

Distributed Power Moves To Intermediate Voltage Bus

An increasing number of supply voltages and rising power demands encourage two-stage dc-dc conversion with point-of-load converters spread across the pc board.

David G. Morrison

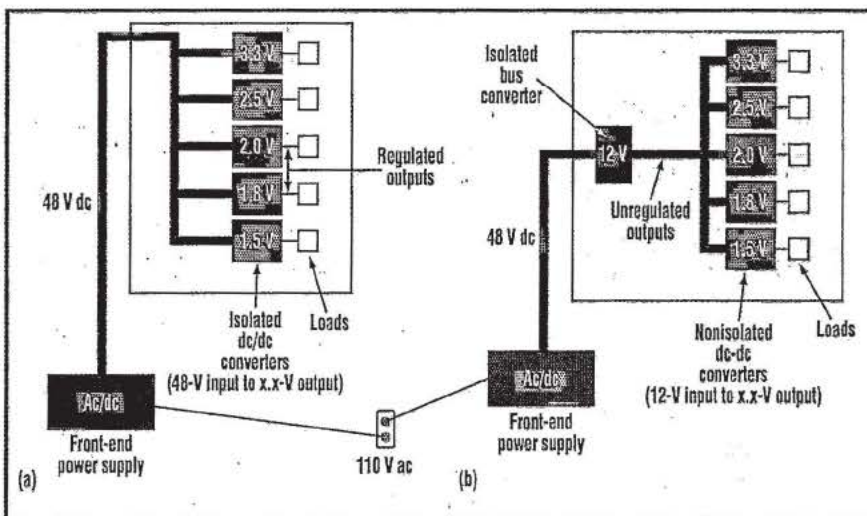
POWER / PACKAGING / COMPONENTS

The 48-V power bus is the basis of distributed power architectures found in telecom and many computing applications. In these systems, ac-dc front ends convert line voltages down to 48 V dc for distribution among various pc boards in the system. Isolated dc-dc converters then generate the lower voltages required by logic, mixed-signal, and analog circuits. Distributing 48 V throughout the system, rather than the lower IC-level voltages, improves efficiency. In particular, it lowers I^2R losses associated with busing high currents at low voltages.

Using isolated dc-dc converters to generate on-board voltages works well in cases of just one or two voltages. But in recent years, the number of voltage levels needed on boards has risen dramatically as new generations of chips were introduced with lower voltage requirements. In addition to the 5- and 3.3-V supplies, designers have to plan for supplies at different voltages that range down to 1 V.

Isolated converters developed initially for telecom offer different output voltages and power levels packaged in standard brick-style formats, including full, half, quarter, and the new eighth bricks. However, the inclusion of an isolation transformer adds to their cost and size. So, to generate the voltage range needed on-board, designers frequently turn to nonisolated, point-of-load (POL) dc-dc converters (often simply called POLs).

POLs, which are typically buck converters, may either be built by the system designer using ICs and discrete components, or purchased from power-supply merchants as functionally complete power modules. The latter



1. In telecom and enterprise applications, the standard approach to distributed power relies on isolated converters (a). An implementation based on an intermediate voltage bus employs an isolated bus converter, like this example from SynQor, combined with point-of-load converters (b).

typically specify operation from a 3.3-, 5-, or 12-V input and come packaged in SIP, DIP, or surface-mount modules. For a given voltage and current output, POLs cost much less than brick-style converters and usually take up much less board space. Also, they can be placed close to their loads, cutting down on I^2R losses in the board and improving transient response.

For some time, it has been common for system designers to run POLs off the isolated 5- or 3.3-V bus. But with current requirements on the rise, some designers are opting to power POLs off of a higher voltage bus such as 12 V. This 12-V bus then becomes an intermediate voltage bus that powers all the POLs (Fig. 1).

Implementing a distributed power system with an intermediate voltage bus can potentially save pc-board real estate and overall cost. Other factors must also be considered in adopting an intermediate voltage bus. These include

the power, efficiency, thermal-management, and noise requirements of the application.

The intermediate voltage bus must provide isolation, but its regulation isn't critical because the POL outputs are regulated. While telecom equipment maintains a need for a wide input-voltage range (35 to 72 V, necessary for battery backup), enterprise equipment like servers, which also run off 48 V, can operate from a much narrower input-voltage range.

Power-supply manufacturers are exploiting these factors to develop bus converters that provide isolation with higher power levels and higher efficiency at lower costs than their counterparts among the standard telecom bricks. At the same time, vendors are developing more powerful POLs to help optimize the implementation of intermediate voltage bus architectures.

Tradeoffs: System cost counts heavily in the decision to add an intermediate

voltage bus to a distributed power system. POLs are considerably cheaper than isolated brick-style converters. So changing from a distributed power scheme that relies solely on half-brick, quarter-brick, or eighth-brick dc-dc converters to generate the board-level voltages will reduce costs as the designer pays for isolation just once.

Moreover, the cost savings increase as the number of output voltages rises. The intermediate voltage bus architecture might become cost-effective with only four voltages on board. Yet, converter costs must be weighed against the necessary current levels. As the current per output rises, the number of POLs per output may grow, adding cost that could offset the savings accrued from using fewer isolated converters (Fig. 2).

However, savings accomplished by using an intermediate voltage bus aren't limited merely to the reduced costs of the converters. They also include savings in the overall system cost—for instance, reduced board space. These savings can be significant, particularly when the board in question may have as many as 20 layers. There can also be reductions in the

amount of copper or number of metal layers needed to distribute power across a pc board. For certain applications, less copper could mean lower overall cost.

Another component of this expense is how the POLs are implemented, whether by ICs and discrete components assembled on the customer's board, or as functionally complete dc-dc converter modules purchased from the power-supply merchants. There's little argument that the bill-of-materials cost for a simple buck regulator built around parts from the established IC vendors will be less than a purchased SIP or DIP converter module.

But module vendors will point out

that the discrepancy in price between discrete designs and modules has narrowed. As Marshall Miles of Bel Power Products, a division of Bel Fuse, says, "We've been able to get closer and closer to a bag of parts, plus we're adding value." That value encompasses saved design time, easier manufacturability for the customer, and improved thermal management. Rather than dumping all of the POL's heat into the board, the modules, particularly the SIPs, can transfer more heat to the air.

Some designers may calculate the cost of manufacturing a POL converter

less damaging to the board than reworking a discretely assembled POL.

One caveat in terms of POL pricing relates to the application's capacitance requirements. Only some POL vendors integrate input and output caps within their converters. Even in these cases, particularly long input lines to the POL, high di/dt requirements at the load or demands for very low noise may dictate the addition of more capacitors on the board, raising overall cost.

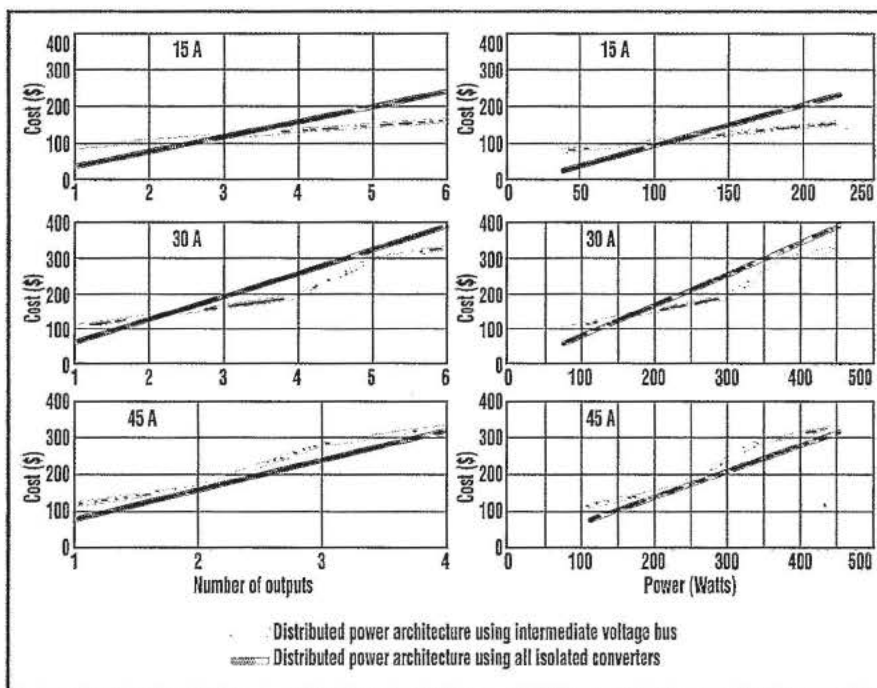
Naturally, the specific voltage and current requirements of the application will influence the decision to buy or

build a POL. One general guideline is that getting the POL to operate efficiently becomes more difficult as the voltage output drops and current out rises. Designing a POL to deliver up to 10 A may be fairly straightforward, given the available regulator IC options and reference designs. But at 15 A or more, POL vendors warn that some power-supply design expertise is necessary.

Efficiency is another key issue for designers considering an intermediate voltage bus. It requires cascading of dc-dc converters, so this approach tends to lower efficiency as the effi-

ciency of the isolated converter gets multiplied by the efficiency of the non-isolated converter. But many factors will influence the difference between single-stage dc-dc conversion from 48 V and dual-stage conversion with an intermediate voltage bus. Designers will have to weigh the need for maximum efficiency against the desire for small size and low cost—two potential advantages of the intermediate voltage bus.

The value of the intermediate bus voltage is one factor affecting efficiency. Opting for a 12-V bus is natural, given that many brick-style converters come with that output. Designers also have been working with this voltage with



2. This design example from Power-One illustrates the cost differences per output and per power for a standard distributed power architecture using all isolated converters' power levels versus a distributed power architecture that employs an intermediate voltage bus. A value of 2.5 V for each output is assumed, as well as a cost of \$15 for a 20-A POL, \$40 for a 25-A quarter-brick isolated converter, \$65 for a 40-A dc-dc quarter-brick dc-dc converter, and \$80 for a 60-A half brick.

themselves as simply the price of placing the POL's discrete components on the board via their company's (or contractor manufacturer's) existing pick and place equipment. But that analysis overlooks the value of placing a known-good POL module—one that's already tested and undergone burn-in.

With a discrete design, the burden of testing the POL falls on the system designer's shoulders. The choice of a discrete or modular POL can make an impact on the customer's pc-board yields, affecting overall costs. Designers also must consider the effect of POL-related changes. Reworking a board with a POL module may be easier and

voltage regulator modules (VRMs), which have been migrating from 5- to 12-V inputs to accommodate higher current demands. Nevertheless, 5 V also is being considered as an intermediate bus voltage, in part, due to the availability of many 5-V output isolated converters and 5-V input POLs.

Stepping down a 12-V input to a low voltage is less efficient than stepping down 5 or 3.3 V. Yet, some of that lost efficiency is offset by the reduction in primary-side currents when the POL is operating off of 12 V. But the other consideration is the tradeoff between the POL's efficiency and the isolated converter's efficiency. As the intermediate bus voltage is lowered, the POL's efficiency rises, while the isolated converter's efficiency falls.

A voltage of somewhere around 8 V appears to be optimal for maximizing the efficiency of the POLs while maintaining the efficiency of the isolated converter. So, some vendors are looking to develop bus converters with a non-standard output at or near this value.

That raises the issue of POL availability. Most currently available POLs are for 3.3- or 5-V input. In recent offerings, the 12-V input has become more prevalent. But for nonstandard input values of 7 to 9 V, POL options are limited. That may change as vendors begin to introduce POLs with wide input ranges (see the table).

The choice of an intermediate bus voltage may also be influenced by the required power level and the space available for the isolated converter. Marty Schlecht of SynQor gives an example: Suppose that a customer wants to use a quarter-brick dc-dc converter with a 5-V output at a given power level. If that power level isn't available at 5-V out in a quarter brick, but is available at 12 V, then he'll go with the 12-V bus. However, if he has space for a half brick, he could obtain the necessary power at 5 V.

Bus Converters: Choosing an intermediate voltage isn't the only factor that shapes the efficiency of the isolated converter. The converter's input voltage range and regulation can be traded off for efficiency. Although telecom applications might not sacrifice the wide input-voltage range, enterprise applications may.

With this in mind, several power-supply vendors are developing isolated bus converters with narrow input-voltage ranges and unregulated outputs. These

converters boost the efficiency of the 48- to 12-V conversion by several percentage points, reducing the efficiency penalty associated with cascading isolated and nonisolated converters.

For example, SynQor is developing a 48- to 12-V bus converter product called BusQor that will deliver 250-W maxi-

mum with 96% to 97% efficiency in a quarter-brick package. Unlike a standard telecom converter, the bus converter operates over an input range from 42 to 60 V.

BusQor's output voltage, which is unregulated, will approximately follow that of the 48-V bus (about $\pm 10\%$). In

RECENTLY DEVELOPED POINT-OF-LOAD DC-DC CONVERTERS

Company/ model no.	Input voltage	Output voltage	Output current	Package	Price and availability*
Artesyn SIL family	3.3, 5, or 12	1.2 to 3.3	3 to 15 (3.3 V input); 3 to 30 (5- or 12-V in- put)	Vertical or horizontal through-hole mount	Available 3rd quarter
Bel Fuse S7DC- 16D120	3 to 15	0.8 to 5	16 (outputs below 5 V) 12 at 5 V	2.0- by 0.4- by 0.4-in. SMT DIP	\$19.75 each per 5000
Bel Fuse S7DB-08B	3.3 or 5	1.0 to 3.3	8	1.22- by 0.67- by 0.345-in. SMT DIP	\$8.35 each per 10,000
Bel Fuse S7AH-05C	3.3 or 5	1.0 to 2.5	5	0.6- by 0.7- by 0.292-in. SMD, vertical mount	\$5.95 each per 10,000
Beta Dyne SR50	3.3, 5, and 12	Prog.: 0.9 to 2, 1.3 to 3.5, and 1.7 to 5	15	1- by 2.6- by 0.3-in. SIP	Prototypes avail- able, production in October; \$35 in OEM quanti- ties
Celestica S016	12	Factory set to 1.2, trimmable up to 5	16 (up to 45 W maximum)	1.2- by 1.1- by 0.39-in. SIP, vertical, hori- zontal mount	\$11.95 each in annual volumes of 10,000
Celestica S111	3.3, 5, or 12	0.8 to 2.5 (3.3-V input), 1.0 to 3.3 (5-V input), 1.0 to 5.0 (12-V input)	10	2.55- by 0.5- by 0.45-in. SIP, vertical mount	\$9.95 each in annual volumes of 10,000
Celestica Verti Cons Family VCN20-025	12	2.5 or 3.3	20 (25 A version in development)	Vertical mount with SIP plug-in or dual-row header	\$28 each in annual volumes of 10,000
Celestica VCN28-015	5 or 12	1.05 to 1.825 programmable	28	Dual row inline package	\$35 each in annual volumes of 10,000
C & D Technologies NGA Series	15	1.8, 2.5, 3.3, or 5	2	20.96- by 21.49- by 5.6- mm SIP with '7805 footprint	Under \$10 in OEM quantities
C&D Technologies 6-PAK	5	2.5 to 3.6, programmable	6 (may be paralleled to 54 A)	2.00- by 0.67- by 0.27-in. SIP	Under \$15 in OEM quantities
Datel LSN D12 models	12	1, 1.2, 1.5, 1.8, 2, 2.5, 3.3, or 5	10	2- by 0.55- by 0.34-in., horizontal or vertical mount	\$11.90 each per 10,000
Power-One SIP/SIE series	5	1.2 to 3.3	6	2.5- by 0.55- by 0.25-in. SIP	\$26.50 to \$28 each per 1000
Tyco Austin Lynx 12-V model	12	0.9 to 3.3	10	2- by 0.5- by 0.326-in. SIP or 1.3- by 0.53- by 0.326-in. SMD	\$13.75 each per 1000

*Units are available now unless otherwise noted

INTERMEDIATE VOLTAGE BUS

terms of power output, BusQor's power levels are significantly higher than that of a standard quarter-brick, which typically produces about 100 W at 12-V output with around 92% efficiency. At under \$0.50 per watt, SynQor's bus converter costs half as much as a comparable standard dc-dc converter.

Another vendor, Celestica, has developed a bus converter that steps down a 48-V $\pm 15\%$ input to an unregulated 9.6-V output with 94% efficiency. For now, this product comes only in custom configurations. Down the road, it may be released as a quarter or half brick.

Similarly, Broadband Telcom Power plans to test the market by introducing an isolated converter with 7.5-, 9-, or 12-V output. This converter will be offered in two versions. One will have the standard telecom features such as full input-voltage range and regulated output. The other will be a low-cost, high-efficiency (a mid-90s percentage) model with narrow input-voltage range and unregulated output. These products could be announced over the next few months.

Meanwhile, Datel plans to introduce

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jlau@btcpower.com
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C&D Technologies www.dc-dc.com
Rob Hill
rhill@cdtechno-ncl.com
+44 (0)1908 615232 **CIRCLE 481**

Celestica www.celestica.com
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msayani@celestica.com
(416) 448-3568 **CIRCLE 482**

Cherokee International www.cherokeellc.com
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mike@cherokeellc.com
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bobl@datel.com
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Andrew.F@galaxypwr.com
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dennis.brondi@power-one.com
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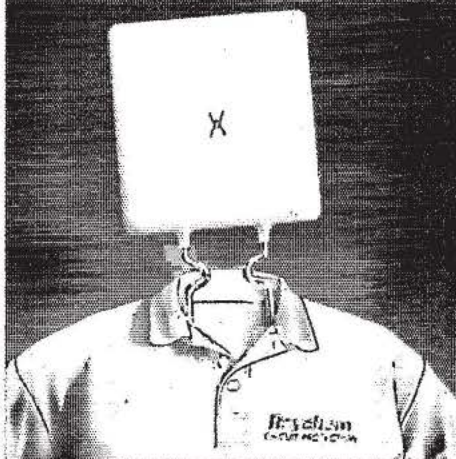
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its UBC series of 48- to 12-V Unipolar Bus Converters that will deliver 16.6 A (or 200 W). The Libra design under development at Galaxy Power is another 48- to 12-V bus converter. This product will deliver 20 A in a quarter-brick package. Additionally, there are efforts to boost the power density of larger brick-style converters for use in intermediate voltage bus architectures. For example, Cherokee International is trying to develop a 48- to 12-V converter that achieves 600 W in a 3/4-brick package. The vendor is working on a 200-W half-brick variation as well.

We may see other variations on the standard brick-style converter, such as 12-V output bus converters that have the full input-voltage range, but with higher efficiency and fewer features. Given that vendors are just now developing bus converters, it's unclear when and if there will be any standardization of these products. Because the implementation of an intermediate voltage bus depends on so many application-specific variables, it's likely that there will be variations.

Mahmoud Sayani of Celestica sug-

gests that some customers may adopt a hybrid of the traditional distributed power architecture and the intermediate voltage bus technique. For example, the designer may employ one isolated converter to generate high current at 3.3 or 1.8 V, then apply a second isolated converter to generate an intermediate voltage bus to feed the POLs.

POL Converters: The continued development of POLs by power-supply vendors is creating new options for implementing an intermediate voltage bus architecture (see table again). When comparing some recently developed products listed in the table, remember that differences may exist with respect to efficiency, derating, noise output, protection features, footprints, and pinouts. Unlike isolated dc-dc converters, which feature standard footprints and pinouts, POLs come in more varied formats. But certain popular product series, such as Tyco's Austin Lynx, have become almost de facto formats for POLs, meaning that multiple sources are available.

For designers considering POLs as replacements for isolated and shielded

converters, signal-integrity issues must be considered. For instance, ground loops could pose potential problems with POLs. Furthermore, unshielded converters, whether isolated or nonisolated, can generate high levels of radiated and conducted noise. Designers should also examine the need for over-voltage protection. If the forward FET in the POL is shorted, the intermediate voltage will be applied directly to the load if the POL's overvoltage protection isn't fast enough. When the load is an expensive IC, inadequate overvoltage protection can be a costly liability.

In contrast, isolated converters reduce the dangers posed by a shorted FET. The turns ratio of the isolation transformer reduces the overvoltage of the intermediate voltage. In some cases, designers may choose an isolated converter over a POL. This option is made more attractive by the availability of isolated brick converters with 12-V inputs and by the tiny eighth-brick packages that deliver 15 to 25 A at low voltages. With its 2.28- by 0.8-in. footprint, the eighth brick is almost as small as POLs with comparable output power. ▀

sometimes size IS everything

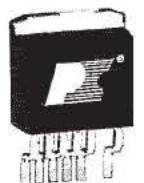
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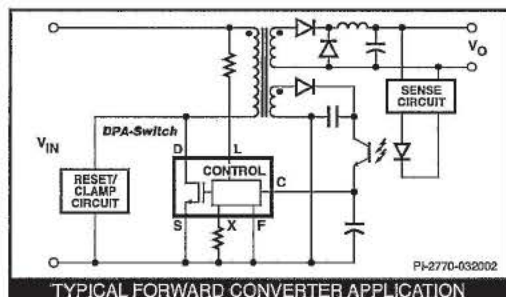
- Built-in auto-restart for output overload/open loop protection
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OUTPUT POWER TABLE						
36-75 VDC INPUT RANGE						
Total Device Dissipation	0.5 W	1 W	2.5 W	4 W	6 W	Max Power Output
PRODUCT						
DPA423R	12 W	16 W	—	—	—	18 W
DPA424R	16 W	23 W	35 W	—	—	35 W
DPA425R	23 W	32 W	50 W	62 W	—	70 W
DPA426R	25 W	35 W	55 W	70 W	83 W	100 W

See Data Sheet for 16 V and 24 V Minimum Input and for Notes and Conditions.



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