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Advanced Power Conversion Provides New Capabilities

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Amid growing demand for power solutions, consolidation of suppliers and restructuring of telecom, datacom and computer markets, the DC-DC converter is undergoing a period of intense technological innovation. From a performance standpoint, power densities are increasing, the cost per Watt is dropping and efficiencies are edging up. Component power manufacturers are increasingly packaging higher power modules for surface mounting and employing synchronous rectification for higher efficiencies at the lower output voltages. What's more, designer demand for even greater power densities, lower costs, smaller footprints, lower profiles and higher reliability continues unabated.

Two additional aspects of power conversion should be considered, one old and one new. Improvements in heat and noise management, traditional adversaries of high-density DC-DC converter designers, are often needed to achieve primary feature improvements. The newest requirement for power components begins at the system level: system availability. Access to information is becoming a mission critical component of business operations. The tolerance for interruption is disappearing; more important, the cost of delivering 100 percent availability is being exceeded by the cost of lost operations. Users of telecom and datacom are demanding at least the same levels of service that they are used to receiving from other areas of communication, such as plain old telephone service (POTS). For the DC-DC converter, that means effective fault tolerant solutions and, frequently, hot swap capability.

Topics to be considered include power density, surface mounting, efficiency and heat management, noise management, wide output voltage range, reliability and fault tolerance.

Power Density

New high density DC-DC converters - some sporting power densities over 150 W/in3 - are helping designers conserve valuable board real estate and minimize the number of modules needed to satisfy their power requirements. In spite of being dismissed by some as marketing hype, high power density continues to be one of the attributes of modular DC-DC converters in demand by OEM power architects. Higher power densities are being achieved in a number of ways, such as advanced transformer designs, packaging without encapsulation, silicon integration, and, of course, high frequency operation.

High-frequency operation has long been recognized as one key to achieving high-power density - e.g., smaller magnetics, filters and capacitors - in switchmode converters. With conventional switchmode converters, however, switching losses increase directly with operating frequency, resulting in a "frequency barrier" that limits achievable power density. Zero-current-switching converters overcome the frequency barrier by having each switch turn-on and turn-off occur at zero-current. Such converters operate at frequencies in excess of 1 MHz and can achieve power densities ten times greater than low frequency converters.

Silicon integration of the control circuitry is another avenue to achieving higher power density in DC-DC converters. Control functions can be reduced to a volume of only 1/10 of a cubic inch. In another example, integration can reduce the size of the pulse coupling transformer by a factor of 10. As a result of such improvements, a DC-DC converter can produce three times the power of previous converter designs in the same package size.

Surface mounting: The use of surface mount technology (SMT) can substantially improve manufacturing throughput, but not all manufacturers are using the same definition. One definition of an SMT-qualified product is it must be: (1) packaged for easy dispensing (such as in a tape and reel configuration), (2) delivered to the PCB by pick and place equipment and (3) be capable of undergoing 280°C, 10-second reflow soldering.

By that rigid characterization, not all so-called SMT converters fully qualify. However, the number of qualifiers, and the power they can deliver, is growing. Increasing power densities, as well as improved packaging and higher efficiencies (eliminating the need for potting or heat sinks), are reducing the size and weight of DC-DC converters and creating more candidates for surface mount capability.

Others are applying the spirit of SMT, if not the definition, by delivering many of the manufacturing benefits of the technology by, for instance, eliminating the need for hand or wave soldering, while still requiring manual placement.

Efficiency and Heat Management

Manufacturers of modular DC-DC converters employ a range of strategies to cope with the unavoidable generation of heat. They strive to make their modules as efficient as possible with many DC-DC converters now operating in the low 90 percent range.

The use of synchronous rectification instead of diode rectification is one popular strategy to improve efficiency. Diode rectification uses a Schottky diode, which has a small resistance and an essentially constant voltage drop. Consequently, the dissipated power is roughly proportional to the current through the diode. Synchronous rectification, on the other hand, operates a little differently and introduces additional cost and complexity. It employs a MOSFET switch or switches to accomplish rectification; the power dissipated in this case is roughly proportional to the square of the current. At lower currents, the MOSFET will generate less heat than the diode. After a crossover point, perhaps about 20 Amps, diode rectification will generate less heat loss than the MOSFET. (See Figure 1.)

Clearly, using synchronous rectification to achieve higher efficiencies is not the answer for every application.

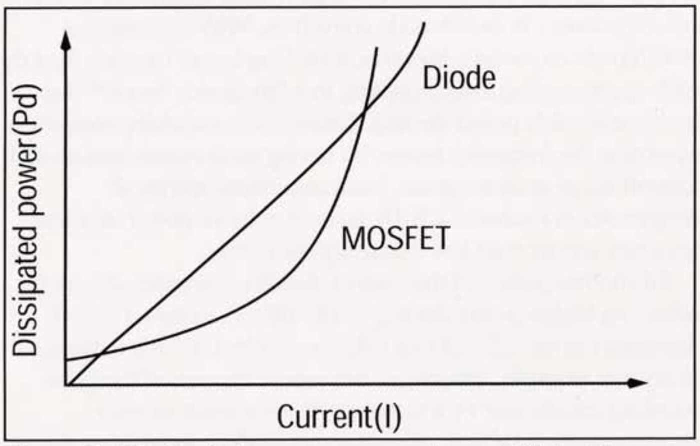

Figure 1. Dissipated power comparison of Schottky diode and MOSFET

Noise Management

Noise can vary widely among DC-DC converters from supplier to supplier and topology to topology. The reasons for this are diverse, but they include fundamental differences in the way noise is produced. Although many DC-DC converter topologies are used to produce the direct current used by electronic equipment, these topologies reduce to variants of essentially two classes: pulsewidth modulation (PWM) and quasi-resonant, such as zero-current-switching (ZCS).

A partial explanation for the difference in noise of each topology is found in the differences in their current waveforms. The spectral content of the ZCS waveform is lower in amplitude and contained in a narrow band. In a PWM waveform, the spectral content is higher in amplitude and spread over a broad range of harmonics.

Wide output voltage range: Among available DC-DC converters, a voltage trimming range of +/-10 percent is most common, while some converters are available with a wide range of +10 percent to -90 percent.

The wide output voltage trimming range offers more choices for designers. A 12 Vout module, for example, can provide a trim range of 1.2 V to 13.2 V, while a module with 5 V, 400 W output can provide 3.3 V, 2 V, or 1.2 V at 80 A.

Wide output voltage range offers designers the ability to create nonstandard output voltages and to minimize the number of different models that must be purchased and stocked. For one-time resetting of the output voltage to a known value, fixed resistor trimming is useful. A typical example of this would be an application involving two similar output voltages, such as 5 Volts and 5.2 Volts, where it is advantageous to stock only one model type. Another example would be in a system where the module is mounted on a card that can be plugged into multiple slots in a backplane, each slot programmed via a fixed resistor on the backplane to a different voltage.

Reliability and Fault Tolerance

Reliability of high-density modular DC-DC converters continues to improve, with MTBFs being quoted in the hundreds of years. The use of silicon integration in one converter family cut the parts count from 113 to only 35, significantly improving MTBF.

The first and foremost requirement for fault tolerance is redundancy, i.e., the existence of at least one extra, or "redundant" converter in the system. Such a system of converters is commonly referred to as an N+M array, where N converters are required to satisfy the power requirements and M additional modules provide redundancy. All modules in the array must be capable of supplying undisturbed power in the event of shutdown or failure of one module, in spite of the sudden change in load current demanded of each. To satisfy these criteria, it is essential that the individual converters share the load current, in order to minimize the dynamic response required of each.

An increasing number of features that simplify application in a redundant parallel array are available. The most significant of these include enable/disable capability, a unique master/slave current share control scheme and the ability to self arbitrate the leadership role. One converter will always assume command of the entire array. These products also possess the commonly available features, such as undervoltage lockout, softstart, output current limiting and remote sense capability.

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