DIGITAL DC/DC PMBUS CONNECT

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1. PMBUS CONNECTIVITY

### DIGITAL DC/DC CONVERTER FAMILY INTEGRATES PMBUS CONNECTIVITY

Able to work with any type of power converter, PMBus is a major success story. Its simple SMBus-based two-wire hardware interface is similar to and generally compatible with I2C, while the improved signaling protocols assure greater robustness. As a result, system designers can easily implement power management strategies that range from voltage sequencing or multi-voltage logic devices to monitoring and controlling entire systems using a uniform approach that has minimal impact upon resources.

Within the context of high-availability systems, PMBus makes it possible to integrate redundant power supply hardware while maximising the system's operating efficiency through intelligent power-management schemes.

This is especially significant for the distributed power architectures that industrial and telecom systems employ and that are becoming more widespread due to initiatives such as AdvancedTCA. Although the individual details vary, the general scheme comprises an AC/DC front-end that downconverts utility power to an intermediate level of typically 48VDC for distribution to all boards within a system.

At board level, an intermediate bus converter (IBC) most often provides another level of isolation to satisfy safety standards, such as EN 60950. This IBC also downconverts to typically 9-12VDC to supply the non-isolated point of load DC/DC converters (POLs) that supply the voltages that logic and support circuits require. In a PMBus system, a local bus interconnects the board-level components and provides a uniform interface to the system host, which often also connects with the AC/DC front-end and peripherals, such as cooling fans – see *figure 1*.

Figure 1
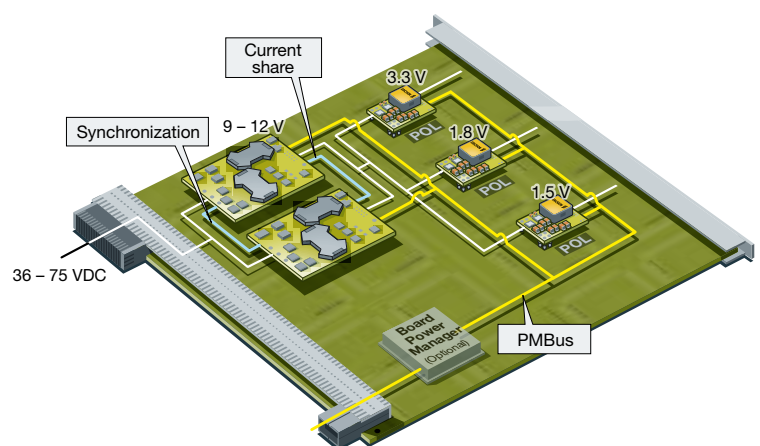
Importantly, PMBus devices must be capable of starting up safely without any host intervention. Also, the mandatory "set-&-forget" mode makes it possible to program a PMBus device once during manufacture, after which time the device can operate indefinitely without any bus communication.

PMBus includes several extensions to SMBus v1.1 as well as some features of SMBus v2.0. These include the group command protocol that sends one or more commands to multiple devices in a single, continuous transmission sequence. Because devices always execute the commands that they receive upon detecting the SMBus STOP condition, it is possible to update multiple devices at the same time. Another example is the extended command protocols that make available another 256 command codes for both byte and word formats. Any parameter that can be written must also be readable.

2. COMMAND LANGUAGE IS KEY

The power of PMBus is apparent in its command language, which comprises standard and device-specific commands. The basic single-byte format permits 256 commands, each of which may be followed by zero or more bytes of data. *Table 1* lists some of the standard commands that Ericsson's BMR450/451 digital DC/DC voltage regulators (3E POLs) implement to enable the host to monitor key operating parameters.

TABLE 1
STANDARD PMBUS COMMANDS

STATUS COMMANDS
CLEAR_FAULTS	03h
STATUS_BYTES	78h
STATUS_WORD	79h
STATUS_VOUT	7Ah
STATUS_IOUT	7Bh
STATUS_INPUT	7Ch
STATUS_TEMPERATURE	7Dh

MONITOR COMMANDS
READ_VIN	88h
READ_VOUT	8Bh
READ_IOUT	8Ch
READ_TEMPERATUR_1	8Dh
READ_DUTY_CYCLE	94h

Operating from 4.5-14VDC, these converters use digital inner control loops to vary the pulsewidth modulation stream that switches the output MOSFETs in a synchronous buck-converter topology. An external resistor sets the output voltage over an exceptionally wide range—from 0.6 to 3.6VDC for the BMR451, or up to 5.5VDC for the BMR450. This approach allows the converter's firmware to optimize performance over a wider range of line and load conditions than is possible using a conventional analog control loop, typically achieving >96 percent efficiency at half load.

The firmware embodies functions such as precision delays and slew rate control at turn-on, while also supporting features such as undervoltage lockout, on/off control, remote sensing, and fault protection. Programmability during manufacture makes it possible for users to specify custom parameters that are then securely set in firmware for the product's lifetime. This implementation of the PMBus "set-&-forget" facility provides configuration flexibility that analogue converters typically cannot match—for instance, permitting adjustments to the inner control loop to optimize transient response—while making the component as easy to use as its analog counterparts. Aiding traceability, each 3E POL carries a unique serial number together with identification data that standard PMBus commands can access.

A key advantage of the 3E POL design is the integration of the PMBus interface and the monitoring and control hardware within the core of the digital controller. By comparison, an analog converter requires additional support circuitry that is less tightly coupled, occupies more space, and consumes

"A KEY ADVANTAGE OF THE 3E POL DESIGN IS THE INTEGRATION OF THE PMBUS INTERFACE"

more power. For instance, an analog-to-digital converter IC that measures the intermediate bus voltage requires additional signal conditioning circuitry to provide filtering and scaling, consuming power and board space. Accordingly, the 3E POL design reduces component count, improving reliability and increasing power density. For example, the surface-mount version of the 40A-rated BMR451 packs 132W into a footprint that measures just 30.85x20.0x8.2mm, which equates to 7.90A/cm3 (129A/in3), while the companion BMR450 can supply

20A/100W from 25.65x12.9x8.2mm or 7.38A/cm3 (120A/in3). By comparison, similar analog DCDC converters manage only 2.37A/cm3 (43A/in3). The MTBF (meantime-between-failure) calculations for the BMR451 and 450 are 2.6 and 5 million hours, respectively.

3. DIGITAL CONVERTERS EASE SYSTEM INTEGRATION

The integrated read-back facility within Ericsson's 3E POL converters forms a fundamental building block in a higher-level power-management strategy.

At the subsystem level, monitoring load current and voltage fluctuations makes it possible to watch for conditions in the load circuitry that may signal that a change in intermediate-bus voltage is desirable, or that may signify abnormal conditions. The converter's temperature read-back facility might also provide an indication of irregular conditions, or be used to vary the speed of PMBus-compatible cooling fans. At system level, real-time measurements of key parameters permits supervisory software to adapt to changing line and load conditions, conserving power and minimizing heat generation.

3E Digital POL BMR450

A programmable IBC such as Ericsson's BMR453 is the hardware partner that enables such energy-saving schemes. This quarter-brick module isolates and down-converts a 36 – 75VDC power-distribution rail to levels that are programmable via PMBus commands within the range of 8.1 – 13.2VDC. Capable of supplying as much as 396W with ≥96 percent efficiency, this digital converter supplies some 5 percent more power than its analog predecessor, the PKM4304BPI. The BMR453 also maintains ±2 percent regulation accuracy—rather than the analogue converter's +4 percent and -10 percent —with approximately half the level of output noise and ripple, and a times-two improvement in transient response. Again, the

BMR453 integrates the PMBus interface with all monitoring and control hardware and firmware elements within its core logic.

Taking advantage of the flexibility that PMBus standard and manufacturer-specific commands offer, the BMR453 implements an unprecedented level of in-system programmability. Divided into control, output, fault-limit, fault-response, time-setting, and supervisory categories, more than 50 standard PMBus commands are available to program the converter. These range from system level operations such as output-voltage and margin settings, turn on/off delays and slew-rate control, and setting fault limits, to device-specific functions such as altering the converter's switching frequency.

More than 20 standard read-only commands interrogate the converter to ascertain parameters such as its input and output

3E Digital POL BMR451

voltage levels, operating temperature, switching frequency and duty cycle. Thirty additional BMR453 specific commands configure features that range from the polarity of the power-good signal to the module's operating as a master or slave in a current-sharing configuration. One of the converter's more unusual design features is its ability to current-share with another BMR453 without needing any external support circuitry, such as OR-ing MOSFETs and diodes.

In conjunction with a development kit that supports the BMR453 and the BMR450/451 modules, Ericsson's 3E CMM software makes it easy for users to become familiar with the facilities that each component provides. Arranged as two channels that mirror one another, the 3E evaluation board accommodates up to three BMR450/451 modules and an optional BMR453 per channel.
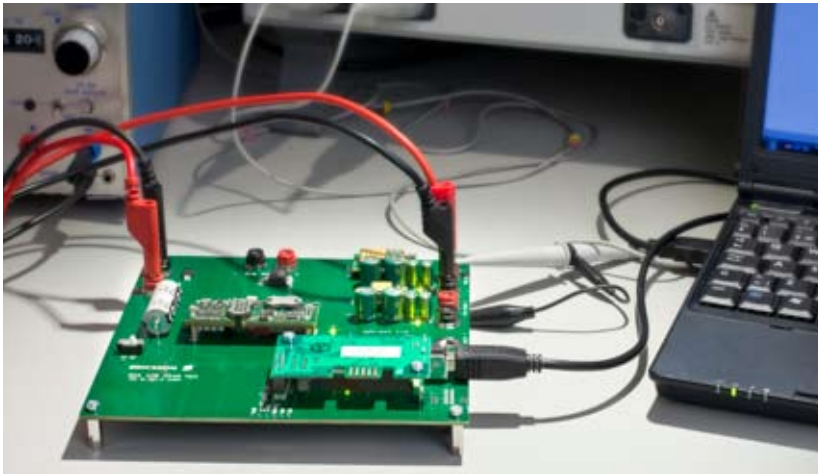
Figure 2

Figure 3

Users can easily connect sources and loads to evaluate the system's electrical performance in configurations that closely resemble their target applications - see *figure 2*.

Together with the evaluation board's USB-to-PMBus interface, the 3E CMM software makes it possible to access each module from a PC. During initialization, the software scans the PMBus to discover which modules are present and lists them in its uppermost pane, together with their addresses and major set-up parameters.

Highlighting a device causes the software to display four tabs— standard PMBus configuration, BMR45x-specific configuration, device monitoring, and file I/O— that access a series of command and view panes. For instance, the BMR453's standard configuration tab identifies the individual converter, allows users to program many of its standard PMBus commands, and reports each PMBus transaction as it executes - see *figure 3*. Similarly, the BMR45x specific configuration tab accesses less frequently altered device-specific parameters, while the device monitoring tab provides a real-time display of each converter's input voltage, output voltage and current, and its temperature together with a status pane that reflects fault and warning settings. The file I/O tab makes it easy to record, modify and restore a configuration file that contains all of the converter's operational settings in text-file format, which users can then use to program other converters and/or retain for documentation purposes.
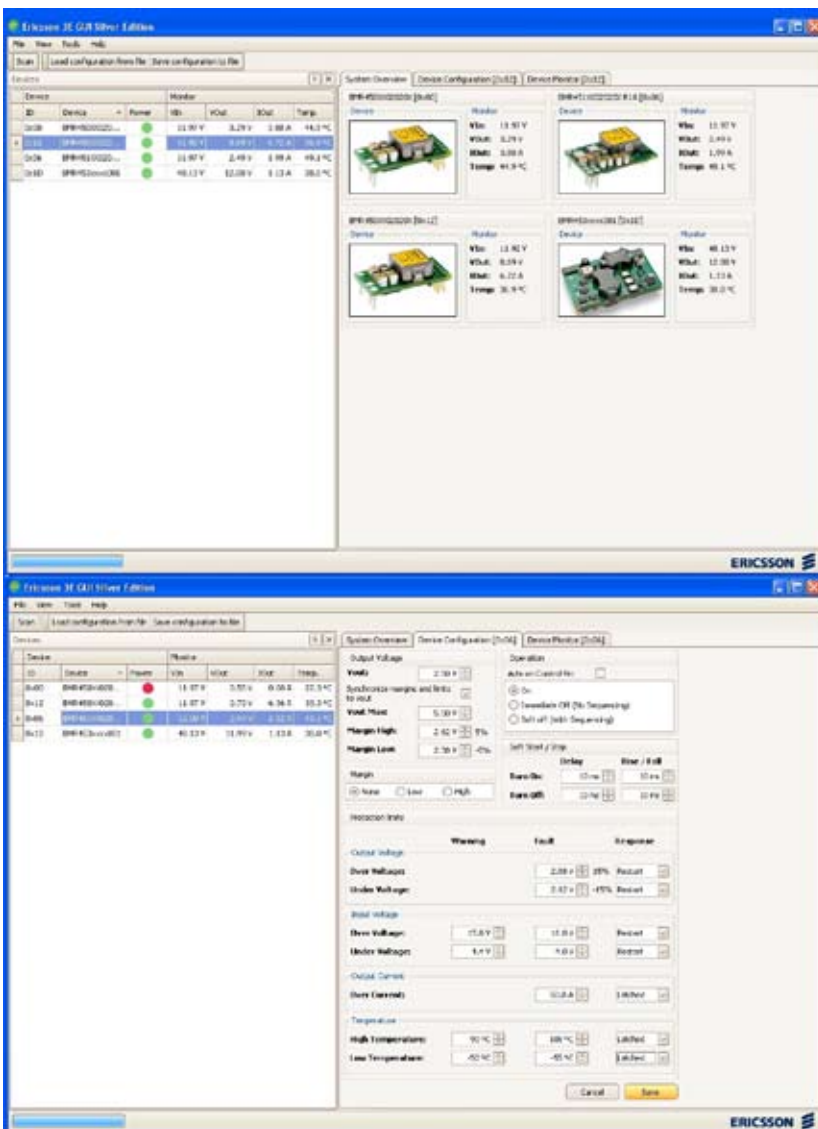
4. PMBUS INTEGRATION SAVES ENERGY

While integrating the PMBus interface and its measurement and control subsystems minimises component count and power consumption.The ability to adjust the IBC during normal operation makes it easy to implement schemes that deliver further system-level power savings.

Dynamic bus-voltage control is an established technique whereby supervisory software commands change in the IBC's output level to

maximize efficiency over a range of line and load conditions. Some analog converters offer output-voltage control using potentiometers— offering the possibility of substituting digitally controlled potentiometers—or analog control voltage that a digital-to analog converter can satisfy. In either case, the adjustment range is relatively small, substantial support circuitry is necessary, and the dynamics of tuning the loop can be challenging.

The BMR453's digital design eases many of these concerns. Using the 3E evaluation board platform, tests at Ericsson demonstrate the effectiveness of dynamically altering the IBC's output in response to varying load conditions.
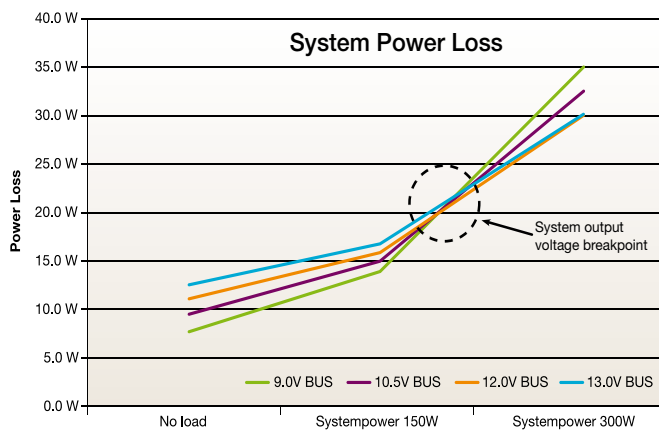

3E Digital DC/DC BMR453

Figure 4

Figure 4 plots the power losses that result from varying the output voltage of a single BMR453 from 9 – 13V while supplying six 3E POL modules that source 0 – 300W. Neglecting external factors such as less energy for cooling, savings of up to 5W are clearly visible.

When a pair of BMR453s supplies the 3E POLs in a current-sharing configuration, the ability to turn off one IBC during low-load conditions can save more than 2W of quiescent current. Furthermore, dispensing with the need for ORing diodes or MOSFETs saves yet more energy and space in the current-sharing and redundant-converter configurations that today's systems increasingly require.

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