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An influx of novel point-of-load converters wrangles with tougher semiconductor demands.

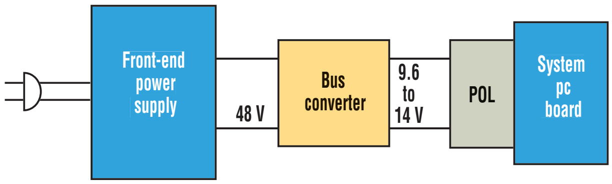
POL POWER SUPPLIES COME IN MANY FLAVORS

Sam Davis, CONTRIBUTING EDITOR

As per usual, the power-supply industry is feeling the heat from the semiconductor industry to meet upgraded requirements for voltage, current, power, and switching speed. That pressure is no more apparent than with point-of-load (POL) converters, which power most low-voltage loads.

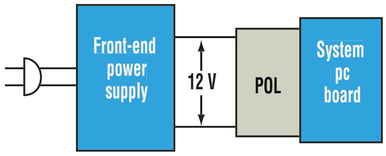
On the bright side, this challenge has spun out several new trends:

- Power-supply companies are developing their own POL ICs.
- New POL architectures promise better performance.
- Digital control is elevating POL converters to a new level.
- Improved power MOSFET packages boost POL efficiency.
- Monolithic IC regulators with higher switching frequency allow for smaller POL capacitors and inductors.



1. Typically, system power management involves an isolated bus converter operating from 48 V (nominal) that delivers a nominal 12 V dc to a non-isolated POL converter.

Ultimately, system designers and integrators must investigate whether to design and build POLs or buy OEM POLs. A company with limited technical resources would probably buy tested and qualified POLs, whereas a company with adequate resources may design and build its own POLs. Regardless of the approach used, designers have many different ways to achieve POL power conversion.



2. IBM doesn't use a bus converter. Instead, it employs a 12-V intermediate bus produced directly by an ac-dc front-end power supply.

To encourage in-house designs, semiconductor companies now provide more "hand-holding." For example, Carl Smith, marketing manager for International Rectifier (IR), points out that his company has developed simulation tools and "demo" boards to assist circuit and system designers who may not have the necessary design resources in-house. IR provides support for power MOSFETs as well as its power-oriented ICs that drive and control the MOSFETs. Thus, IR's support is at the POL system-design level.

WHAT'S A POL? • Why exactly are these trends taking place? To get that answer, designers first must understand POLs. These non-isolated converters accept power input from an isolated dc-dc converter and provide dc power to close-proximity loads. This configuration costs less than an isolated dc-dc converter approach, because the non-isolated POL converters don't have a transformer for I/O isolation. *(For a look at some groups that have formed in this area, see "POLA And The Power-Management Bus," p. 50.)*

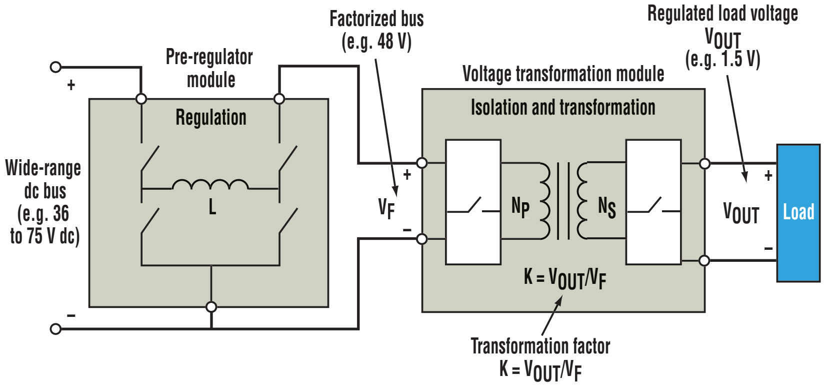
POL dc-dc converters are usually found in small, nonbrick packages, such as a single inline package (SIP) or surface-mount-technology (SMT) module. POL converter modules must be located as close as possible to the circuits they power, which aids voltage regulation. This has become increasingly important as processors operate at lower voltages and higher currents. Also, higher clock frequencies mean that POLs must possess fast dynamic response.

Today, most POL converters are part of a distributed power architecture (DPA). Many but not all distributed power systems employ an intermediate bus architecture (IBA) that inserts a bus converter in front of the POL *(Fig. 1)*.

Randy Malik, a member of IBM's senior technical staff, is responsible for computer power-system design. Therefore, he's involved with power-system design of desktop and industrial computer systems. He points out that the company's POL goals include at least 90% efficiency (45°C to 55°C) with minimum space requirements. The company purchases POLs based on its specifications and occasionally designs and builds some of its own.

These POL converters operate from a 12-V-input bus derived from an ac-dc front-end power supply *(Fig. 2)*. Because the 12-V supply is required for fans and hard drives, it's also used directly for the POLs that provide output voltages in the 1- to 2-V region. No intermediate bus converters are necessary. Virtually all circuits use synchronous rectification and multiphase conversion. Most multiphase circuits employ four phases, while a handful use six or eight phases. A typical multiphase POL for a microprocessor might handle over 100 A at about 1 V.

At the system level, the major problems Malik has encountered are those related to thermal management. Problem heat sources emerge primarily from inductors and multilayer pc boards.

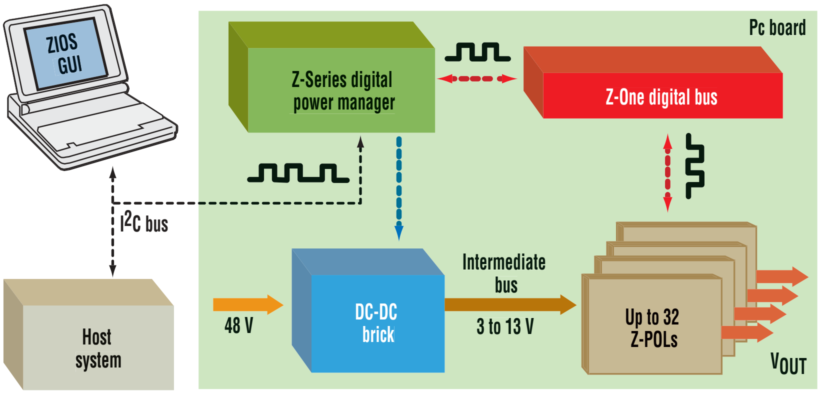


3. The FPA approach uses unique ICs and a unique architecture that offers advantages over the conventional bus converter-POL approach.

FACTORIZED POWER ARCHITECTURE • Vicor is one of the power-supply manufacturers that has developed its own POL ICs, called V·I Chips (VICs). Vicor's factorized power architecture (FPA) uses these chips, which provide a fundamentally different approach to POL conversion. FPA separates dc-dc power conversion into its two essential elements—isolation and transformation on the one hand and output voltage control and regulation on the other—providing these functions in the form of cost-effective modules with very high density.

Figure 3 shows the FPA approach. Voltage transformation modules (VTMs) put isolated current multiplication and voltage division directly at the POL, providing a constant voltage division ratio, or "K factor," as high as 32. Upstream, a pre-regulator module (PRM) controls the factorized bus voltage applied to the VTM. Because VTMs provide true voltage and current transformation, the factorized bus voltage can be relatively high. Narrower copper traces can minimize distribution losses. And, the PRM may be located at any convenient location, either adjacent to or remote from the VTM.

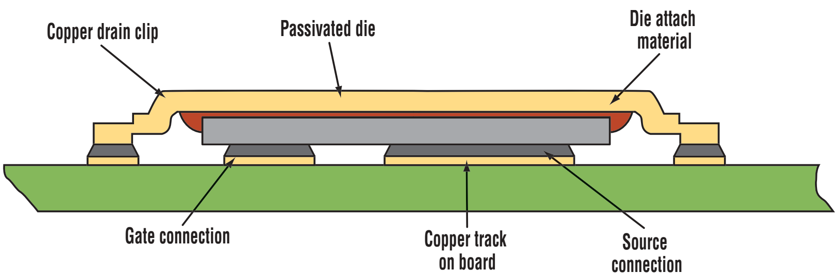
The VTM's very high bandwidth, unimpeded by series inductance, allows support for highly dynamic loads using efficient energy storage at the relatively high factorized bus voltage. Without bulk capacitors at the POL, board real estate is reclaimed for its essential functions. Thus, more advanced, more competitive products can be powered by the density, efficiency, performance, and cost-effectiveness of the FPA—the highest performance and least intrusive form of distributed power.



4. Power-One's Z-One system includes a digital power manager, Z-One digital bus, 48-V bus converter, and up to 32 Z-POSs that integrate digital PWMs.

V·I Chip VTM models can efficiently supply up to 100 A at regulated output voltages of as low as 0.8 V dc or higher, when needed. Compatible V·I Chip PRMs are available for use with a wide variety of input sources. Available now are 48-V_{IN} PRM models for telecom, IT, and distributed power systems. In development are 24 V_{IN} (telecom and industrial); a narrow-range 48 V_{IN} (PoE); 18 V_{IN} (ac adapter); 12 V_{IN} (silver box, intermediate bus); and 28 V_{IN} (military and aerospace).

Initially available in a "Full-VIC" package, V·I Chips occupy only 1 $in.^2$ of pc-board area at power densities of



5. The DirectFET, with pads that mount to a pc board, can be cooled from both the top and bottom of its case.

up to 1000 W/in.[3] Mounting options include BGA in-board mounting and above-board J-lead configurations. To address lower power applications, future "Fractional VICs" will occupy just a fraction of a Full-VIC package's area.

DIGITALLY CONTROLLED POL CONVERTERS • Power-One invested in silicon-based technology to develop its Z-One architecture, which integrates a power system's management and power-conversion functions. The company claims this cuts overall system-level costs by 20% to 50% compared with more conventional approaches. It enables 32 POL converters to fully communicate with each other under the control of a digital power manager (DPM). Each digital Z-Point-of-Load (Z-POL) converter can operate with a 3- to 13-V input and provide a programmable 0.5- to 5.5-V dc output.

The Z-One system uses a single-wire Z-One Digital Bus controlled by the DPM *(Fig. 4)*. This high-speed bidirectional bus provides both frequency synchronization and data transfer, and it can access all Z-POL converters in one communication cycle. The bus carries all information to and from the Z-POL converters and DPM, including all operating parameters for each POL converter.

Operational parameters, such as the output voltage, sequencing, tracking, monitoring, interleaving, and protection thresholds, are user-programmed via a graphical user interface (GUI) and stored in the DPM. Control of this power-management system is furnished by the GUI-based Z-series Intelligent Operating System (ZIOS).

At system startup, this stored information programs the Z-POL converters. After system programming, ongoing communications between the DPM, Z-POLs, and host system support intelligent operation. Designers can repeat this point-and-click process for power-system optimization. The GUI need only interface with the power system during programming, and it can be easily reconnected to support power-system changes.

Communications with the host system use the industry-standard I^{2}C bus communication protocol. Besides remote programming of each POL, the latest status information of each POL (output voltage, output current, and temperature) is stored in the DPM and can be transmitted to the system.

Hardware for the Z-One system integrates two ASICs—the ZM7100 DPM and the maXyz ZY7000 series of Z-POL converters. The ZM7100 DPM programs and controls sequencing, tracking, supply supervision, and intelligence with the aid of analog-to-digital converters.

THE TRADITIONAL APPROACH • One of the traditional power-supply companies is SynQor. The company's NiQor series comprises non-isolated buck POL converters. NiQor modules employ synchronous rectification for very high efficiency. Dissipation throughout the converter is low, so it doesn't require a heatsink or metal baseplate for operation. The NiQor series includes SIPs and SMT using standard footprint and pin-out configurations.

These POLs have a trim adjustment that lets users adjust the output voltage with an external resistor. For example, the NQ12T50SMA16 module accepts a 9.6- to 14.4-V input and provides a nominal 0.725 V at a 16-A output. Thanks to a single external resistor, users can increase the output voltage above its nominal setpoint.

Among its protection features is undervoltage lockout, which turns off the converter if the input voltage is too low and prevents input system instability problems. This family of converters employs foldback current limiting at about 125% of rated current.

POLA AND THE POWER-MANAGEMENT BUS

The Point of Load Alliance (POLA) comprises a number of leading companies, including Artesyn Technologies, Emerson's Astec Power Division, Ericsson Power Modules AB, and Texas Instruments. The organization's goal is to promote pin-compatible, advanced non-isolated, POL plug-in power modules. POLs offer pin-compatible footprints that provide the same functionality and form factors, ensuring full interoperability and true second sourcing.

In December 2004, POLA announced that it will jointly design and release products in accordance with the PMBus (Power Management Bus) digital interface and control specification during 2005. PMBus will permit flexibility in the digital control of power-conversion products.

The PMBus founding group consists of companies from POLA and the semiconductor industry, including Intersil Corp., Microchip Technology Inc., Summit Microelectronics, Volterra Semiconductor, and Zilker Labs Inc. Its goal is to release an open protocol supporting communication to power supplies via a digital bus. Implemented over the industry-standard I^{2}C serial bus, this protocol will establish a common command set for configuring, controlling, and monitoring dc-dc converters. However, it will not dictate how those commands are generated. ***ED Online 9653***

POLs ACCEPT POWER INPUT from an isolated dc-dc converter and provide dc power to close-proximity loads. This costs less than an isolated dc-dc converter appraoch.

SynQor also produces bus converters, like the 240-W BusQor BQ55090QTA27 with 2000-V input-output isolation. Its efficiency is 96% at full rated load current. This board-mountable, isolated, fixed-switching-frequency dc-dc converter uses synchronous rectification to achieve its high conversion efficiency. Packaged in a standard quarter-brick module, the isolated BusQor series steps down 48 V to an unregulated 9.6-V (7.2 to 11 V) intermediate bus. BusQor converters are well-equipped to create the mid-bus voltage required to drive POL (non-isolated) converters in intermediate bus architectures.

Its protection features include input undervoltage lockout and overvoltage shutdown, which protects against abnormal input voltages. It also includes latching output current limit and short-circuit protection, along with latching thermal shutdown.

The POL converters in Tyco Electronics Power Systems' Austin MiniLynx series are available with an input voltage range of 2.4 to 5.5 V dc or 8.3 to 14 V dc *(Fig. 6)*. At 12 V_{IN}, they support intermediate bus voltage architectures and POL currents up to 3 A with an output voltage range from 0.75 to 5.5 V dc. At 3.3/5 V_{IN}, they support output voltages from 0.75 to 3.3 V dc with output current capacity up to 3 A without any thermal derating at 85°C and zero airflow. Efficiencies of 91% for the 12-V_{IN} modules and 94% for the 5-V_{IN} modules are achieved when tested at nominal input conditions and full rated output current.

Offered in SMT packages, both versions are pin-for-pin compatible with the widely used 5-A Austin MicroLynx converters. With output voltage programming by an external resistor, the Austin MiniLynx modules have remote on/off (negative or positive) capability, making it easier for designers to implement power on/off control.

Additionally, Austin MiniLynx modules provide a migration path to higher-current modules in the same pin-outs. They offer an alternative to discrete designs on boards by saving design time and providing low-cost solutions as well. These converters measure 0.80 by 0.45 by 0.286 in. (20.3 by 11.4 by 7.27 mm) and are offered in tape and reel for automated production.

Robust construction enables the modules to operate in temperatures ranging from –40°C to 85 °C. They also can withstand industry-standard handling, cleaning, and soldering processes. Additional protection features include overcurrent, overtemperature, and undervoltage lockout.

AT THE COMPONENT LEVEL • Power MOSFETs are a key component for virtually all POL converters. They're usually the semiconductors within a POL converter that consume the most power, so their performance has a major impact on circuit efficiency.

There's also a need to fully optimize the overall power-management solution. This requires selecting the correct control and driver ICs to work with the MOSFETs. Inadequate controllers and drivers can cause additional power dissipation in the MOSFET as well as in the driver itself. For the past two years, MOSFET manufacturers have pursued various packaging techniques to improve MOSFET performance, such as ball grid array (BGA), "bottomless" packages, and the DirectFET.

The International Rectifier DirectFET combines HEXFET power-MOSFET silicon technology with packaging that provides low on-state resistance in a package featuring the footprint area of an SO-8 and only a 0.7-mm profile *(Fig. 5)*. The DirectFET package is compatible with existing layout geometries used in power applications; pc-board assembly equipment; and vapor-phase, infrared, or convection soldering techniques. The DirectFET product family is also optimized to work with IR's latest-generation controllers and drivers, including X-Phase and the bus converter chip sets.

With DirectFET packaging, dual-sided cooling can maximize thermal management and improve power density by a factor of two. It also cuts board space and component count from 50% to 60%, and it reduces junction temperatures up to 50°C. Reduced losses and improved thermal performance foster high efficiency and low temperatures, and therefore enhance system reliability, suiting this device for POL converters.

Initially, IR introduced DirectFETs with 20- to 30-V ratings. Recently, the company introduced 40- and 100-V parts. The higher-voltage MOSFETs employ the same packaging concept and allow the benefits of the DirectFET technology to be employed in a broader range of applications, including 48-V input isolated dc-dc converters.

One of the DirectFET's major accomplishments is reduced on-state resistance, which includes the silicon itself as well as the means for connecting to external connections. For example, an SO-8 power MOSFET usually has about 1.4 mW of resistance for wire bonds and lead resistance. With the DirectFET, the equivalent resistance is only about 0.1 to 0.15 mW. The result is a lower overall on-resistance.

Lower on-resistance and improved thermal resistance breed higher-efficiency MOSFETs. This lets designers operate the MOSFETs at a lower junction temperature for a given power level. Or, they can drive the MOSFET harder without exceeding its maximum rated junction temperature, increasing system-level power density.

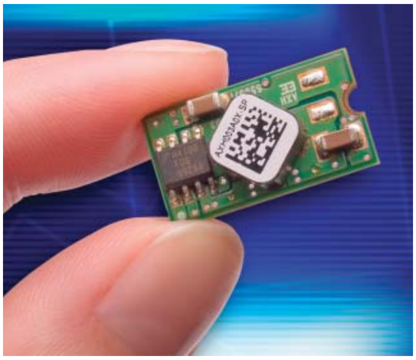
Currently, there's no second source for the Direct-

FET. However, International Rectifier has established similar production facilities in the U.S. and Europe.

ICs SUPPORT POL SYSTEMS • Input voltage for POL systems may range from 5 to 12 V. In a system upgrade, a 5-V dc supply may be available, and a specific load could require less than 1 V. Linear Technology's LTC3418, scheduled for introduction in the first quarter of 2005, fits this type of application.

This 4-MHz, monolithic, synchronous step-down dc-dc converter uses a constant-frequency, current-mode architecture. Operating from a 2.25- to 5.5-V input range, it provides a regulated output voltage from 0.8 to 5 V while delivering up to 8-A output. Switching frequency is set by an external resistor or synchronized to an external clock. OPTI-LOOP compensation optimizes the transient response over a wide range of loads and output capacitors.

Linear Technology also will introduce ICs that fit bus converter applications, such as the LTC3706, a PolyPhase secondary-side controller for synchronous forward converters. When used with the company's LTC3705 gate driver and primary-side controller, the combination creates a complete isolated power supply that combines the power of PolyPhase operation with the speed of secondary-side control.



6. The Austin MiniLynx series from Tyco Electronics Power Systems offers 91% and 94% efficiencies in a 0.80- by 0.45- by 0286-in. package. Input voltage ranges include 2.4 to 5.5 V dc and 8.3 to 14 V dc.

The LTC3706 simplifies the design of highly efficient, secondary-side forward converters. The LTC3705 and LTC3706 form a robust, self-starting converter that eliminates the need for the separate bias regulator commonly used in secondary-side control applications. In addition, a proprietary scheme multiplexes gate drive signals and dc bias power across the isolation barrier through a single, tiny pulse transformer.

Another interesting IC for POL-system applications is the LTC3736-1. This two-phase, dual synchronous step-down switching controller has tracking that drives external complementary power MOSFETs. Its constant-frequency, current-mode architecture with MOSFET drain-to-source voltage (V_{DS}) sensing eliminates the need for current-sense resistors, lowering cost and boosting efficiency. Operating the two controllers out of phase minimizes power loss and noise caused by the input capacitor's equivalent series resistance.

The LTC3736-1's unusual spread-spectrum architecture randomly varies the switching frequency from 450 to 580 kHz, significantly reducing the peak radiated and conducted noise on both the input and output supplies. This makes it easier to comply with international electromagnetic-interference standards. Pulse-skipping operation improves efficiency at light loads and 100% duty cycle capability offers low-dropout operation. ED

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