SCALABLE FOOTPRINTS EXTEND DIGITAL POWER CONVERTERS' FLEXIBILITY

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3E - Enhanced performance,
Energy management and
increased End-user value

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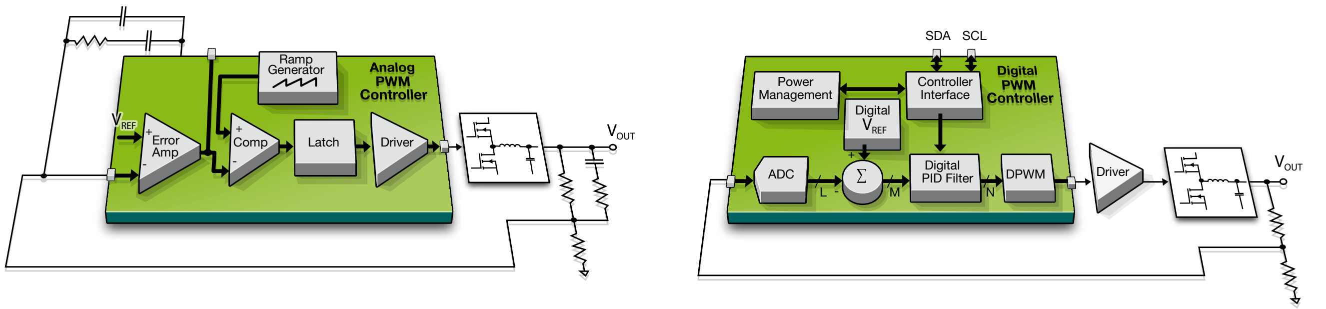
The advent of digitally-controlled power converter modules presents designers with a raft of new opportunities to explore in their continual quest for ever-greater system efficiency, flexibility, reliability, and overall cost-effectiveness. In developing the first commercially-available family of digital power converters — the 3E series — Ericsson proved the innate superiority of the digital control-loop architecture over its analog counterpart in terms of conversion efficiency improvements over a much wider range of output load conditions. This attribute alone can often justify upgrading an analog-based system with digital converters that offer drop-in replacement equivalency, especially for the increasing number of systems that experience significant variations in load demand. However, the transition from traditional analog-control based power converters to today's digital converters offers much more than improving the conversion efficiency and power density metrics that previously dominated system architects' thinking.

The core of any representative digital converter is a mixed-signal block that substitutes an analog-to-digital converter and digital signal processing techniques for the traditional error amplifier, ramp generator, and comparator that control the power switches via a pulse-width-modulator — see *figure 1*. It is the digital converter's ability to optimize its internal loop dynamics to line and load conditions in real time that explains its superior conversion efficiency relative to analog designs that are conventionally fixed by passive component networks. As a result, analog converters are typically set to operate best at around 50 – 70% of their full load capability, this being the area over which most users will apply them. While this profile suits systems that run continuously under similar load conditions, today's systems increasingly power down entire circuit blocks to save power whenever it is practical to do so, leading to far greater variations in load current demand that digital converters accommodate far better than analog-based designs.

At the same time, sizing a system's load-current demands is becoming another dynamic that designers must increasingly consider. Systems frequently evolve over several iterations that build upon a common platform, with inevitable changes in power needs that designers may be able to address by specifying power modules from a family that shares a scalable footprint. With some thought, this footprint can satisfy not only a range of power levels, but also serve a variety of applications that span analog-converter replacement to implementing sophisticated power-management schemes that can further reduce a system's power consumption. Because power modules are relatively bulky to solder and for pick-and-place equipment to handle, it is imperative that the packaging's mechanical design overcomes manufacturability issues. It is also helpful to be able to offer through-hole-mount packages and surface-mount versions that support identical functionality.



ANALOG PWM CONTROLLER

DIGITAL PWM CONTROLLER

Figure 1. Digital converters embody mixed-signal technology that greatly extends their efficient operating range and packs power management functions on-chip.

EASING THE ANALOG TO DIGITAL TRANSITION

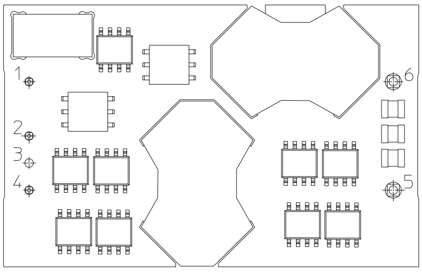
In designing its 3E series, Ericsson paid great attention to these everyday practical issues as part of the company's quest to deliver Enhanced performance, Energy management, and End-user value. A primary electromechanical consideration when making the transition from analog converters to any digital successor is the interconnection between the power module and its host board. Analog power modules almost invariably include dedicated pins for functions such as on/off control, output voltage adjustment, and remote voltage sensing. For a digital converter to be able to replace an analog one, it is essential to include these basic functions and to ensure that they can operate in a "stand-alone" mode — that is, independently of any overall supervisory control scheme that the digital converter may also implement.

Because the digital converter's core is a mixed-signal block, chip designers can pack supervisory measurement and control circuits alongside the basic dc/dc converter logic at negligible additional cost. This step offers previously unprecedented flexibility in implementing power-management schemes by integrating functions that previously required substantial external circuitry to realize. The module designer's challenge is now to design a footprint that accommodates the new digital connections alongside the traditional analog functions — and preferably in such a way as to ease life for system architects and board layout designers alike. The module designer's challenge is complicated by the fact that every new generation of digital control IC seems to add more functions that typically require extra pins to utilize, all of which requires a degree of forward planning that can only realistically be undertaken on a "best-effort" basis.

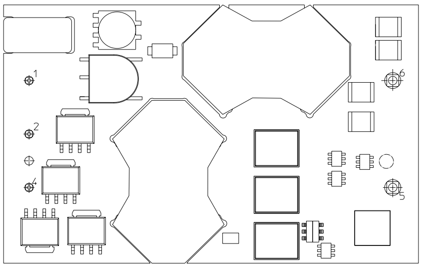
Ericsson's first 3E family member — the BMR453 advanced intermediate-bus converter that handles as much as 396 W from a standard quarter-brick footprint (*Figure 2*) – illustrates the result of a first-generation electromechanical design philosophy for digital converters that perfectly fits its intended purposes while allowing for future enhancements without requiring any substantial re-thinking on behalf of equipment designers.

Figure 2. BMR453 – 396W fully-regulated, digitally-controlled quarter-brick advanced intermediate-bus converter with PMBus interface. From top to bottom: top view, bottom view of through-hole version, bottom view surface-mount.

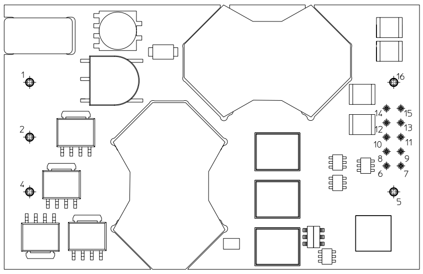
As *figure 3* shows, comparing the company's previous-generation high-power quarter-brick intermediate-bus converter — the 377 W-rated PKM4304B PI — shows the minimal impact on footprint design that Ericsson's designers achieved in moving from a "dumb" voltage-in, voltage-out analog device to a fully-featured digital design that includes legacy analog functions such as remote control and voltage sensing as well as adding PMBus™ connectivity. Alternatively and to preserve total footprint compatibility, the BMR453 is available without the new communications connector to suit stand-alone applications that will still benefit from its superior performance.



PKM 4304B PI – ANALOG (377W)



BMR453 – DIGITAL (396W)
WITHOUT PMBus CONNECTOR



BMR453 – DIGITAL (396W)
WITH PMBus CONNECTOR

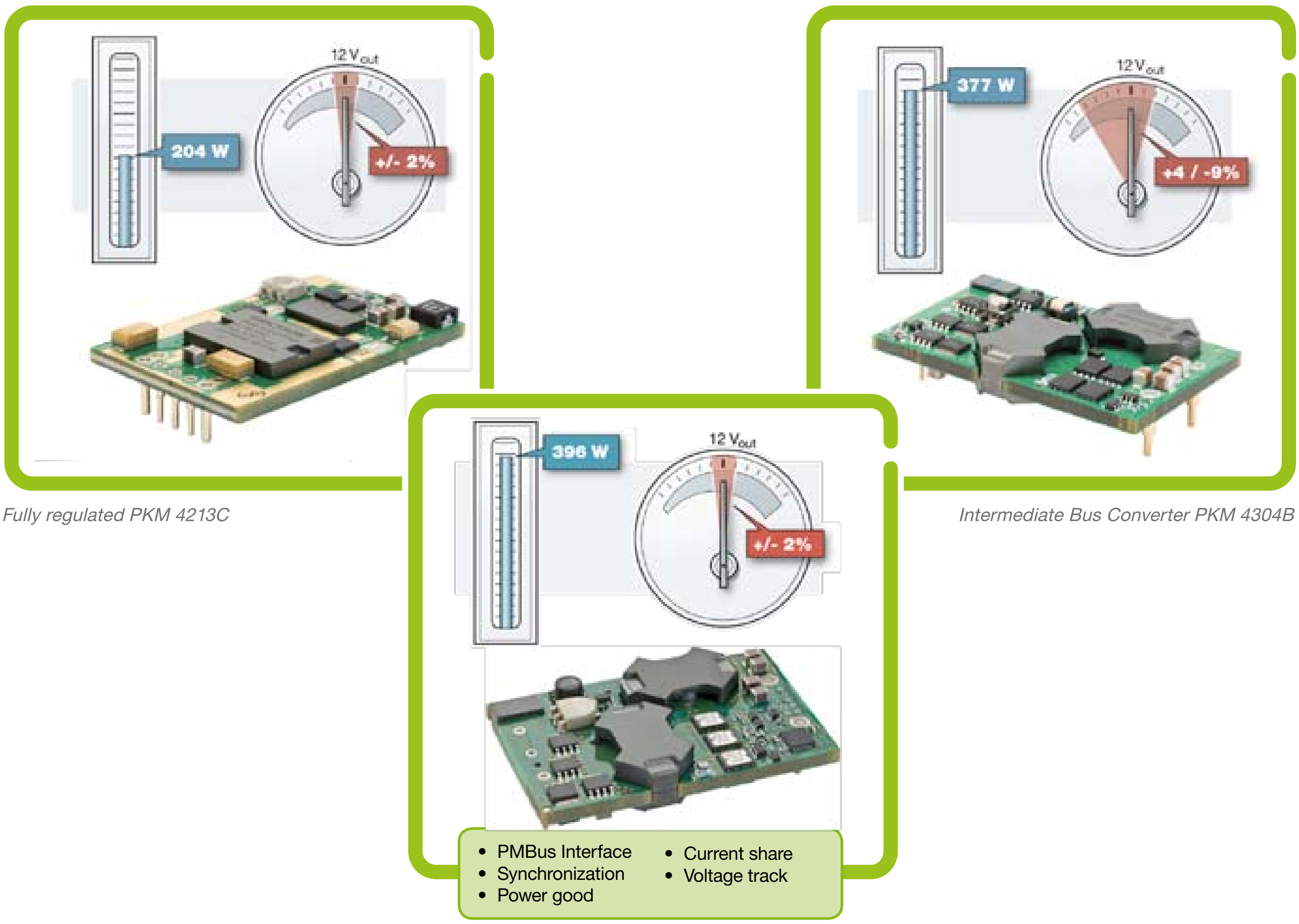
Pin	Designation	Function
1	+In	Positive input
2	RC	Remote control
3	Case	Case to GND (optional)
4	-In	Negative input
5	-Out	Negative output
6	+Out	Positive output

Pin	Designation	Function
1	+In	Positive input
2	RC	Remote control
3	Case	Case to GND (optional)
4	-In	Negative input
5	-Out	Negative output
6	+Out	Positive output

Pin	Designation	Function
1	+In	Positive Input
2	RC	Remote Control
3	Case	Case to GND (optinal)
4	-In	Negative Input
5	-Out	Negative Output
6	S+	Positive Remote Sense
7	S-	Negative Remote Sense
8	SA0	Address pin 0
9	SA1	Address pin 1
10	SCL	PMBus Clock
11	SDA	PMBus Data
12	PG SYNC	Configurable I/O pin: Power Good output, SYNC-, tracking-, or ext ref-input
13	DGND	PMBus ground
14	SALERT	PMBus alert signal
15	CTRL CS	PMBus remote control or Current share
16	+Out	Positive Output

Figure 3. The transition from analog to fully-featured digital intermediate-bus converters shows the minimal additional impact that Ericsson's upgraded footprint creates. If PMBus connectivity and the additional features are not necessary, the BMR453 can use the same footprint as its analog predecessor.

Importantly, the BMR453's digital control system substantially increases the power density that a tightly-regulated power module can achieve. *Figure 4* compares the BMR453's performance alongside the previous-generation analog converters — the fully-regulated PKM4213C that achieves ±2% output regulation and 204 W of output power and the loosely-regulated PKM4304B PI that manages +4%, -9% output regulation and 380 W. The digital converter combines ±2% output regulation performance with 396 W of output power to provide a useful 5% improvement in raw power handling ability over the PKM4304B PI, and a >90% improvement for the equivalent regulation performance of the PKM4213C within a similar quarter-brick footprint. As the next section shows, the digital 3E point-of-load regulators also offer spectacular power-density improvements that shrink their footprint requirements.



Fully regulated PKM 4213C

Intermediate Bus Converter PKM 4304B

Digitally controlled BMR453

Figure 4. The 3E DC/DC converter's digital architecture achieves the tight output tolerance of a traditional fully-regulated DC/DC converter and the high power and efficiency of an intermediate bus converter while adding digital power control and management facilities.

NEW SIGNALS, NEW POSSIBILITIES

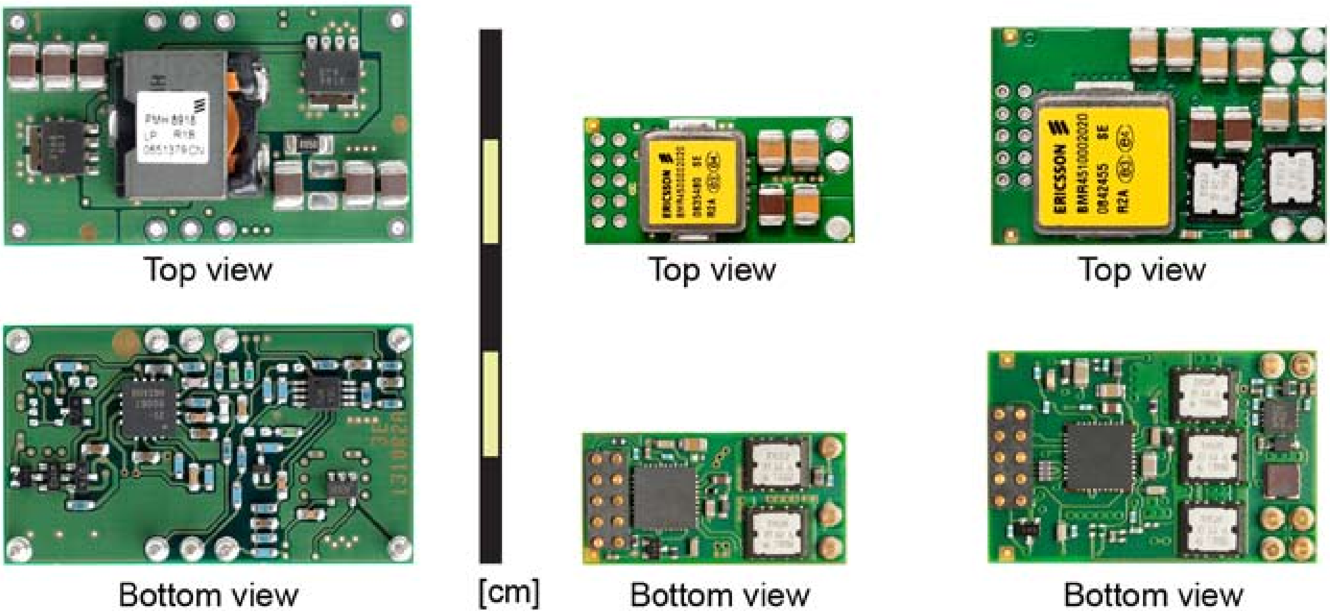
The signals that the BMR453's header carries include remote voltage sense; a configurable I/O pin that can function as a power-good output or as a clock synchronization, voltage tracking, or external reference input; a configurable remote PMBus on/off control or a dedicated module-to-module current-share input; and the PMBus connections that make it possible to configure and monitor the converter via a board-level serial bus.

With some functional variations to suit different target applications, other 3E family devices carry a similar set of signals that allows each device to operate stand-alone, or within a PMBus environment that offers designers hitherto unprecedented functionality and flexibility within device footprints that are similar to or smaller than their "dumb" analog predecessors.

For instance, *figure 5* compares the outline of a representative 18 A analog point-of-load regulator with the 20 A-rated BMR450 and its 40 A BMR451 companion part from the 3E product family. As for the BMR453, these digital point-of-load regulators offer greatly improved power density, superior electrical performance, and integrated PMBus functionality that further shrinks board area requirements.

The PMBus is a bidirectional multi-node digital interface that uses the two-wire SMBus™ standard (basically a more robust version of I2C) for serial communications. Like I2C and SMBus, implementation details typically limit PMBus to single-board applications. To support power control applications, PMBus adds two lines for a total of four conductors that comprise serial clock (SCL), serial data (SDA), control (CTRL), and SMBus alert (SMBALERT#). The serial clock and data lines transfer follow SMBus protocols to exchange bidirectional data between the board's power management logic and connected 3E family devices, as well as any other PMBus devices within the local network. The control line provides a signal for simultaneously turning devices on and off, while the alert line is an interrupt signal that devices can use to gain the board power manager's attention.

Each PMBus device must have a unique address that all 3E family products set using a space-saving pin-strap technique that minimizes the impact upon their respective footprints. Depending upon the specific 3E product, one or two resistors provide a sufficient number of individual addresses to suit any practical PMBus system. All 3E products embody a measurement and control subsystem that is fully configurable via the PMBus for a host of parameters, from output voltage setting to configuring warning and fault thresholds to fine-tuning a device's loop dynamics to optimize its transient response performance for a particular combination of load and bulk capacitance conditions. Each 3E product can also provide a wealth of information while it runs — such as the output current level and the converter's temperature — in response to standard PMBus commands.



Device	Power density W/cm3	Area current density A/cm2
18 A analog POL – PMH8918LP	7.4	2.1
20 A 3E POL – BMR450	24.3	6.0
40 A 3E POL – BMR451	26.1	6.5

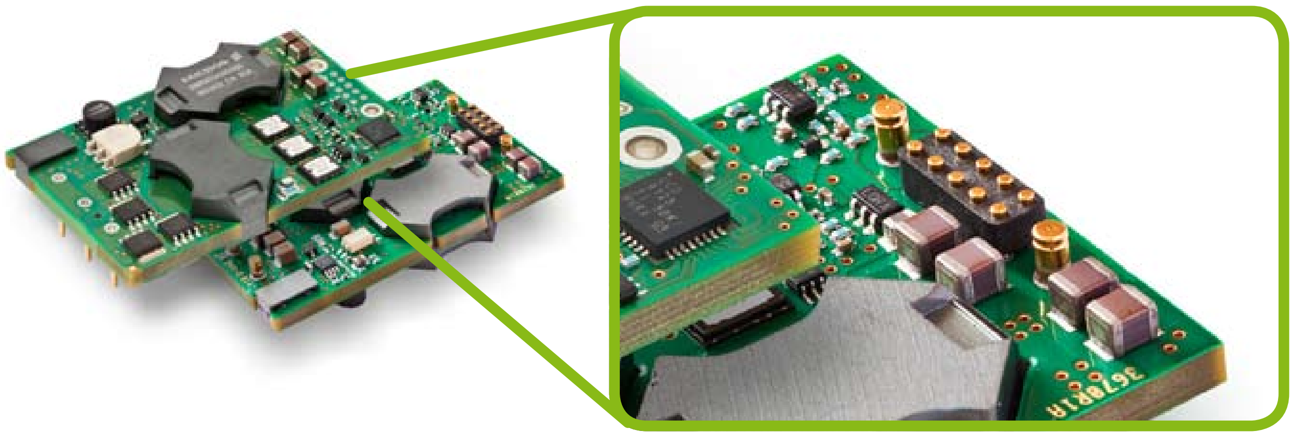
Figure 5. From left to right—the size of a traditional 18 A analog point-of-load regulator compared with the 3E family BMR450 (20 A) and BMR451 (40 A) devices.

PINS BETTER PADS FOR HIGH CURRENTS

Recognizing that many designers continue to prefer through-hole-mount technology for high-current devices, Ericsson offers the 3E family in through-hole as well as surface-mount versions. Like other currently-available 3E family members, the BMR453 uses robust pins to carry power into and out of the module while a metric-standard 2mm pitch pin-header provides the signal connections. *Figure 6* shows the through-hole-mounting version alongside the surface-mount derivative that uses a proprietary precision-fit pin design to guarantee co-planarity and easy solderability. Notice that this strategy permits one footprint to accommodate both through-hole and surface-mount outlines.

In favoring pins over alternative connection schemes such as land-grid-array style PCB pad lands that can suit simple low-current point-of-load regulators, Ericsson's designers recognized that pins provide superior performance for the applications that the currently-available members of the 3E family target. Through-hole-mount technology makes it easy to spread high currents through multilayer boards while using pins for surface-mount applications provides more thermal mass than pad lands, improving heat transfer between the converter and the board. Using pins can also significantly ease inspection tasks as it is then possible to use automated optical inspection equipment rather than the x-ray based techniques that pad lands require.

Similarly, Ericsson chose its simple gold-flashed surface-mount pin design over techniques such as solderball-on-pin to maximize compatibility with established manufacturing processes. Another important feature of Ericsson's pinning layout is that it effectively forms a "three-legged stool" structure that minimizes co-planarity problems during soldering — as *figure 7* shows for the underside of a surface-mount BMR451 point-of-load regulator — while substantial flat surfaces on the module's top side make it easy for pick-and-place machines to handle using conventional vacuum nozzles. All 3E series modules share a similar coherent approach to their construction that simplifies board layout, minimizes manufacturability issues, and eases future compatibility concerns.



BMR453 PI (top view)
BMR453 SI (bottom view)

BMR453 SI
signal input/output connector

Figure 6. Available in through-hole and surface-mount versions, the BMR453 advanced intermediate-bus converter benefits from a very well-developed interconnection system.

Figure 7. Ericsson's pin-based surface-mount interconnects form a "three-legged stool" structure that minimizes co-planarity problems during soldering.

SCALABLE, EXTENSIBLE FOOTPRINTS MADE REALITY

Ericsson's designers have been careful to preserve pinning arrangements that are as similar as possible between devices within the same category. This approach makes scalable footprints a reality for intermediate-bus converters such as the eight-brick BMR454 and the quarter-brick BMR453 — which share mechanically identical pin positions — as well as the BMR450 and BMR451 point-of-load converters that can again share a common outline. As a result, one footprint can accommodate up to 204 W or 396 W of intermediate bus power. Similarly, *figure 8* illustrates the harmonized footprint arrangement for the BMR450 and BMR451 that respectively source up to 20 A and 40 A:

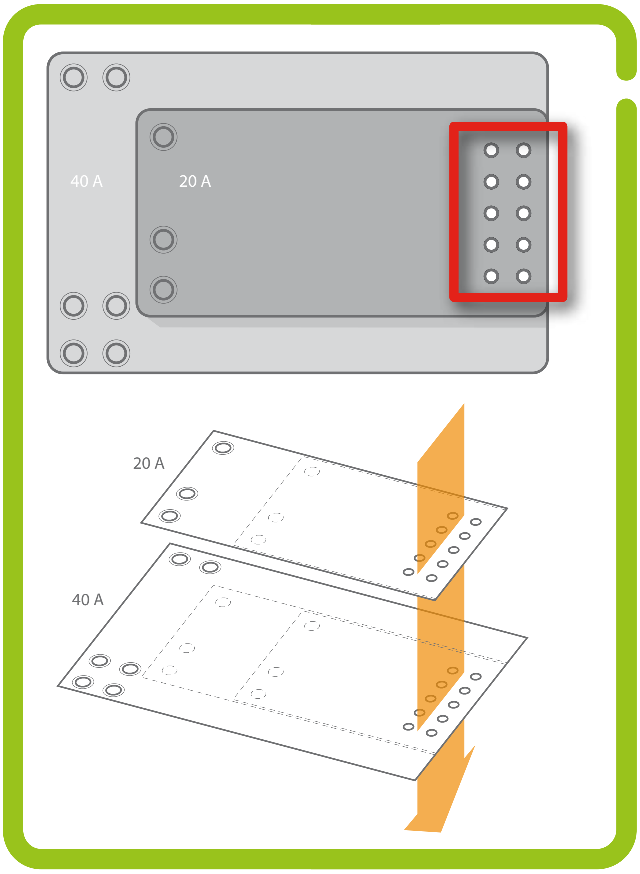
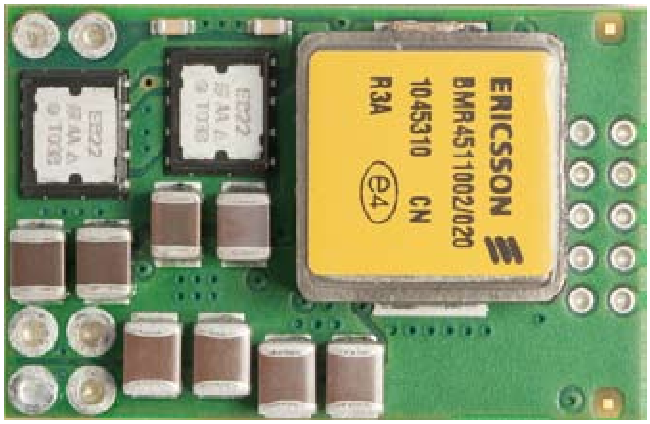
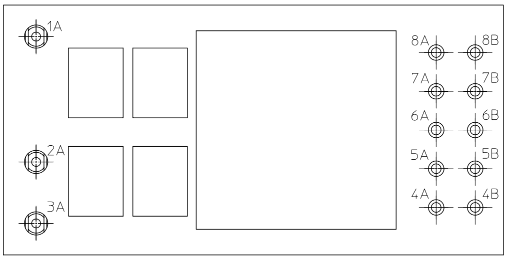
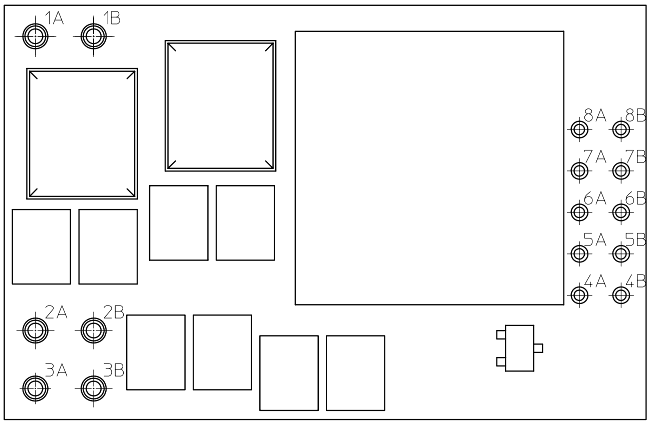


Figure 8. Like other 3E family devices within the same category, the BMR450 (20 A) and BMR451 (40 A) point-of-load regulators can share a common footprint.

The evolutionary challenge that a digital power module designer faces with regard to developing a generic footprint is easy to see by comparing the pinning arrangements of the original BMR450/BMR451 parts with the second-generation BMR46x devices that offer 12 A, 20 A, and 40 A load current ratings. The first-generation parts employ a 10-pin signal header whose pin-out appears in *figure 9*:







Pin	Designation	Function
1A	VIN	Input Voltage
2A	GND	Power Ground
3A	VOUT	Output Voltage
4A	+S	Positive sense
4B	–S	Negative sense
5A	SA0	Address pin 0
5B	SA1	Address pin 1
6A	SCL	PMBus Clock
6B	SDA	PMBus Data
7A	FLEX	Analog voltage adjust / Synchronization
7B	DGND	PMBus Ground
8A	SALERT	PMBus Alert
8B	CTRL	PMBus Control (Remote Control)

Pin	Designation	Function
1A, 1B	VIN	Input Voltage
2A, 2B	GND	Power Ground
3A, 3B	VOUT	Output Voltage
4A	+S	Positive sense
4B	–S	Negative sense
5A	SA0	Address pin 0
5B	SA1	Address pin 1
6A	SCL	PMBus Clock
6B	SDA	PMBus Data
7A	FLEX	Analog voltage adjust / Synchronization
7B	DGND	PMBus Ground
8A	SALERT	PMBus Alert
8B	CTRL	PMBus Control (Remote Control)

Figure 9. Connection arrangements for the first-generation BMR450 and BMR451 3E digital point-of-load regulator (top view).

Relative to the BMR450, the higher-current BMR451 doubles its input voltage, power ground, and output voltage connections (1A through 3B) to ensure loss-free power connections. This “right-sizing” scheme follows through in the BMR462/463/464 with similar pin placements that ease board power-layout considerations, while the 10-pin header that the first-generation parts employ has now expanded to occupy a 12- and 14-pin format that is necessary to accommodate additional features that the second-generation digital control chips offer — see *figure 10* and *figure 11*:

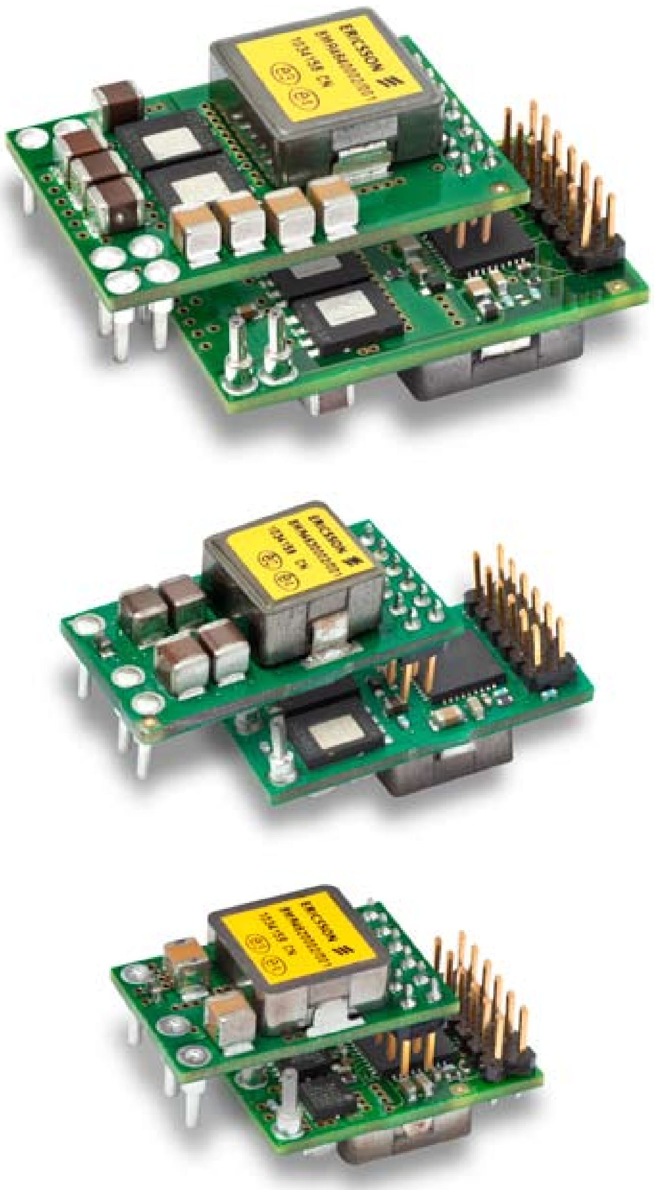
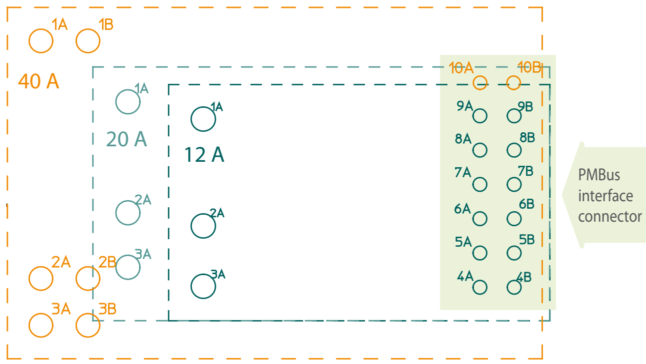


Figure 10. Second-generation of 3E digital point-of-load regulators, from top to bottom, BMR464 (40A) – BMR463 (20A) – BMR462 (12A)

FOOTPRINT BMR462/463/464



ELECTRICAL PINNING

Pin	Designation	Function
1A, B*	Vin	Input voltage
2A, B*	GND	Power ground
3A, B*	Vout	Output voltage
4A	Vtrk	Voltage tracking input
4B	SGND	Pin-strap ground reference
5A	+S	Positive sense
5B	–S	Negative sense
6A	SA0	PMBus address pin-strap
6B	GCB	Group communication bus
7A	SCL	PMBus clock
7B	SDA	PMBus data
8A	Vset	Output voltage pin-strap
8B	SYNC	Synchronization I/O
9A	SALERT	PMBus alert
9B	CTRL	PMBus control (Remote Control)
10A*	PG*	Power Good
10B*	SA1*	PMBus address pin-strap

*only on BMR464

Figure 11. Despite new signal connections, the footprints for second-generation 3E digital point-of-load regulators remain scalable.

For instance, the new group communication bus (GCB) pin now allows multiple converters to communicate autonomously — that is, with no need for supervisory PMBus control — to support functions such as fault spreading and current sharing. In the event of a fault such as temporary overload, fault spreading allows regulators that are appropriately configured via PMBus commands to broadcast a fault event over the GCB that can initiate a controlled shutdown-and-restart sequence in a predetermined order. In this way, a system can automatically and safely remove and re-apply power to sensitive multi-rail devices, such as ASICs, FPGAs, and many microcontrollers. Again simplifying multi-rail applications, the analog voltage-tracking input complements the PMBus-programmable output voltage sequencing facility to make it possible for a regulator to track an external voltage and ramp up its output, either at the same rate as the reference voltage or as a configurable percentage of that rate.

The current sharing facility now includes the ability to add or shed phases in response to load conditions and offers several alternative approaches to implementing this feature. The analog output voltage pin-strap and clock synchronization I/O functions now have dedicated pins rather than the original multi-mode FLEX pin, improving application flexibility. It remains possible to synchronize each converter to a common clock frequency to eliminate beat frequencies and simplify EMC filter design, and the interleaving/phase-spreading capability that can drastically reduce peak currents on the input supply rail is still available. The 14-pin header that appears on the BMR464 (*Figure 12*) now provides an external power-good signal, which the converter asserts to signal that no fault condition is present and that the output voltage is within about -10/+15% of its target value. This tolerance is programmable for each BMR46x device, and each device's power-good status is readable from the PMBus.

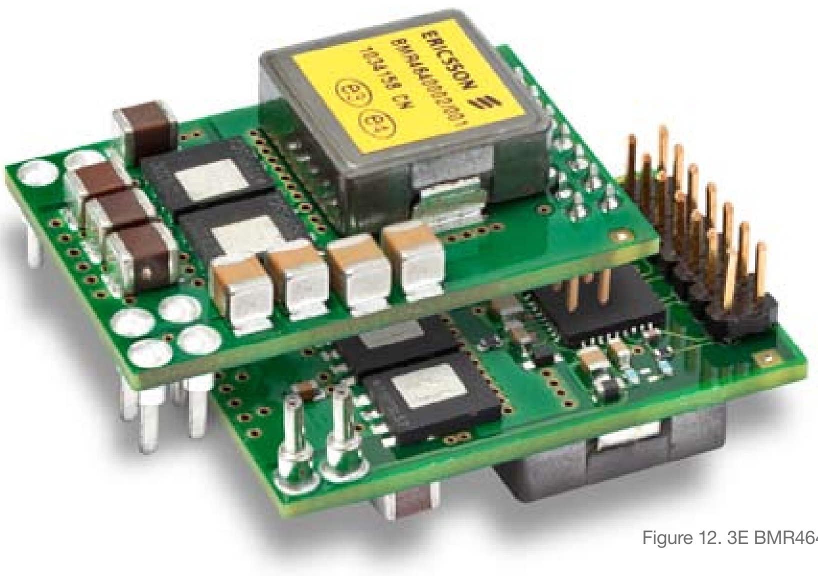


Figure 12. 3E BMR464 (40 A) POL.

These points illustrate that more parameters are accessible and configurable via the PMBus to make the second-generation parts more capable and flexible than their forerunners, and this trend can confidently be expected to continue with future digital control ICs. Yet Ericsson's designers have retained the harmonized footprint philosophy that allows board designers to use a common footprint for all three new devices to accommodate systems whose power requirements are either not precisely known, or are likely to change over the lifetime of the equipment series. This strategy too will continue insofar as Ericsson's designers can possibly accommodate it, providing the company's customers with an ongoing assurance of continuity between succeeding generations of digital power converters.

DIGITAL CONNECTIVITY IS A KEY ENABLER

While any 3E series converter can operate stand-alone in analog-replacement mode, adopting the PMBus offers designers massive scope for innovation. Such benefits span the converter's entire lifecycle, from experimenting with different settings during initial development to programming custom parameters during manufacture to facilitating system-level power-management schemes that actively save energy in the end-user's equipment. To assist designers to become familiar with 3E family devices and PMBus protocols, Ericsson offers a 3E evaluation kit that allows users to configure, monitor, and control the power converters from a PC. Please visit the extensive resources at www.ericsson.com/powermodules for much more application information.

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