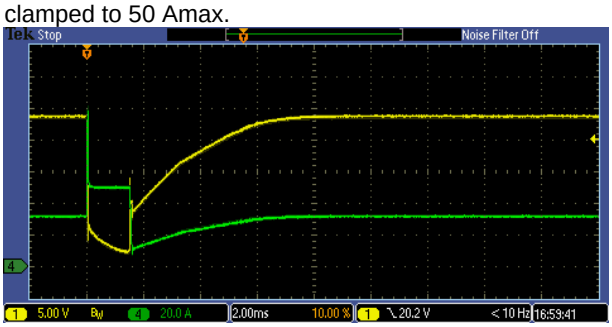
Short @ Vin = 110 VDC, Load = 0 W

Due to limitation of the current-probe, the measured current is clamped to 50 Amax.



Circuit breaker trips after 1.6 ms

Short @ Vin = 110 VDC, Load = 800 W



Circuit breaker trips after 1.6 ms

With one IC303_1, the circuit breaker 20A with characteristic B does not always trip.
With two paralleled IC303_1, the circuit breaker 20A with characteristic B tripped under all conditions within 2 ms. Two paralleled IC303_1 are sufficient to trip this circuit breaker reliably.

5. CONCLUSIONS

The new IC303_1 with the power-boost feature is able to trip reliably circuit breakers in case of a short on a load-branch as follows:

Characteristic Circuit Breaker	Circuit Breaker Current			
	Tested with one IC303_1	intreXis recommendation with one IC303_1	Tested with two paralleled IC303_1	intreXis recommendation with two or more paralleled IC303_1
B	ok up to 16 A	ok up to 10 A	ok up to 20 A	ok up to 20 A
C	ok up to 10 A	ok up to 6 A	ok up to 13 A	ok up to 13 A