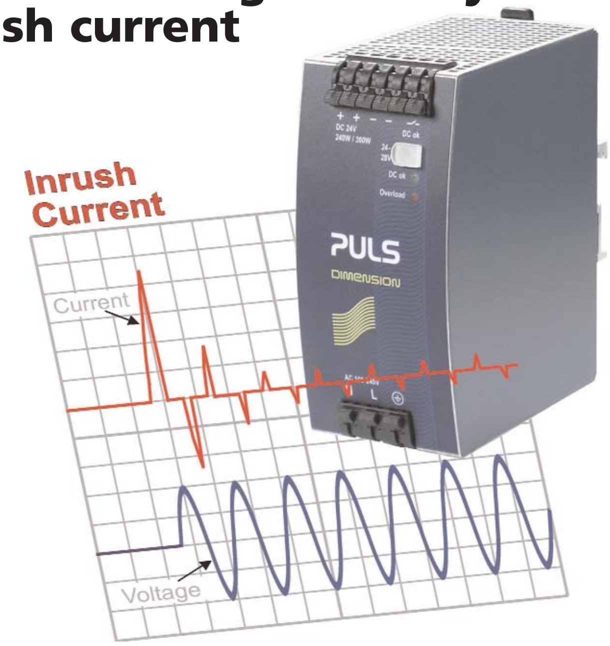
Power supplies with significantly reduced inrush current

by Michael Raspotnig

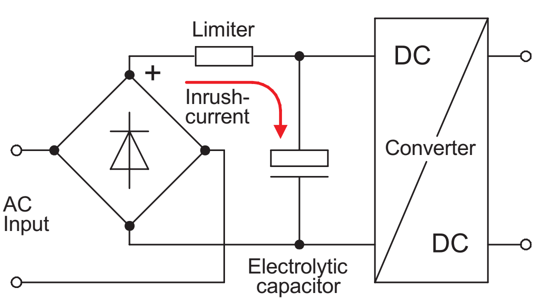


When electrical and electronic devices are switched on, they load the supply network momentarily with high current pulses. MCBs and breakers have to be designed for these peak currents to prevent nuisance trips or contact welding. Besides this, such high current pulses produce voltage dips in the supply voltage, which in turn can cause malfunctions in other consumer circuits. Often, this inrush current is not given sufficient consideration or is overlooked when selecting power supplies, which can lead to unexpected circumstances later on.

PULS, the power supply manufacturer, has developed an effective method for reducing inrush current. The method is unique up to now and, for the first time, almost completely eliminates high inrush currents.

What causes the inrush current?
Modern drive systems, inverters and power supplies convert electrical energy by means of pulsed technology. The supply voltage is filtered, converted to DC by means of a bridge rectifier and smoothed with a large electrolytic capacitor. The voltage only reaches the actual conversion stage after that and the charging current of this large electrolytic capacitor causes the inrush current and must be limited. Devices can differ here through the use of different concepts.

Inrush current limiting by means of NTC resistors
This is undoubtedly the simplest form of inrush current limiting. The charging current is limited by an NTC resistor and with an NTC resistor, the resistance value decreases with rising temperature. On initial switch-on the resistor is cold, has a high-resistance and limits the charging current effectively. After a relatively short time, the resistor heats up to around 110°C due to its own losses and the resistance decreases by a factor of 15. As a result, the losses in service stay within limits.



Simplified schematic of a switch-mode power supply

However, this simple method has disadvantages, too:

- Due to the nature of the components, the effect of the inrush current limiting is heavily dependent on the ambient temperature. Low temperatures (minus range) can lead to starting problems and at high temperatures the inrush current limiting is inadequate.
- Another serious disadvantage is that the inrush currents are only partially limited after momentary mains failures (a few 100 ms). The electrolytic capacitor discharges during this interuption, but the NTC resistor has stored the heat, stays at a low resistance and is virtually ineffective.

- The NTC resistor generates a power loss and reduces the efficiency by approx. 1%. This is equivalent to 15% more losses with a power supply rated at 92% efficiency.
- The data sheet information of different equipment manufacturers is very difficult to compare. The parameters used as a basis are different, but have a decisive effect on the result.

External inrush current limiters

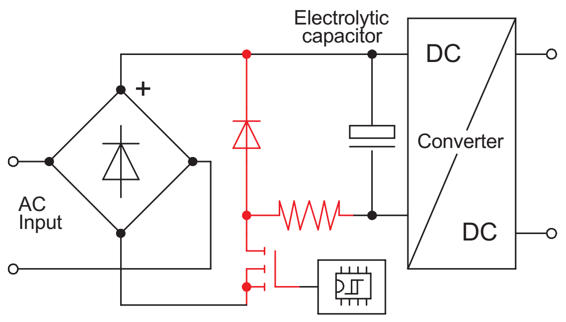
High inrush currents are also known when transformers are switched on. However, the effect is different in this case. When a transformer is switched on at a zero crossing of the sinusoidal input voltage, the magnetization of the magnetic core of the transformer is driven into an unbalanced state during the first few cycles. As a result, the magnetic core saturates on each half-cycle. The magnetizing current, which is only limited by the leakage inductance, increases dramatically and causes the high inrush currents. There are special input devices for transformers that switch on at the voltage maximum and prevent inrush currents. If these input devices are used on switch mode power supplies, they have precisely the opposite effect. They would always switch on at the worst possible time and cause high peak currents.

Inrush current limiting by means of fixed resistors

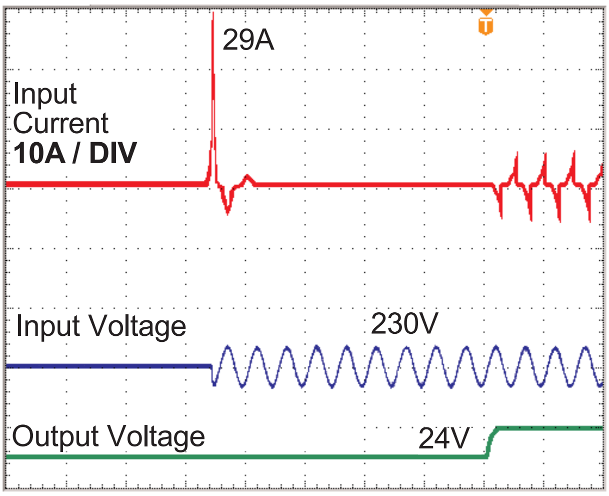
With this method, a power resistor is used to limit the charging current. The resistor is bypassed after the electrolytic capacitor is fully charged. Relays, triacs, IGBTs or other components can be used to bypassed the resistor. This method is significantly more expensive than inrush current limiting with NTC resistors and is normally only used at rating classes above 250W. The advantages are that the charging current is independent of temperature and there is significantly less power loss.

The premium solution: pulsed charging of the input capacitor

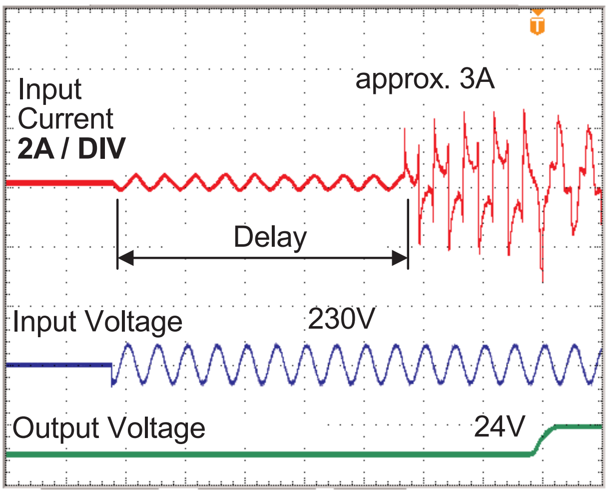
This method, newly developed by PULS GmbH, "soft" charges the electrolytic capacitor. The electrolytic capacitor is pulse charged with low losses by means of a switch, inductor and free-wheeling diode. Parameters such as peak current and charging delay can be precisely calculated and suitably incorporated. On the high-performance units of the PULS Dimension Q series, the electrolytic capacitor is intentionally charged after a delay. This helps the restart after mains failures, when lots of con-



Simplified schematic of the Dimension Q-Series Inrush current limitation with pulsed charging of the input capacitor.

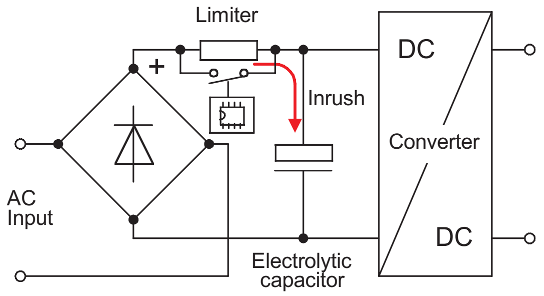


"Cold start" of a 24V, 10A power supply with NTC resistor inrush current limiting
typ. peak inrush current = 29A



24V, 10A power supply from the PULS Dimension series with pulsed charging of the input capacitor
typ. peak inrush current = 3A

sumer circuits are trying to meet their starting current requirements simultaneously when the mains supply is restored. In this case, the peak inrush currents of all the consumer circuits summate and load the MCBs and the system voltage heavily. The delay in the PULS Dimension Q series anticipates this initial current surge and switches on a few 100 ms later. This gives a softer restart and prevents unnecessary fuse blowing or MCB trips.



Inrush current limiting by means of fixed resistors which will be bypassed after a certain period of time

Advantages of inrush current limiting by means of pulsed charging:

- Peak inrush current is only marginally higher than the maximum operating current
- MCBs do not have to be rated for the peak inrush current, but can be designed for the operating current
- Inrush current is independent of temperature, input voltage or other conditions
- Low power loss
- Delayed charging process mitigates peak currents after the supply voltage is switched on
- No starting problems at low temperatures

Evaluation of the individual methods of inrush current limiting

++ very good
\+ good
\- not so good

	NTC	Resistor with shorting circuit	Pulsed charging
Limiting of the inrush current, cold start	+	+	++
Inrush current after momentary mains failures	-	+	++
Temperature dependency	-	+	++
Input voltage dependency	-	-	++
Power loss	-	++	++
Suitability at low temperatures (< -10°C)	-	+	++