Power, Packaging & Components
TECHNOLOGY FOCUS--POWER SUPPLIES

When It Comes To CompactPCI Supplies, Standards Are Helping

Despite Evolving Standards, The Wide Variety Of Supply Topologies Leaves It Up To The User To Match The Product To The Application.

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Although an increasing number of embedded-systems integrators are using the CompactPCI architecture, the power-supply requirements for these systems have not yet been standardized. This task belongs to the PCI Industrial Manufacturers Group (PICMG), which is charged with generating both mechanical and electrical specifications for PCI-based systems and boards for industrial computer applications. The group currently is working on establishing the necessary standards for the power supplies used in these systems. These standards will ensure compatibility among systems as power requirements rocket skywards.

Unfortunately, the term *standard* can be misleading, as manufacturers have a number of power-supply methods for achieving that electrical compliance. Thanks to a wide range of available topologies, different power supplies can provide varying levels of performance on a number of key parameters. These parameters can include output-power/current capability, power-factor correction, filtering, current sharing, and live insertion. The topology each manufacturer uses is a key differentiator when it comes to choosing the supply most suited to the application.

CompactPCI (cPCI) itself is a leading bus architecture for embedded systems in the industrial-control, computer-telephony, and telecommunications markets, to name a few. By combining the PCI desktop architecture and the rugged Eurocard form factor, cPCI increases the functionality and/or flexibility of embedded systems.

The existing cPCI specification (Rev. 2.1) includes portions detailing general power-supply requirements. While these basic requirements are expected to remain, they do not leave room for expansion as systems evolve. In fact, most front-end, pluggable power supplies used in cPCI systems prior to this year were less than 150 W. As power requirements increase, integrators will need power supplies that provide more power, are scalable, and are cost effective. The cPCI power-interface specification will ensure the commonality of such power supplies, both mechanically and electrically.

The mechanical definition of cPCI power supplies generally will follow the guidelines set in various IEEE 1101 specifications. The power supplies will be limited to the size of a particular system being designed, typically 3U or 6U high, 160-mm deep, and 8HP wide. The existing cPCI specification details the use of a DIN "M"-type connector for use on power supplies. The new specification also will include other connector types to enable flexibility as power requirements increase and different features are needed.

With regard to electrical requirements there is, to date, no single document that would specify all cPCI power-supply parameters. There are, however, a number of preliminary document drafts. These drafts,which list only a few basic requirements, include the Power Interface specification PICMG 2.11 D0.3, CompactPIC specification PICMG 2.0 R2.1, and Hot Swap specification PICMG 2.1 R1.0.

For example, the document PICMG 2.0 (Sept. 2, 1997) sets nominal voltages (5 V, 3.3 V, ±12 V), tolerances (±5%), and maximum ripple (50 mV), measured with external 22-µF and 0.1-µF capacitors at the measurement point. The PICMG 2.11 D0.3 draft (Oct. 30, 1998) sets tighter tolerances of +4% and -2% for 5- and 3.3-V outputs. This draft also lists some basic power-supply design rules, such as the use of internal OR-ing diodes, enable and inhibit signals, and a new connector pinout. It's expected that the next revision of PICMG 2.11 D0.4 already will include the above mentioned parameters from PICMG 2.0. Most of the important power-supply features, like power and current capabilities, power-factor correction, method of current sharing, and EMI requirements, are not specified by any cPCI document. Instead, they will be determined by the general system requirements.

Power-Supply Design Features

The predominant dc bus voltages required for cPCI systems are 5-V dc, 3.3-V dc, and ± 12-V dc. Other voltages may be required for unique features in some systems. The 5-V dc and 3.3-V dc outputs will provide the bulk of the power, and therefore have the higher current ratings. The input voltages for the power supply will be wide-range ac for worldwide use, and 48-V dc for telecom applications.

One of the challenges for cPCI power supplies is to achieve ever-higher power density. Power supplies use slots in a cPCI system that otherwise would be filled with other feature-filled boards. The smaller the power supply, the more features can be offered by the system integrators. For example, a typical quad-output, full-featured, 150-W model supply and its dc twin can deliver about 4.6 W/in.^{3}, and have a 3U by 8HP cPCI form factor ***(Fig. 1)***.

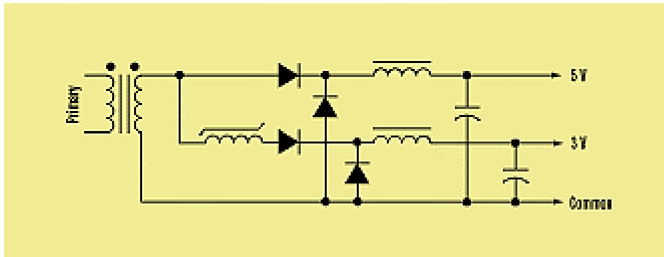
1. These 150-W CompactPCI supplies conform to the standard's mechanical requirements of 3U or 6U high, 160-mm deep, and 8HP wide. The specification also calls for the use of a DIN "M" connector.

Thanks to the lack of standards governing electrical performance, power supplies designed for compliance with the power-interface standard theoretically could use many different topology designs, and provide varying levels of performance on key parameters. Depending upon the type of systems being designed by the system integrator, some particular performance parameters will be more important than others. The following sections relate to different performance parameters, and how different designs lend themselves to better or worse performance.

Output Power and Current: Currently, power supplies are available in 6U (two-slot) packages providing 350 W, and 3U (one-slot) packages providing 150 W, with ever-increasing pressure to provide more power from within these packages.

All microprocessor-based systems use multiple voltage sources with main power often falling on 5 V and 3.3 V. The basic cPCI power supply will provide high current on the 5- and 3.3-V outputs, relatively less current on the 12-V output, and even less current on the -12-V output. In most systems, maximum current from the 5- and 3.3-V outputs normally isn't needed simultaneously. Microprocessor and logic power will drive these requirements. The general industry trend is toward increased current on lower-voltage outputs.

One company's approach to this issue was to develop a proprietary circuit with combined current ratings on 5 and 3.3 V, where individual currents on these outputs may vary in any combination. For example, 150-W models allow up to 25-A combined current on 5 and 3.3 V. Today, for example, a system may need 20 A off 5 V and 5 A off 3.3 V, but two years from now it may need only 5 A off 5 V and 20 A off 3.3 V. A power supply with a dual-output rating will accommodate such evolution of the cPCI system. The dual-rating circuit uses the same transformer winding and the same heatsink for both 5-V and 3.3-V outputs ***(Fig. 2)***. A high-efficiency magnetic amplifier (mag amp) post-regulator provides 3.3-V output from 5-V transformer winding with minimum energy losses. The same mag-amp regulator may be used to reduce the output to 2.5 or 1.8 V.



2. One approach to meeting the general industry demand for increased current on lower-voltage outputs is to use the same transformer winding and the same heatsink for both 5- and 3.3-V outputs. In this case, the individual currents on these outputs may vary in any combination. For example, 150-W models allow up to 25-A combined current on 5 and 3.3 V.

Power-Factor Correction (PFC): Many system integrators will require their systems to be compliant with various input-current harmonic requirements. This, in turn, will require power supplies to include power-factor correction in their design. PFC can be accomplished in various ways.

Passive PFC uses circuits with inductances, capacitors, and diodes that smooth the input-current waveform to some extent. Generally, passive PFC cannot provide high power factor over the wide input-voltage and output-load ranges.

Active PFC usually uses a boost converter with a control circuit that senses a replica of an input current. It then programs the converter's duty cycle so that current drawn from the ac line is in phase with the input ac voltage. This method provides near-unity power factor, and as an added benefit, allows easy operation over a universal input-voltage range of 90- to 264-V ac.

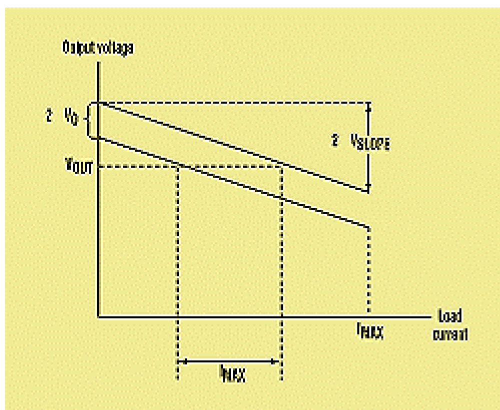
It's important to note, however, that unity power factor does not automatically guarantee compliance with the EN60555 standard for harmonic content. If the input voltage has a high harmonics level and is not sinusoidal, the input current will have the same problem. But in most practical conditions, the input ac voltage is sinusoidal for all intents and purposes, and near-unity power factor practically ensures compliance with EN60555.

Current Sharing: Power supplies designated for use in cPCI systems, in a majority of cases, will be operated in a parallel, redundant mode. To increase reliability, paralleled power supplies ideally should share load currents equally. There are many methods of providing current sharing. These are generally divided into two main classes: third-wire methods and programmed-slope methods.

Third-wire methods (or forced current sharing) use a third wire, in addition to output and return, which has to be connected between all paralleled power supplies. This allows the sharing of individual-current information, and lets their current-sharing circuitry adjust their outputs to balance the currents. It also ensures the best current-sharing accuracy and the best output regulation. On the other hand, it increases the cost and complicates the circuit (separate current-sharing circuitry and an additional wire are needed for each output), and may introduce a single-point system failure.

The programmed-slope method provides automatic current-sharing without additional wires. When the output current increases, the circuit will slightly reduce the output voltage with a predetermined slope. Should one of the supplies try to provide more current, the slope circuit will reduce its voltage to ensure automatic current-sharing with other supplies. This method cannot introduce a single-point failure. It also uses fewer components, thereby increasing system reliability and reducing overall cost.

There is a common misconception among power-supply users that the programmed-slope method provides poor regulation and poor current-sharing. Actually, programmed-slope current-sharing provides accuracy sufficient for most microprocessor applications. Let's look at this method more closely. Suppose a power supply has a maximum output-voltage deviation defined as ΔV_{SLOPE} and an initial adjustment tolerance ΔV_O ***(Fig. 3)***.



3. Despite a common misconception to the contrary, programmed-slope current sharing provides accuracy sufficient for most microprocessor applications. In practice, typical changes in output and slope voltages will yield a maximum current imbalance of only 5%.

In this case, assuming linear "droop," the maximum current imbalance between two supplies will be:

$\Delta I_{MAX} = I_{MAX} * \Delta V_O / \Delta V_{SLOPE}$

where I_{MAX} is the maximum load current.

For typical values, $\Delta V_O = \pm 0.1\%$ and $\Delta V_{SLOPE} = \pm 2\%$. Therefore, the maximum current imbalance ΔI_{MAX} will be only $0.05 * I_{MAX}$, or 5%.This accuracy and load regulation (±2%) are acceptable for most systems.

Live Insertion: Systems integrators must consider voltage transients while using this technique. Live insertion and removal should be allowed by cPCI power supplies without causing any glitches. The problem is that every power-distribution bus has a finite inductance. No matter how good the transient response of a power supply, according to Faraday's Law, a current across inductance cannot be changed instantaneously.

It's important to understand that during live extraction, the initial deviation of the voltage on the backplane, $\Delta V_{HOTSWAP}$, does not depend on power-supply performance, but is a function of backplane impedance. Backplane capacitors with low equivalent inductance and low equivalent resistance may effectively reduce $\Delta V_{HOTSWAP}$. Therefore, the system should have enough tantalum or ceramic capacitors evenly distributed across the whole backplane. Otherwise $\Delta V_{HOTSWAP}$ may be severe, and can trigger system reset or even cause damage to sensitive components.

Also, during live insertion of a power supply, a high in-rush current of tens of amperes flows from the input voltage source. This causes some voltage sag at the input of cPCI power supplies. If this sag goes below the power-supply brown-out voltage, it may cause an output-voltage sag. To avoid this, system designers have to ensure a low impedance from the input voltage source to the input terminals of the power supplies. This is especially important for battery-operated units with dc input. One solution to this problem may be a single, or few, electrolytic capacitors with a combined capacitance of several thousand µF connected across the 48-V input and physically located close to the power supplies' input terminals.

EMI Filtering: The cPCI specification does not specify that a power supply must meet any particular EMI/EMC specifications. The systems that will be using the power supplies, though, will have varying requirements for EMI/EMC filtering.

Most power supplies will include filtering that ensures compliance at least with FCC Part 15, Class A, EN55022 Class A, and CISPR22 Class A. These are the predominant requirements set by the applicable markets for cPCI systems.

A power supply's ability to meet these requirements depends upon the filtering included in the power supply and EMI shields. Typical filtering methods include passive LC filters and front-panel EMI gaskets.

Output Ripple and Noise: The cPCI output-noise specifications require a certain level of noise attenuation along with additional capacitance (typically 22 µF) located on the system backplane. These parameters are set forth in various PICMG specifications and typically are 50 mV or 1%, whichever is greater.

Decision Points: When choosing a power supply, systems integrators most likely will base their choice on a number of performance features, as well as additional available options. Of course, power supplies that include the basic performance characteristics, without additional features, generally will be the most cost-effective solutions. If the system requires more than the basic performance features, system integrators can expect to pay higher prices.

A word of caution here: Power supplies that are extremely low in cost probably do not perform as well as others in some basic performance parameters. Systems integrators should use care in selecting a power supply, as there probably will be many unequal choices. If cost is to be the sole factor in selecting a power supply, expect to sacrifice performance and/or features. The best bang for the buck will be a power supply with good performance parameters, without the unnecessary bells and whistles.

Just as the cPCI marketplace is likely to continue its exponential growth, the capabilities of power supplies servicing this market can be expected to grow as well. System integrators are challenged to retain their competitive edge by enhancing their systems' features at lower cost. The same can be said for power supplies. All power supplies used in cPCI systems will be required to provide the same basic functions, but may differ in performance and features. Power-supply cost, the level of performance, and the amount of additional features a power supply can provide will all affect its reliability and the reliability of the system it serves. The trick is to select the power supply that gives you the best of all worlds.

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