RUGGED CONVERSION TECHNOLOGIES FOR EXTREME ENVIRONMENTS

Factors such as component characteristics, materials selection, topology and assembly have helped to deliver a new range of DC/DC conversion technologies for defence and aerospace applications.

Pushing the boundaries of performance is not always about the search for more MIPS, greater energy efficiency and smaller size. For military and aerospace designers in particular, advancement is just as often about eliminating failures, increasing safety, designing in longer term reliability and ensuring resistance to extreme environmental conditions.

By these measures, materials and manufacturing processes are often every bit as important as electronic components themselves - particularly when it comes to attaining exacting environmental specifications.

Recent advances in these areas from International Rectifier (IR) have laid the groundwork for the development of a new generation of power conversion products that promise to substantially exceed the performance of existing commercial-off-the-shelf (COTS) alternatives, particularly in the area of high temperature operation.

**DC/DC converters for extreme environments**

Until recently, DC/DC converters for extreme high temperature environments (over 150°C) were not readily available off-the-shelf. In fact, few commercial products could exceed 125°C, and none were available beyond 175°C. Designers seeking to satisfy the utmost temperature and vibration requirements, such as those encountered in aircraft engine control and oil drilling applications, therefore commonly needed to build their own converters, with consequently long lead-times and substantial non-recurring engineering (NRE) costs.

International Rectifier has recently solved these problems with the launch of its HTA series of DC/DC converters. Already available in a 20W version that tolerates temperatures from -35°C to +185°C, the core technologies used for the HTA series promise to deliver even greater performance in the future, with power handling of up to 90W and operating temperatures of up to 200°C and higher.

The basic HTA design topology (figure 1) is based on IR's APL series - itself a proven performer, used for more than a decade in military, aerospace and other high reliability applications. It uses a single-ended forward topology with resonant reset. Two high voltage power MOSFETs in series allow the units to accommodate high input voltages - 250V continuous and 300V for short durations - and minimise voltage stress.

The nominal switching frequency is 500kHz and the PWM controller incorporates an IR ASIC to minimise size and component count. Input/output isolation and excellent output voltage regulation are achieved through the use of magnetically coupled feedback. Voltage feed-forward with duty factor limiting provides high line rejection and protection against output overvoltage in the event of an internal control loop failure. The design includes an LC input filter to control the conducted emission propagating back on to the input lines. The typical input ripple current is limited to less than 15mA peak-to-peak.

On the output side, two isolated windings with the traditional rectification arrangement are followed by individual low pass output filters that attenuate the higher frequency ripple and noise. The built-in output overload and short circuit protection makes use of the resistance of the inductor wire to reduce power losses. Output voltage is sensed and the control loop is closed across the positive output. The negative output is expected to provide regulation with balanced loads. For single output models, only a single secondary winding, associated rectification and filter circuit are used.

As well as topological choices, the designers of the HTA series were aware that selection of devices was an important element. They therefore delivered an electrical design with conservative derating of electrical components, to minimise stress.

*Figure 1 - HTA dual output block diagram*
and to ensure that the completed product would function well within the required parameters. The result is a product that does not require derating with increasing temperature.

Assembly and packaging
Assembly and physical design is just as important as circuit topology and device selection in delivering the HTA's high reliability. The device is based on a hermetically sealed thick film hybrid to ensure the lowest possible junction thermal impedances. The hybrid approach, which provides an inherent iso-thermal plane, offers the shortest thermal paths from the components to the base for cooling. This, in conjunction with the use of high thermal conductivity materials throughout the design, ensures the best possible thermal performance.

As with any component, the package is possibly the most important factor in ensuring that heat is conducted away from the electronics, and that cooling is therefore effective (figure 2). In the case of the HTA, IR has chosen a uni-body aluminium-silicon construction for the base and side walls, bestowing excellent thermal conductivity and mechanical robustness.

The assembly process itself is also vital. This begins with attachment of electrical components by solder reflow or adhesive epoxy to bare beryllium oxide (BeO) thick film substrates with screen-printed resistors. Transformers and other magnetic parts are attached to the substrates and base of the assembly with thermally conductive epoxy. The assembled substrates are then solder reflowed to the base. Lead frames and wire bonds are attached from substrate-to-substrate and from the substrates to the I/O pins.

When the electrical interconnections are complete, the assembly is inspected for manufacturing defects and tested to ensure proper functionality. High profile components are then secured with silicone-based gap filler to enhance mechanical stability, and guarantee the required shock and vibration performance. The lid is laser sealed to complete the assembly, which is retested for function, and subjected to reliability screening.

Qualification testing includes an operating life test at 185°C, extending to device destruction or 10,000 hours. Temperature cycling and 500G shock testing is also carried out. For vibration resistance, devices are subjected to 20G RMS, from 5Hz to 500Hz, for 60 minutes per axis.

Not only do these tests demonstrate that the design performs within specification, just as importantly they show little variation from device to device, demonstrating that users can reliably characterise the converters' expected operation.

Added value features
Conservative design disciplines, well characterised performance and COTS availability all contribute to a DC/DC conversion technology that will address the performance, reliability and commercial requirements of military and aerospace OEMs. Furthermore, in order to optimise the familiar COTS advantages of reduced NRE and faster time-to-market, IR has also designed in a number of value added features. These include the ability to synchronise multiple converters and thus service higher power requirements, precise output adjustment and on/off control.

Single output models include remote output sensing, and the galvanic isolation between input and output not only allows several converters to be stacked to deliver higher voltages, it also protects the output load from input-side system failures.

Advanced performance
The HTA series (figure 3) represents a significant advance in the performance of rugged DC/DC converters, delivering reduced programme costs, short lead time and ease of system integration. The key factors in its development have proved to be an in-depth understanding of component characteristics, materials selection, a proven circuit design topology, conservative component derating, advanced assembly design, and process development. With products already realised that deliver 20W at 250V and 185°C, the same technologies will easily enable the creation of 45W and 90W platforms. 400V continuous voltage handling and operating temperatures of up to 200°C.

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