

# Using Modular DC-DC Converters to Meet European Standards for Railway Applications

Vicor Application Engineering



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## Introduction

In Europe, the performance of electrical and electronic equipment in railway applications is governed by two international standards.

The one most frequently cited in design specifications is the document IEC571, “Electronic Equipment on Rail Vehicles,” also known as European Norm **EN50155**, “Electronic Equipment Used on Rolling Stock Equipment.” In the U.K. the standard that applies is **RIA12**, “General Specification for Protection of Traction and Rolling Stock Equipment from Transients and Surges in DC Control Systems,” developed by the Railway Industries Association (RIA).

While these two standards are similar in most respects, the RIA12 standard also requires a specific surge withstanding capability.

The following discussion shows how to comply with these standards using modular Vicor DC-DC converters to facilitate the design of complex power supplies.

## Electrical Requirements for EN50155 (IEC571)

### Operating Voltage Ranges

Table 1 lists the nominal input voltages ( $V_N$ ) provided by power sources used for railway applications.

Equipment powered directly from batteries with no voltage stabilizing device must function properly with input voltages that range from  $0.7V_N$  to  $1.25V_N$  during normal operation. The equipment must also withstand input voltage drops of  $0.6(V_N)$  for 100 ms and overvoltage surges of  $1.4V_N$  for one second that may occur during startup.

Table 1 shows that, with some exceptions, standard Vicor DC-DC converters cover all of the specified input ranges and transients.

**Table 1**  
Input Specifications for EN50155 vs. Vicor DC-DC Converters

Nominal Inputs ( $V_N$ )	Input Ranges $0.7V_N - 1.25V_N$	Transients		Vicor DC-DC Converter Input Ranges
		Low (0.1s) $0.6V_N$	High (1s) $1.4V_N$	
24V	17 – 30V	14V	34V	18 – 36V <sup>[1]</sup>
36V	25 – 45V	22V	61V	21 – 56V
48V	34 – 60V	29V	67V	36 – 76V <sup>[2]</sup>
72V	50 – 90V	43V	101V	55 – 100V <sup>[3]</sup>
96V	67 – 120V	58V	135V	66 – 160V
110V	77 – 137V	66V	154V	66 – 160V

<sup>[1]</sup> Low limit at 18V  
<sup>[2]</sup> Low limit at 36V  
<sup>[3]</sup> Power de-rates to 75% of rated load at 45V

## Fast Transient Specification

Equipment must also be able to withstand a direct transient of 1,800V lasting 50µs. The impedance of the transient source is specified as 100Ω, with transient energy around 100mJ.

To prevent damage to the DC-DC converter, the module must be connected to a suppression device, such as a transient voltage suppressor (TVS), directly across the input. A TVS able to withstand up to 1.5J would be suitable. The TVS's clamping voltage must be selected so that it will not exceed the high line voltage or transient limits of the converter.

## RIA12 Surge Protection

The RIA12 standard specifies that equipment must withstand a 20ms overvoltage surge 3.5 times greater than the nominal input voltage. To meet this standard, a suppression circuit must be used with the DC-DC converter.

For each of the standard input voltages, the maximum input surges are as follows:

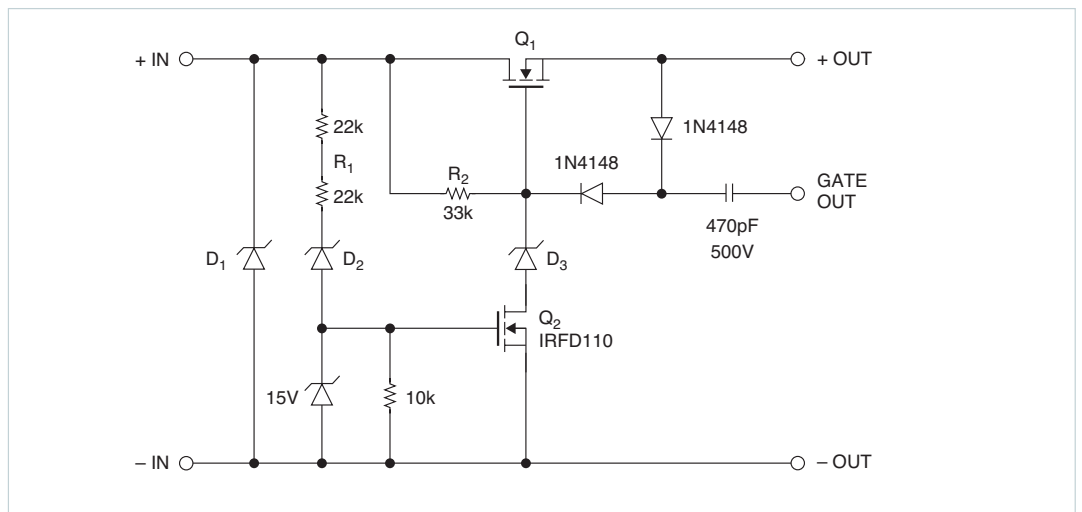
$V_N$	$3.5V_N$
24V	84V
36V	126V
48V	168V
72V	252V
96V	336V
110V	385V

Since the source impedance of this overvoltage pulse is 0.2Ω, a common clamping device, such as a TVS, will not provide a suitable solution because the energy dissipated would be:

$$E = \frac{3.5(V_N) - V_{Zener}}{0.2} \cdot V_N \cdot 0.02$$

Instead, an active circuit as shown in Figure 1 is necessary.

**Figure 1**  
An Active Circuit Designed  
to Prevent Fast Transients  
and Surges



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## Railway Standards

In this circuit, D1 clamps the fast, high voltage spikes, while the active part formed by D2, D3 and Q1, Q2 limits the surge. During normal operation, Q1 is kept in full conduction by the charge pump circuit made up of the 1N4148 diodes and the 470pF capacitor. The Gate Out signal from the converter drives the charge pump.

When overvoltage occurs, the diode D2 conducts, with current limited by R1, and turns Q2 on. With Q2 in conduction, the gate voltage of Q1 is held to the clamping voltage of D3. The output voltage equals the clamping voltage of D3 minus the gate source voltage of Q1. When overvoltage ceases, the system resumes normal operation.

### Component Selection

The components in the Figure 1 circuit remain essentially the same for all input voltage ranges. Only the main MOSFET Q1 and the clamping diodes D1, D2 and D3 are selected according to nominal operating voltage and power.

To select Q1 it is necessary to consider the values of  $3.5V_N$  and the operating current ( $I_N$ ) as well as the S.O.A. limits for a single 20ms pulse. The  $R_{DS(ON)}$  must also be taken into account, since the power dissipation under normal operating conditions is calculated as:

$$P = R_{DS(ON)} \cdot I_N^2$$

The diodes D<sub>2</sub> and D<sub>3</sub> can have the same breakdown voltage, in which case the output (clamped) voltage will equal D<sub>3</sub> minus the gate source voltage.

The RIA12 standard prescribes an input voltage variation of up to  $1.5V_N$  for one second. For converters with an input voltage range that allows the module to withstand this, the breakdown voltage for D2 and D3 must be greater than  $1.5V_N$  to prevent the protection circuit from operating under this condition, but less than the converter's high line voltage.

The diode D1 clamps high voltage spikes that have low energy but amplitudes that may exceed 1000V. Therefore, D1 must be a TVS with a clamping voltage higher than  $3.5V_N$  to prevent damage by this transient.

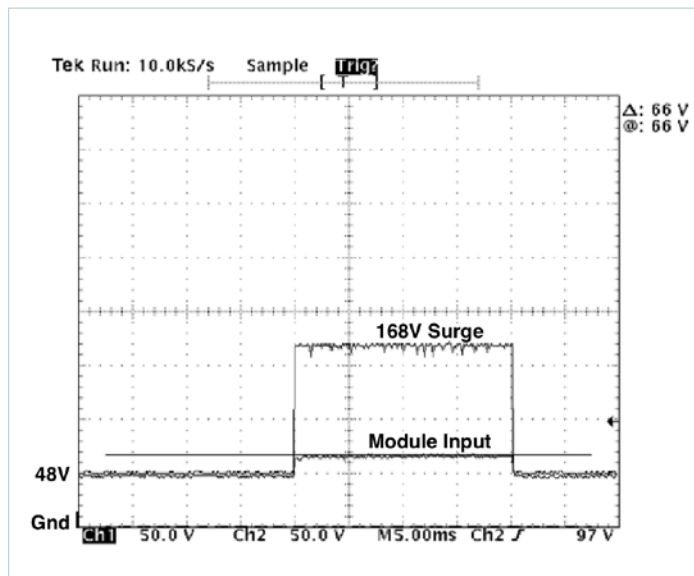
### Test Results

This circuit has been tested in the lab for 48V and 110V inputs - the two most common in railway applications - supplying a 150W DC-DC converter. The table below lists the components used.

Converter	48V <sub>N</sub>	110V <sub>N</sub>
D1	1.5KE200A	1.5KE440A
D2	68V/0.5W	160V/0.5W
D3	68V/0.5W	160V/0.5W
Q1	IRFP250	IRFP450

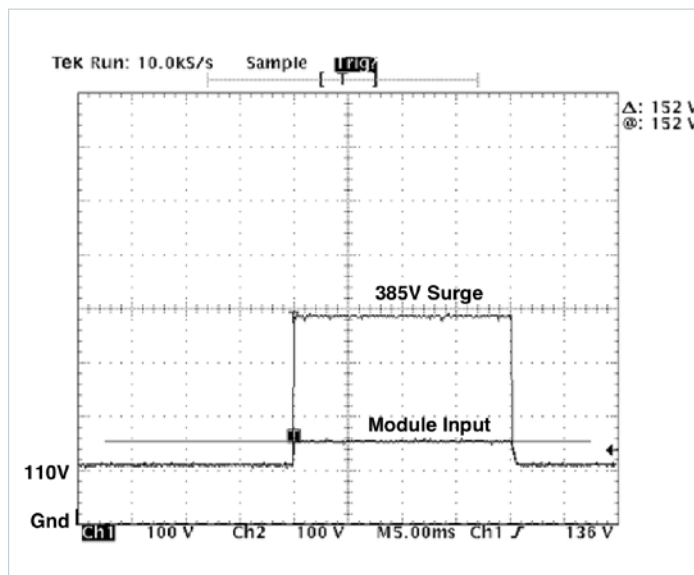
**Figure 2**

For a 48V Input, a 20ms Input Transient with Output Voltage Clamped to the Converter's High Line Limit



**Figure 3**

For a 110V input, a 20ms Input Transient with Output Voltage Clamped to the Converter's High Line Limit



Figures 2 and 3 show the 20ms input transient and the output voltage clamped to the converter's high line limit.

## Physical Requirements

### Operating Temperature Range

Operating temperatures are divided into four classes according to the severity of the environment, as shown in Table 2. When designing the power supply, it is necessary to consider overtemperature during start-up, indicated in the third column.

In some railway applications, the equipment is bulkhead mounted on the wagon walls. This setup can take advantage of the Vicor converters' planar baseplate and use the cabinet as a large heat sink.

**Table 2**  
Operating Temperature Ranges

Operating Temp. Classes	Internal Cubicle Temp.	Internal Cubicle Overtemp. (10 min.)	Air Temp. Around PCB
T1	-25 / +55°C	+15°C	-25 / +70°C
T2	-40 / +55°C	+15°C	-40 / +70°C
T3	-25 / +70°C	+15°C	-25 / +85°C
TX	-40 / +70°C	+15°C	-40 / +85°C

### Vibration and Shock

EN50155 specifies that electronic equipment mounted on boards and boxes fixed to the vehicle frame must be able to withstand vibration on all three axes at the levels below:

- Frequency range: 5 – 150Hz
- Cross-over frequency: 8.2Hz
- Displacement amplitude (below cross-over frequency): 7.5mm
- Acceleration amplitude (above cross-over frequency): 20m/s<sup>2</sup>

The equipment also must be able to withstand a 50ms, semi-sinusoidal shock of 50m/s<sup>2</sup> amplitude.

Because they are fully encapsulated in epoxy resin, Vicor modules can easily sustain these mechanical stresses. However, close attention must be paid to the PCB design and wiring to prevent relative movements that can stress the modules' pins.

The Vicor Applications Manual contains complete information about how to use Vicor component power products.

To address application conditions outside the range of standard Vicor DC-DC converters, contact: <http://www.vicorpower.com/contact-us>

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