Bel Fuse

The Future of Railway Power Conversion – The RCM500E

By Silvan Mueller

Introduction

Power conversion in railway applications forms a critical component in power distribution and safety, ensuring that energy is efficiently transformed and managed to support various onboard systems.

Choosing the right partner for power conversion equipment can significantly benefit engineers by ensuring reliability and performance enhancements, while maintaining an edge with the latest innovations. Bel's next generation of DC-DC converter under the Melcher brand, the RCM500E, does just that.

Using modern technologies and manufacturing, this converter delivers all the same rugged and efficient design expected of the Melcher brand, while significantly reducing cost and form factor. This article investigates the design and innovations inside the latest railway DC-DC converters.

The Challenges of DC-DC Conversion

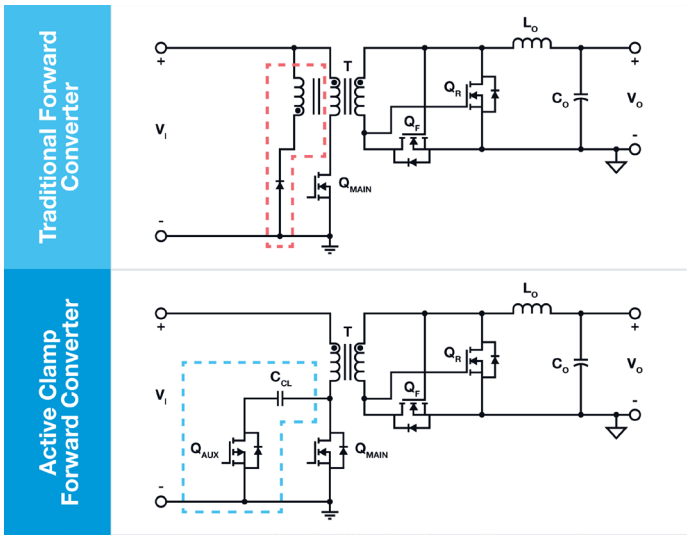
The challenges faced by DC-DC converters are well documented, and yet, the need for their use remains constant. Some of the biggest challenges faced by DC-DC converters by far are the tradeoffs between size and efficiency.

The size of reactive components, such as transformers and capacitors, are all frequency-dependent and shrink with increasing frequency. However, switching losses go up with frequency, lowering efficiency and giving designers a choice between designing a small converter or an efficient converter. At the same time low efficiency means more thermal management, which can negate any power density gains from increased frequency.

The high-frequency make/break of inductive currents through transformers can also induce large voltage spikes which can damage components. This is often compensated for with larger, less efficient switches and makes them more expensive. These spikes can also lead to EMI and require additional large magnetic filtering components to mitigate. All of this can make a DC-DC supply larger and heavier, which can negatively affect an application with physical constraints.

A lot of research has gone into developing new methods and topologies that can limit switching losses, enable higher switching frequencies and reduce form factors.

Bel's RCM500E from the Melcher brand is the next generation of DC-DC for railways



Comparison to traditional forward converter schematic (top) and active clamp forward converter (bottom)

The Benefits of Active Clamping Forward Converters

One design topology that is starting to gain traction in the power industry is active clamp forward converters (ACF). In an ACF, an active switching device and capacitor replace the core reset winding and diode of a traditional forward converter.

In both the traditional and ACF cases the reset circuit prevents so-called flux-walking, where the flux in the transformer core increases with each switching cycle until it saturates. However, the ACF's active reset circuit brings other benefits that make it an excellent choice for DC-DC conversion including:

- Low switching loss
- Reduced voltage stress
- Low EMI
- High power density

A key benefit of the active clamp is zero-voltage switching (ZVS), which reduces switching losses and allows for increased switching frequencies. In the traditional forward converter, the voltage across the switch is still high when current begins to conduct, leading to large power losses until the switch is fully turned on. With ZVS, the switch voltage is kept low while the switch is turned on which significantly reduces these losses.

The soft ZVS switching, enabled by the active clamp, also reduces the large voltage spikes and high-frequency noise generated during switching events. This reduces voltage stress on the semiconductors and other components and helps in minimising EMI, making it easier to meet electromagnetic compatibility (EMC) standards without requiring extensive filtering.

Reduced switching losses, increasing switching frequency and better utilising the transformer core all help improve the power density of the topology and extend its viable power range. Where a traditional forward converter could only reasonably achieve 200W, the ACF is useful up to 500W or more.

However, the downside to active clamp forward converters is the inclusion of additional design complexity. Compared to the simple and passive reset winding method, the active clamp method has additional timing stages, gate drivers, and design considerations that can make it a challenging topology that requires expertise in DC-DC converter design to successfully apply.

How the RCM500E Solves These Challenges

Recognising these challenges faced by engineers in the railway industry, Bel has introduced its latest Mecher brand DC-DC offering, the RCM500E, which takes advantage of the active clamp forward topology to achieve significant reduction in size and cost without sacrificing performance or efficiency.

Because traditional forward converters could not achieve the necessary power levels, previous generations of Bel DC-DC converters used two power stages to achieve their industry-leading performance. By applying the newer ACF topology, Bel's engineers reduced the number of power stages from two to one without sacrificing performance or efficiency. This also resulted in a lower component count, around 60% less than previous designs.

The RCM500E also makes minimal use of through-hole parts, resulting in faster production times, which in turn allow for more extensive testing and inspection. Furthermore, the automation of the manufacturing has reduced overall cost of production while increasing the number of tests that can be performed each time.

The improved manufacturing techniques, combined

Bel's Mercher-brand DC-DC converters support the power needs of modern railway systems

with reduced component counts has led to a 36% reduction in cost compared to the previous generation.

RCM500E Specs

- Input voltage range from 72V to 110V designed for railway
- Output voltage of 24V
- Up to 500W output
- Compliant with EN 50155, EN 50121-3-2, AREMA
- Safety-approved to the latest edition of IEC/EN 62368-1 and UL/CSA 62368-1
- Fire and smoke: compliant with EN 45545 and NFPA 130
- Overtemperature, overvoltage, overcurrent and short-circuit protection

Hidden Risks of DC-DC Selection

When it comes to railway systems, the importance of choosing the right DC-DC converter cannot be overstated. Unlike other applications, where a DC-DC converter may be a small, inconspicuous component, in railway systems, the size and weight of such units can be a major issue. The fact that several hundred of these units can be present within a single train makes this a critical consideration.

The increased weight that comes with larger DC-DC converters can lead to higher fuel costs, while the high component count introduces multiple points of failure. Additionally, the need for quiet, EMI-free designs can be particularly challenging, requiring careful attention to detail and a deep understanding of the complex interactions between different components.

State-of-the-Art Solutions

Fortunately, engineers now have access to state-of-the-art solutions that can help address these challenges. One such example is the RCM500E, which employs an active clamping forward converter topology. By reducing the number of switching components from six to one, this design achieves a 60% reduction in component count, resulting in considerable cost savings of around 30%. This reduction in complexity not only makes the design more efficient but also more reliable, as there are fewer potential points of failure.

The Melcher brand has been a leading developer of high-quality power electronic solutions for decades, earning a reputation for delivering reliable and efficient systems even in the most demanding environments. With a deep understanding of the unique challenges faced by railway systems, Bel's power solutions are designed to meet the highest industry standards.

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