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POWER SOURCES

DOES POWER CONVERSION TOPOLOGY MATTER?

By Robert Marchetti

DC-DC power conversion is omnipresent. Electronic systems throughout the world are powered by direct current, which in most cases is converted by DC-DC converters to the voltages needed by each part of the system.

Today this power conversion is usually accomplished by high-density DC-DC converter components based on high-frequency switching technologies. Efficient high-frequency operation has long been recognized as the key to achieving high-power density and improved performance in switch-mode converters. High-frequency operation translates into smaller magnetics and capacitors, faster response times, lower noise levels and smaller filters.

Although the number of designs, or topologies, of DC-DC converter components certainly number in the hundreds, they fall into only two dominant classes: pulse-width modulation (PWM) and quasi-resonant zero-current switching (ZCS). Whatever the topology, however, modules are available that deliver high-density power at low cost and small size, in a wide variety of input and output voltages. The question is: does power conversion topology matter?

In some cases, topology does matter. With the pulse-width modulation approach, the input voltage is switched at a constant frequency (usually several hundred kilohertz) to create a pulse train. The width of the pulses is adjusted to provide the necessary power to load at the correct voltage. At full load, the current waveform looks much like

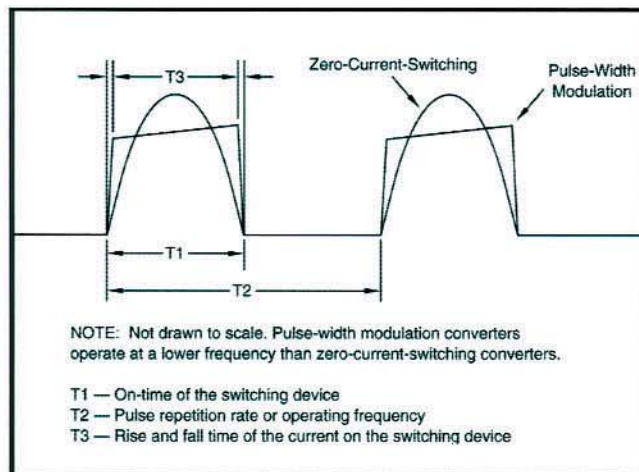


Figure 1. Current waveforms produced by zero-current switching and pulse-width modulation.

a square wave (see Figure 1).

PWM converters are power density limited because they inherently trade off efficiency against operating frequency. The problem is 'switching losses:' heat is generated in the switching element each time it discontinuously makes and breaks inductive current flow during its brief turn-on and turn-off transitions (T3 is fixed). Power dissipation, due to switching losses, increases directly with operating frequency in PWM converters until it becomes a dominant loss factor (T1 is variable). At that point, efficiency declines rapidly, and the thermal and electrical stresses on the switch element become unmanageable. Losses attribute to non-zero-current-switching result in a 'frequency barrier' which limits achievable power density in conventional converters.

Quasi-resonant ZCS converters overcome the frequency barrier by implementing a forward converter switching at zero-current.

Each switch cycle delivers a quantized 'packet of energy to the converter output, with switch turn-on and turn-off occurring at zero-current. Zero-current-switching results in an essentially lossless switch. ZCS converters can operate at frequencies in excess of 1 MHz. By eliminating the fast current discontinuities characteristic of conventional topologies, zero-current-switching results in a virtually lossless transfer of energy from input to output with dramatically reduced levels of conducted and radiated noise.

Quasi-resonant converters have sinusoidal waveforms (as shown in Figure 1) that produce less harmonic noise. In addition to less harmonic noise, the lack of sharp edges in the current waveforms produces much less excitation of the parasitic elements, resulting in far less parasitic noise. On the other hand, the sharp edges of the PWM pulse train not only create harmonics of the switching frequency, they also excite parasitic elements in the converter, resulting in the generation of much higher frequencies (10 - 30 MHz). All of this is considered noise, which is returned to the input line (conducted) and broadcast through the air (radiated). Filtering and shielding can be major design issues, depending on the noise requirements of the final system.

In addition, because of their ability to operate at higher frequencies (resulting in smaller reactive components such as capacitors and magnetics), ZCS converters achieve power densities up to twice those of PWM converters. They also have essentially constant efficiency from 20% load to full load

while the efficiency of PWM units begins dropping off below full load. This is an important consideration if the load is dynamic or operation at low loads is anticipated.

Other features are available as a direct consequence of the ZCS topology: a wide output voltage trimming range and a power sharing capability that facilitates parallel operation for power expansion or redundancy.

The wide output voltage trimming range offers more choices for designers. Among available DC-DC converters, voltage trimming ranges of +/- 10% are common, and converters with a range of +20%/-50% can be found. A Vicor second generation con-

verter, however can be adjusted or programmed from 10% to 110% of the nominal output voltage using fixed resistors, potentiometers, or voltage DACs. A module with 24 V output can provide 12 V or 15 V while a 400 W module with 5 V output can provide 3.3 V, 2 V, or 1.2 V at 80 A.

The vicor N+M power sharing architecture elects one module as the master, or talker, at start-up. The other modules, the listeners, synchronize to it. Based on an input-side bus, the modules communicate by means of high-speed pulses. This allows the status of the system to be monitored on a pulse-by-pulse basis. In the unlikely event that the master fails, another module will be elected master and the system will continue to oper-

ate without interruption. Because the synchronizing pulses have a duration of nanoseconds, the modules can be AC coupled with a small capacitor. The ability to duplicate the bus and the isolation provided by the capacitor ensure that a single interruption or short circuit will not affect the system's integrity.

Topology, then can have a significant bearing on converter selection if noise, high power density, constant efficiency, wide output voltage trimming range, or fault-tolerant redundancy are important in a given application.

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