

Next Generation Power Modules Further Simplify Power Design

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Executive Summary

A sound discrete power supply design requires a high level of expertise and is time-consuming to design. Power modules offer an easier path, in a ready-to-use plug-and-play reliable design for rapid prototyping or end use.

A new generation of power modules on the market today offers greater integration, for a smaller system-in-package power solution. New process and packaging technologies have enabled these devices to become more compact and operate with higher efficiency, while eliminating the daunting task of designing a worry-free power supply. This enables system designers to spend greater time on the core design, for faster time to market.

Next Generation Power Modules Further Simplify Power Design

The fundamental advantage of power modules is that they allow system designers to focus on their core IP while leaving power supply design to someone else. But now, yesterday's off-the-shelf PCB power modules and bricks have given way to even better, and smaller, "System-in-Package" modules.

These next-generation power supply modules take today's new design challenges into account. Technological advances have made modules easier to use, while also decreasing the overall size and reducing the total BOM. The best of these next-generation modules have even higher efficiency than before, are pin-to-pin compatible across different voltages and currents, and are designed with an easy migration path for cost reduction.

Power Supply Design: Not an Easy Task

It's not a simple task to design a robust power supply from the ground up, and that's even more true of one that includes a switching regulator integrated circuit (IC). The typical approach, a complicated mix of discrete components, requires specialized expertise and knowledge to keep the circuit free of problems. Power supply issues are problematic because they can lengthen

time to market or—if not resolved—even cause the system to fail in the field.

Furthermore, discrete power supply designs require many external components, which in turn require time and effort to source, stock, order, and surface-mount, and whose availability can be challenging to ensure. Discrete power designs also usually mean a larger PC board layout, which takes up valuable real estate at a time when—more than ever—space is at a premium.

Power Modules Are the Solution

Advancements in smaller-geometry processes, IC design, and integrated package technologies now allow module manufacturers to combine the passive components needed for a power supply circuit, along with the base ICs, into a single, small power supply solution. Synchronous switching regulators include integrated FETs, which are smaller, more efficient, and more accurate than older switchers. The latest power module solutions merge these new synchronous switchers with components such as resistors, capacitors, MOSFETs and inductors, for a simple-to-use hybrid power module that reduces solution size, cost and layout complexity.

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Not All Power Modules Are the Same

Many power modules on the market today are simpler to use than ICs but don't fully address all design challenges. An ideal module speeds time to market, by combining a low total cost of ownership with other key design benefits like these:

- High efficiency and low power dissipation, based on customer-proven robust ICs
- Small size, achieved by integrating more components
- Easy to use, with pin compatibility across voltages and currents for design flexibility
- Flexible, with a transparent cost reduction option ideal for migrating from module to IC for volume production

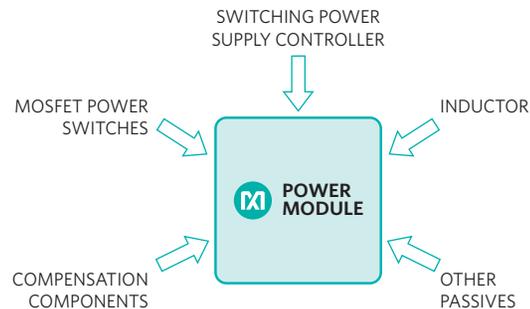


Figure 1. Power modules integrate all the key components needed for a complete power supply

The result is a reliable new generation of System-in-Package (SiP) power solutions that eliminates discrete design problems and addresses the aforementioned key design needs, allowing engineers to spend their time on other critical design areas (Figure 1).

Proven Synchronous Regulators as a Foundation

Improvements in IC processes and designs have led to the integration of the MOSFET transistors utilized in switching power supplies. This integration, in turn, has led to the development of synchronous rectification power supplies that have revolutionized the DC-DC power market, especially in the high voltage application space. The latest synchronous buck converters provide extraordinarily high efficiency, cooler operation and smaller size.

FEATURED TECHNOLOGY

Advantages of Synchronous Versus Non-Synchronous Power ICs

Figure 2 shows the difference between synchronous and nonsynchronous power designs. Traditional non-synchronous converters use an external Schottky diode, to rectify and conduct the output inductor current during the high-side transistor off-time. In theory, this technique is simple. Unfortunately, in practice, it's difficult to design in—and harder still to control, even though it was commonly used for several decades. Its biggest drawback is that the diode dissipates a lot of heat due to its forward voltage drop, so the resulting system is not very efficient.

A synchronous converter replaces the external rectification diode with an integrated low-side power MOSFET. Compared to the diode on the non-synchronous converter, the MOSFET's low resistance causes a much smaller voltage drop; the MOSFET can also be turned off when not needed. Hence, power loss during the conversion is significantly reduced. That means the circuit runs cooler—and more efficiently. Both the rectification low-side MOSFET and the once-external compensation circuitry are now part of the IC itself.

To better explain the benefits of this technology, let's do a quick power loss calculation to compare synchronous and non-synchronous solutions.

As you can see, the synchronous solution reduces the power loss in the rectification diode by 60 percent! And that is cool—literally.

The corresponding thermal images clearly indicate how much cooler the synchronous DC-DC converter is operating, compared to its nonsynchronous counterpart. This is important because heat can reduce the lifespan of an electrical component. To quote Svante Arrhenius, "For every 10 degree reduction in temperature, the circuit's life doubles." It follows that a 30°C temperature difference means that the synchronous solution should last 8 times longer than the non-synchronous solution.

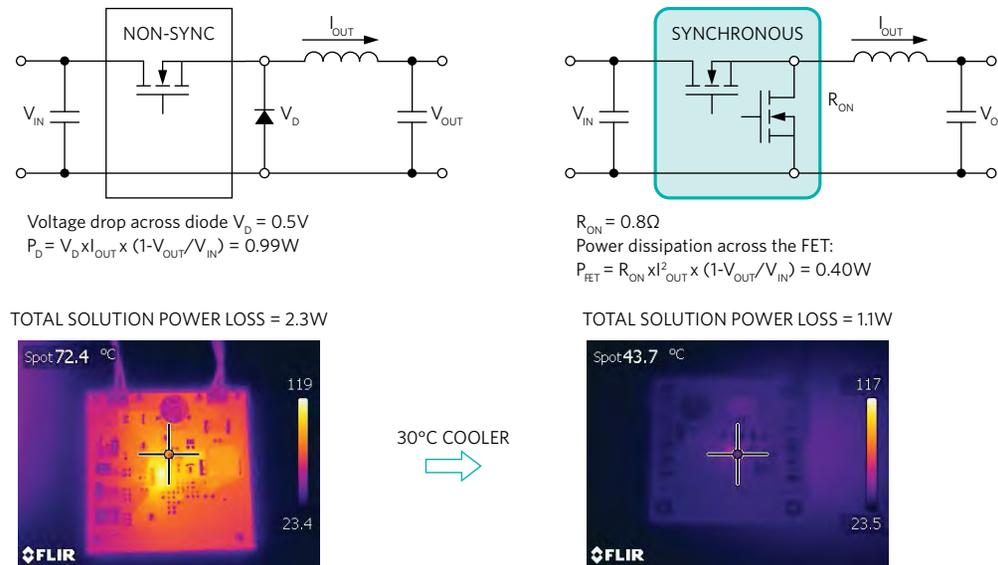


Figure 2. Synchronous vs. non-synchronous rectifier power dissipation

By integrating the compensation circuitry, synchronous rectification boosts the accuracy of feedback regulation. But more dramatically, built-in compensation across the output voltage range eliminates the need for external components, notably reducing component count and footprint size. An additional benefit is high internal reference voltage accuracy, which provides more precise voltage regulation—close to $\pm 1\%$ over an extended operating temperature range.

Using these new integrated FET switching regulators with synchronous rectification as a foundation for power modules, suppliers can offer the same benefits of high efficiency, cooler operation, smaller size, and more precise voltage regulation. For example, Maxim integrates its Himalaya ICs together with other components, to create the Himalaya family of power modules.

How Power Modules Simplify the Design Process

Even with these advanced synchronous buck ICs, a robust power supply still has numerous requirements and challenges to overcome. A designer must assess the input voltage, output voltage, load current, temperature, noise immunity and/or emissions, to name a few. Some of the most difficult challenges associated with switching power supply designs include external component choice, component placement, PCB layout, and controlling issues like electromagnetic interference (EMI), radio frequency interference (RFI), and radio frequency susceptibility (RFS). Any of these, if unchecked, may introduce electrical noise that can couple into and out of the power circuit.

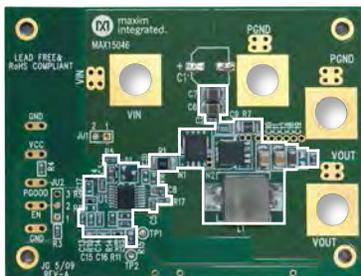
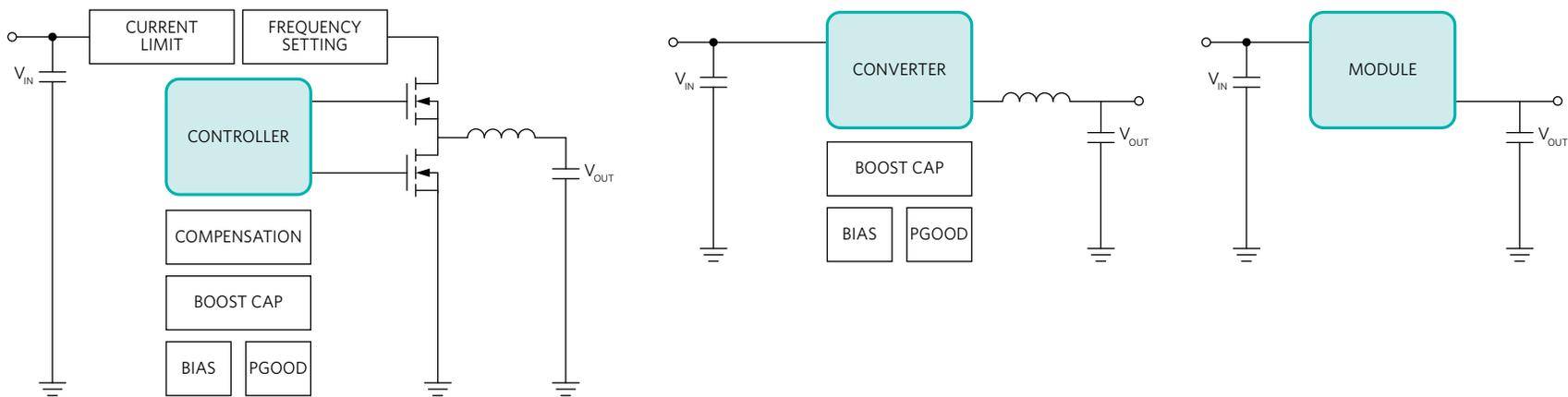
When choosing external components for a discrete power supply, careful judgment is critical. For example, inductors of the same inductance value can have different saturation points, causing problems when fast transients demand high currents. There are many styles of inductors, all with different factors that control their specifications, including the exact magnetic core material, coil shape, separation between turns, frequency response, DC resistance, quality factor (Q), and shielded vs. non-shielded. Choosing the wrong inductor may cause problems such as instability, spiking at the input or output, or even complete failure, if the inductor is not properly suited for the system's power requirements. Capacitors can also cause instability, if not properly chosen, since their value may vary over frequency, voltage and temperature.

With power modules, some external components are already integrated, removing a great deal of risk. In fact, it's now possible to integrate everything from the switching power supply controller to the MOSFET power switches, inductor, and other passive components needed for proper compensation and bias, with only four or five minimum external components required for operation. All integrated components are carefully chosen for optimal performance, taking the guesswork out of design. Engineers are free to focus on choosing a suitable off-the-shelf power module that matches their exact power supply requirements.

Choosing the correct components for a discrete power circuit is important, but equally important is properly placing them near the IC, which requires a high level of skill and expertise. The designer needs to keep in mind the length and size of the high-current paths, be concerned with high-frequency nodes, and take precautions with ground return paths to both the IC and the input power supply. Inductors and capacitors located too far from the IC can cause problems, by increasing parasitics and resistance within the high-current loop. (Most modules on the market utilize shielded inductors; these help to lower the EMI associated with switching regulators, making it more predictable.) Compensation and feedback circuitry can also be affected by ground noise if not properly designed. Sealing modules into encapsulated packages can help protect their ICs from the PCB layout issues so prevalent in discrete power designs. Because the module is soldered down like a standard IC, and the compensation circuit, FETs and inductor are all internal, the ground configuration is well known, and designed to control the ground currents near sensitive devices. This control helps safeguard the power circuits from ground bounce and other system level noises that can be injected into the compensation circuit, ultimately resulting in a more efficient and reliable power supply.

Smaller is Better

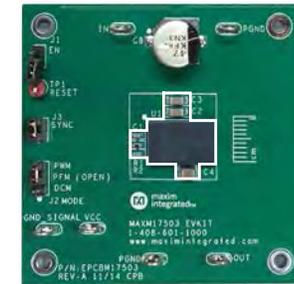
Besides eliminating many of the hurdles typically associated with designing a robust power supply, these next-generation power modules have the added benefit of being much smaller than discrete power solutions that use PWM controllers or even integrated FET switching regulators. Over the years, power supply circuits have progressed from simple power controllers with all external components (Figure 3A), to power converters with IC integration that use an external inductor but fewer additional external components (Figure 3B), to their latest iteration, a more compact power module (Figure 3C). Himalaya power modules, for example, require as little as four to five small external components: input capacitor, output capacitor, two resistors to set the output voltage, and possibly a capacitor for soft start. Figure 3 shows this progressive integration of power solutions, along with the footprint size associated with each.



3A. MAX15046 SYNCHRONOUS BUCK CONTROLLER



3B. MAX17503 SYNCHRONOUS BUCK CONTROLLER



3C. MAXM17503 MODULE

Figure 3. Progressive Integration of power solutions

Convenience and Flexibility Are Key

As you can see, the latest power modules clearly have a smaller footprint. But this is only one advantage of using modules. Another is design simplicity.

A new kind of layout configuration that brings the pins to the periphery of the package, via a QFN-like pin out, makes PCB layout easy and less expensive for designers. Locating key signal pins at the perimeter of the package eliminates the need for multilayer boards that use vias to route to center pins located on the module's interior, as is the case with a ball or grid array type module (Figure 4). Perimeter pin location also creates room on the underside of the module for exposed pads, which can help dissipate heat away from the module for even cooler system operation. Multiple separate exposed pads provide additional protection, by isolating sensitive module areas from each other. Package height as low as

2.8mm is another key attribute for the next generation of power modules. It enables their use in mezzanine card applications where height clearance is important, and also makes it easier to integrate heat sinks—particularly important for high-power applications that need to disperse a lot of heat (Figure 5).

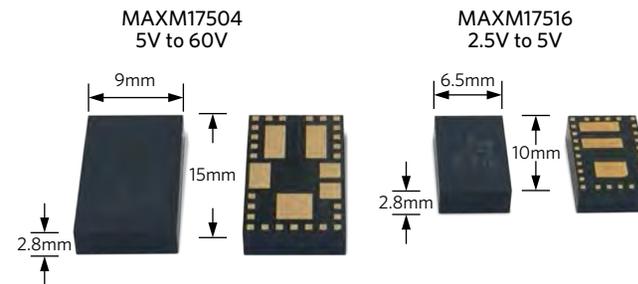


Figure 5. Just two examples of Maxim's Himalaya modules, small in both size and height

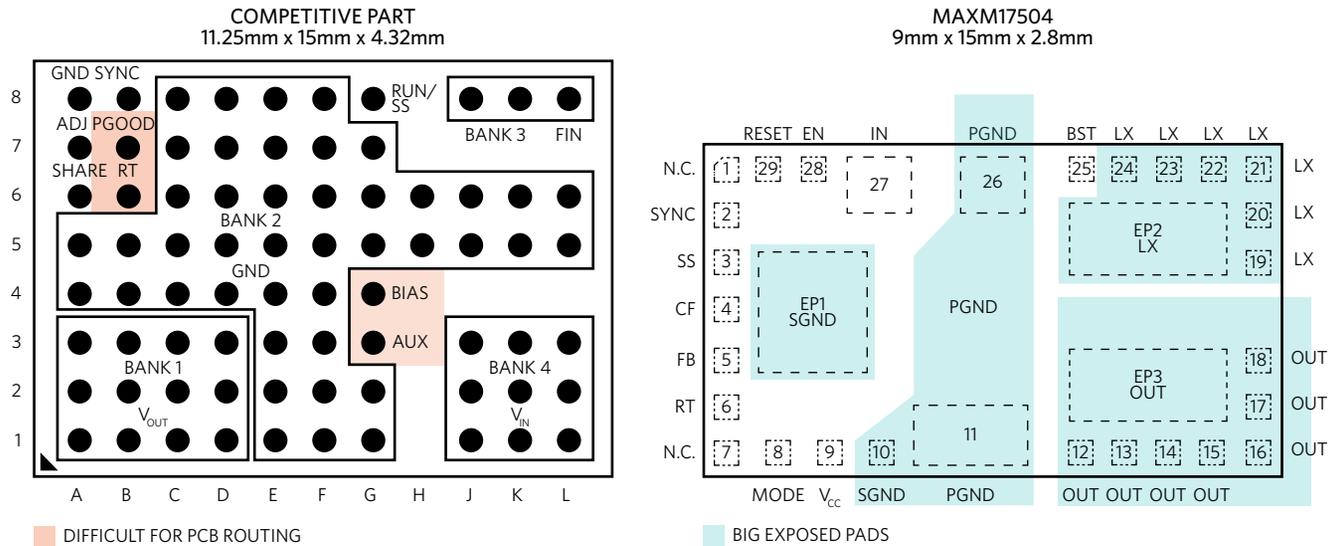


Figure 4. Pinout comparison between Maxim's QFN approach and an older grid array layout

Migrate with Ease Across Voltages and Currents

Power requirements can change frequently throughout the various design phases of a project. So why should customers be forced to redesign and re-spin their boards whenever their voltage or current requirements change? It's costly—and time-consuming.

Look for power module families that offer pin-to-pin compatible options across different current ranges and voltages. This allows the same layout to use different modules interchangeably with no impact to the PCB, and thereby accelerate time to market.

Cost Reduction Path: Migration to Discrete ICs

Some designers are hesitant to adopt power modules because they aren't as customizable as discrete power solutions, and are typically priced higher. The missing link, which is now a reality, is the ability to migrate. Today's designers can start with a module, for rapid development. They then have the option to seamlessly migrate to a solution using the identical IC, in discrete form. This flexibility optimizes both performance and costs when it's time for high-volume production, and can be invaluable to designers who want the best of both worlds.

Simplify Design

Innovation in IC process and packaging technologies has allowed for more integrated power modules than ever, at both IC and package levels. These next-generation power modules strip away all the complex problems associated with discrete components, while providing a complete and reliable power supply solution. They are highly efficient, are virtually immune to most PCB noise, and have more predictable EMI performance than the older nonsynchronous designs, while also operating at much cooler levels. Such power modules allow system-level designers with limited time and resources to quickly design the power circuit they need, so they can spend more time on other, more important design areas.

Maxim Integrated has taken these power modules to a new level. Its modules use customer-tested Himalaya synchronous buck regulator ICs, with their cooler operation advantages and small size benefits. They are designed with the engineering mind, from their smaller form factor with minimal external BOM components, convenient QFN-like pinout, and flexible pin-to-pin compatibility across different voltages and currents, to their easy migration path from modules to ICs in high-volume projects.

Power modules will continue to evolve toward more integration, cooler operation and a smaller size, with an emphasis on cost reduction. With these advances, power design has never been simpler or easier.

About the Author

Robert Nicoletti has 15 years' experience in the semiconductor industry with Maxim Integrated as an applications engineer, and has managed an applications team for 9 years. His experience spans a wide range of system-level disciplines such as system power, interface and audio solutions. He holds a bachelor's degree in Electrical Engineering from San Jose State University