Off-the-shelf DC/DC converters simplify challenges of ruggedized applications

Abstract

Equipment using DC/DC converters for rail, industrial, and other ruggedized applications in environmentally challenging conditions, need to meet special requirements for DC input range, EMC compliance and shock/vibration. Wide temperature swings are also present, often coupled with the challenge of condensation. Compliance with fire safety regulations must likewise be addressed. With general requirements requiring high efficiency and compact size, power converters have a complex set of specifications to meet. This article explains some of the challenges and introduces off-the-shelf solutions that simplify and de-risk system design.

Article

The transportation market is on the upturn, with rail in particular expected to be worth around €188bn [1] in 2019. The forecast growth rate of 2.8% is being driven by increased traffic, environmental considerations, and renewal and modernization programs in Europe and North America. However, the proportion of spend on electronic systems in rail is exponentially increasing as safety, telemetry and infotainment systems are expanded. The move away from fossil fuels to electric drives also adds further layers of electronic control.

By the nature of the application, electronic systems in trains are powered from a relatively noisy DC source. Voltage spikes, surges and drop-outs are common, along with radiated and conducted EMI from the high-power transmission systems. Shock and vibration are a constant stress and temperature extremes and swings are normal. The safety of passengers and staff is also of utmost concern and the flammability of the materials used, and the smoke and gas emissions that may result, need careful consideration. Additionally, there are other markets that face some or all of the same challenges. Industrial mobile systems, such as construction and material handling machinery and forklift trucks, are also exposed to the harsh outdoors. And similar requirements apply to equipment used by protection and recovery services, such as police and fire services, snow ploughs, and electric vehicle charging stations. With no clear standards of their own, applications in these markets typically turn to existing, ruggedized solutions already designed and built to railway standards.

The conditions in in such systems make standard industrial electronics seem relatively benign. Such solutions are often simply commercial grade with support for an extended temperature range, supply rails are expected to be 'clean', and shock and vibration levels are low.

Ruggedized solutions leveraging standards for railway power electronics

The rail environment, although harsh, has well defined characteristics. Historically, when on-board electrical equipment was simple signaling, control, heating, and lighting, power rails were not filtered heavily and the equipment was expected to simply tolerate variations. The situation has improved but the current relevant specification for rail electronics equipment, EN 50155, still allows extreme voltage swings. Additionally, EN 61373 defines the sometimes harsh shock and vibration environment for different prescribed areas within the train. Other generic standards, such as the EN 61000-4 series for EMC, are also often referenced. Finally, compliance with the British Railway Industries Association standard RIA 12 is often required, including its severe, high energy surges.

EN 50155

EN 50155 is the basis standard for railway electronics, as well as most other ruggedized DC/DC converter applications. It defines environmental and service conditions, reliability expectations, safety, design and construction methods. Documentation and testing are also covered. Typical industrial-grade electronics might meet the general requirements but DC/DC power converters must withstand much wider input voltage variation with several possible nominal values (figure 1).

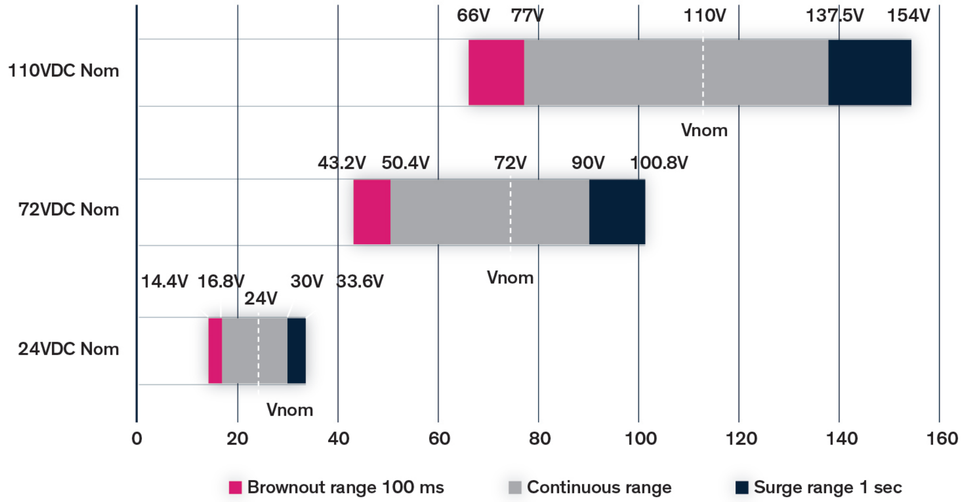

Figure 1: DC input ranges for different rail applications

The variations around each nominal can be summarized as follows:

- Continuous range = 0.7 – 1.25 x VNOM
- Brownout = 0.6 x VNOM for 100ms
- Surge = 1.4 x VNOM for one second

It is typically not practical to ride through brownouts for 100ms, and surges of one second have too much energy to clamp. Power converters must therefore operate over the complete range shown in Figure 1 with some safety margin. In practice, this means an input range of more than 2.33:1. Nominal voltages of 48V and 96V are also possible, with other French and US ranges having different minimums and maximums. The DC/DC converter manufacturers meet these requirements by offering converters with wider 4:1 input ranges (typically 43 – 160V) to cover the majority of applications.Higher voltage, short duration surges, and transients are also specified according to EN 50121-3-2, derived from the basic standard EN61000-4. Fast transients are +/-2kV with rise and fall times of 5/50ns and repetition rate of 5kHz. Surges are +/-2kV line to ground and +/-1kV line to line with rise and fall times of 1.2/50µs from a defined source impedance, AC coupled.

Extra system requirements may include compliance with RIA 12

There may also be contractual requirements to meet extended or different specifications, such as RIA 12. This requires immunity to surges of up to 1.5 x VNOM for 1 second and 3.5 x VNOM for 20ms from a very low source impedance of 0.2ohm. For a 110VDC nominal system this is a peak of 385VDC. This lies outside the normal range of a converter, especially if it needs to work down to the 66VDC brownout minimum. The energy available from such a low impedance source means that the voltage cannot be clamped by a Transient Voltage Suppressor (TVS). Depending on the power level, a pre-regulator on the supply input or a circuit is required that switches off the input for the duration of the surge. Hold-up in the DC/DC converter is required to maintain the output during this time. Another requirement, also from RIA 12, may require withstanding fast transients of up to 8.4kV with a trapezoidal waveform of 100ns duration from a 100ohm source impedance. These are relatively low energy and can be clamped effectively with a TVS diode or proprietary filters from DC/DC converter manufacturers.

Fulfilling EMI and electrostatic discharge requirements

The EN-61000-4 series is normally encountered as a standard for testing compliance with the EMC directive for AC input power supplies, all of which must have appropriate filtering. Industrial DC/DC converters, however, are normally embedded in electronics and protected from supply-borne conducted EMI. Since they do not normally include filtering suitable for direct connection to rail DC supplies they require additional external filter networks. EN 50121-3-2 also includes requirements for immunity to conducted common mode RF up to 80MHz and immunity to electrostatic discharge and electromagnetic fields at the enclosure port level. Conducted emissions follow the requirements of the basic standard EN 55016-2-1. EN 50155 provides an example of physical EMC areas A, B and C in rail applications (figure 2) that guide the system designer to choose the appropriate level of EMI filtering.

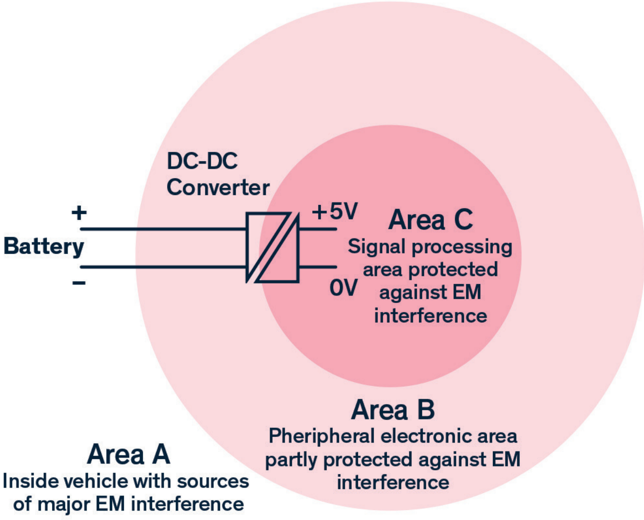

Figure 2: Typical positioning of a DC/DC converter between EMC areas in a rail application

Railway shock and vibration requirements are tough

Shock and vibration tests for rail applications are defined in EN 61373. This specifies different categories of locations with increasing levels of test severity.:

- Category 1, Class A, Body mounted
- Category 1 Class B, Body mounted
- Category 2, Bogie Mounted
- Category 3, Axle mounted

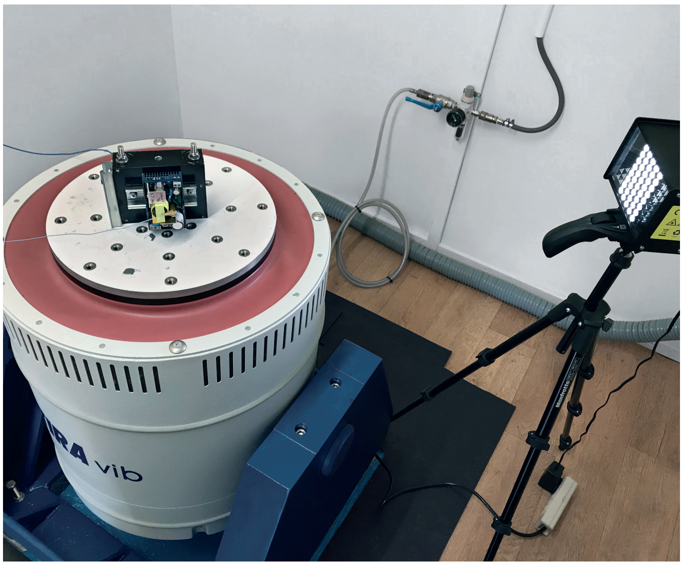

Figure 3: Vibration test setup at the Traco Power Solutions laboratory in Wexford, Ireland

IAs an example, low mass items in Class B body-mounted equipment must withstand vibration accelerations of 5.72m/s2 in the vertical direction at test frequencies between 5 and 150Hz, with longitudinal shocks peaking at 50m/s2 (almost 5g). In the most severe axle-mounted environment equipment must withstand vibration up to 144m/s2 (nearly 15g) and shocks of more than 100g in any direction. Using a vibration exciter (also known as shaker) coupled with a stroboscope it is possible to evaluate the movement of individual components (figure 3). This enables the detection of potential mechanical weaknesses during the development process.

Functional conditions and higher severity long life stress levels are defined for different mounting orientations and, again, power modules not built to be rugged are unlikely to be adequate. At low power, SIP style mounting of DC/DC converters does not provide sufficient mechanical support. For this reason, the TMR 3WIR and other similar products feature offset mounting pins that provide additional mechanical stability, as does the encapsulation used (figure 4). Larger devices, such as the TEQ 300WIR series, combat the effects of vibration through the use of spring clamps for the cable connectors, ensuring a stable and long-lasting connection (figure 5).

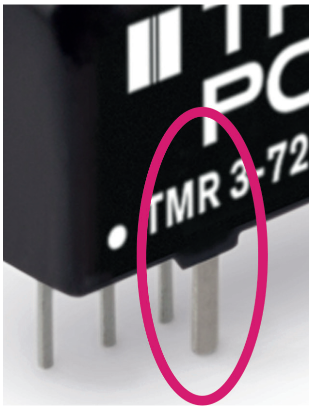

Figure 4: Additional offset mounting pins on the TMR 3WIR offer mechanical stability

Figure 5: TEQ 300WIR offer additional security against vibration-effects with the spring clamps

Temperature shock, the operating environment and fire safety

Continuous operating temperatures in rail applications are normally not very severe with passenger and cab areas expected to lie at 25°C nominal, rising up to 55° C. Equipment cubicles may be at 70°C but, in all cases, equipment must survive an extra 15°C degrees for 10 minutes. Thanks to the optimal design of integrated heatsinks, solutions such as the TEP 150WI and TEQ 300WIR fulfil these cooling requirements (figure 6).

Figure 6: TEP 150WI like the TEQ 300WIR include a passive-cooling-system (heatsink) and does not require any additional cooling.

At first glance, power converters rated for -40 to +85°C seem adequate for most thermal environmental challenges. Thermal shock, however, must also be considered. This replicates a train or other vehicle entering and leaving a tunnel or building where 40°C differences may be encountered at rates of change of 3°C per second. This sudden change in temperature may cause condensation to occur suddenly. Power converters for such environments require encapsulation or conformal coating with special precautions against damage from differential expansion rates and thermal shock. The selection of nickel-plating, as opposed to gold, for the TEN 40WIR series of DC/DC converters provides protection against the corrosion that can result from repeated exposure to condensation.

To ensure the safety of passengers in the event of a fire, the materials used in DC/DC converters must also conform to EN 45545-2. For rail transportation this is defined using a combination of the vehicle's construction and utilization category that determines the hazard level (HL). This is then coupled with the requirement set that determines which product requirements apply, such as R26 for small electronic products. Resultant from this process is the testing approach and the maximum permissible values for oxygen index, flue gas density, and smoke toxicity. The ultimate goal is to minimize the likelihood of a fire but, should one occur, limit its impact on passengers and staff in getting to safety unaided.

Off-the-shelf solutions

Fortunately, designers do not need to worry about these harsh specifications for DC/DC converters as manufacturer Traco Power [2] has addressed the rail requirements with a wide range of off-the-shelf products (figure 7).

Figure 7: Typical products from Traco Power suitable for rail and similar applications ranging from 3 to 300W

Power ratings are from 3W to 300W, with the PCB mounted solutions supporting 11 ranges of power and the chassis mounted solutions providing 9 power ranges. All offer a 4:1 input range with variants that include 43-160VDC for 110VDC nominal as well as 9-36VDC and 18-75VDC for 24 and 48VDC nominals. Packages include metal-can SIP8 in 3 and 6W variants with additional mounting tabs for vibration-proofing; 8W in a DIP24 package; and industry standard 1" x 1" and 2" x 1" types for ratings of 10W through 40W. Chassis-mounted versions are also available from 20W to 300W. Depending on the variant, the converters include input filtering up to EN 55032 class B level and feature the ruggedizing and environmental sealing required for rail and similar applications [3].

Summary

Swiss company Traco Power is well known for its broad range of quality AC/DC power supplies and DC/DC converters for general applications. By using their ruggedized range of DC/DC converters, designers of critical systems in rail and similar industries, such as construction machinery and material handling, can concentrate on developing their end system, secure in the knowledge that their power supply challenges have already been resolved.

References / Links

[1] SCI study forecasts upturn in global rail market: https://www.railjournal.com/in_depth/sci-study-forecasts-upturn-in-global-rail-market

[2] Traco Power: www.tracopower.com

[3] TRACO POWER - Railway Power Solutions Portfolio: https://www.tracopower.com/fileadmin/files/support/

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Date June 2019

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