WHITE PAPER

Programmable Power Management Provides Ultimate Flexibility

By Jon Alejandro

In modern electronic devices, versatility and control have become paramount. The expectations for flexibility are higher than ever, including customizing the date format on an alarm clock, navigating complex menus on a bicycle helmet camera, or harnessing the power of AI to predict home occupancy patterns and intelligently manage heating, cooling and hot water systems in a smart home. Even in the industrial sector, the convergence of technology and the Industrial Internet of Things (IIoT) is pushing boundaries, empowering sensors and devices to autonomously make decisions about what to measure and when to report data.

All this flexibility is achieved through software, which can be pre-configured and updated at will, often over-the-air, to reflect changed circumstances, implement performance updates or fix bugs. At the hardware level, controllers and CPUs have become standardized, allowing data-processing components to be shared across multiple products and defining the final functionality during the last programming step on the production line.

Amidst all this progress, however, one aspect of electronic products often lags in flexibility: the internal power system. In the past, a 5V logic supply and a 12V source for electromechanical components sufficed for most applications. Today, even basic devices frequently require more than ten different power rails, catering to various components such as the CPU, static and dynamic memory, digital and analog interfaces, isolated gate drive supplies, and more. These voltage values can range from 0.6V-12V, with input power sources ranging from a single Li-ion battery cell (3V-4.2V) to fixed, system bus voltages of 3.3V, 5V, 12V, 24V or 48V, derived from an AC-DC power supply.

A Power Tree is the Starting Point

Product designers create a "power tree" that outlines their final power needs as a starting point. From there, they reverse-engineer a configuration of series and parallel DC/DC converters to fulfill these requirements. Subsequently, they adjust the power tree to enhance overall system efficiency, minimize power dissipation, maximize battery lifespan, reduce size, lower cost or optimize any other relevant parameter. **Figure 1** serves as an illustrative example.

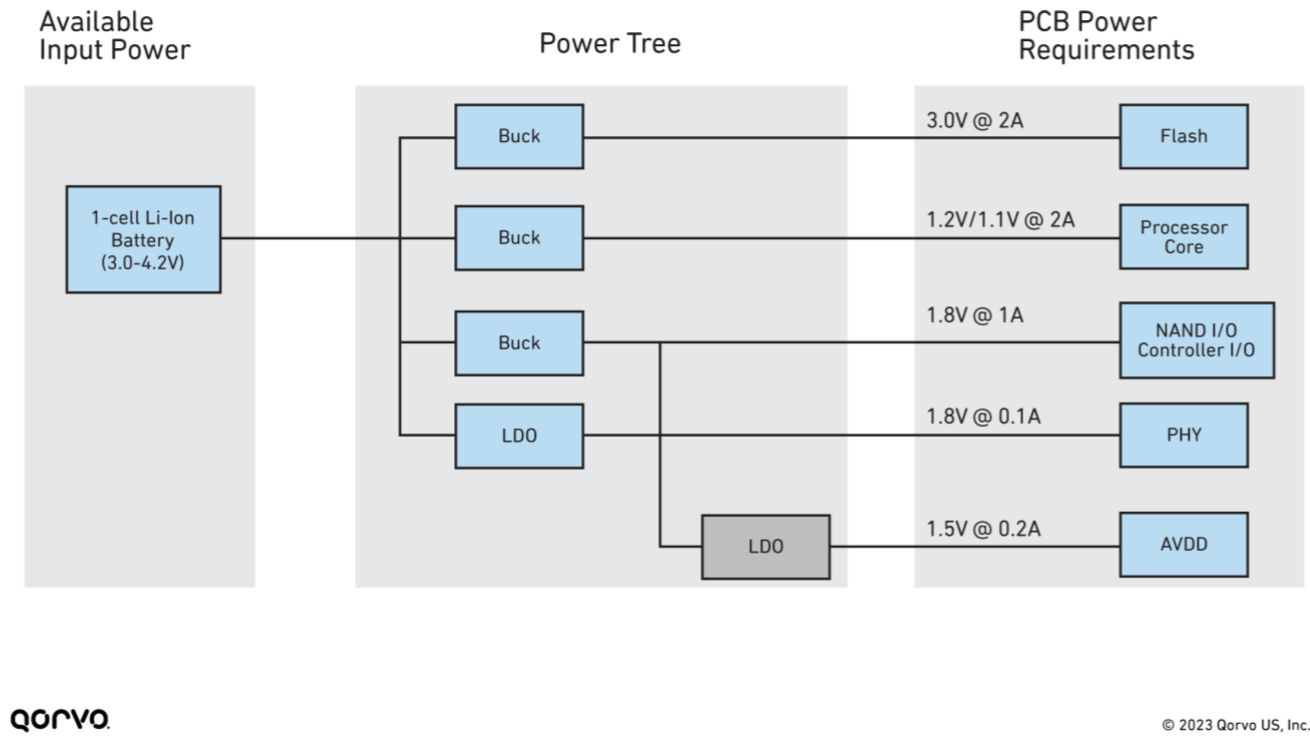

Figure 1: A typical power tree in a portable product design.

The widespread availability of low-dropout (LDO) linear regulators and modular switching DC/DC converters, capable of efficiently lowering, boosting or even adjusting voltages in both directions, has greatly simplified the process of designing the power tree. Some of these converters function as basic power controllers and necessitate the inclusion of numerous external components such as external power devices, inductors, control circuitry and compensation elements. In contrast, certain converters offer a high level of integration, demanding only a minimal set of external components.

DC/DC Converter Types

Regardless of the method employed to generate individual voltage rails, only five basic topologies of converters are typically used. These are the linear type and switching types: buck, boost, four-switch buck/boost and two-switch buck/boost (**Figure 2**).

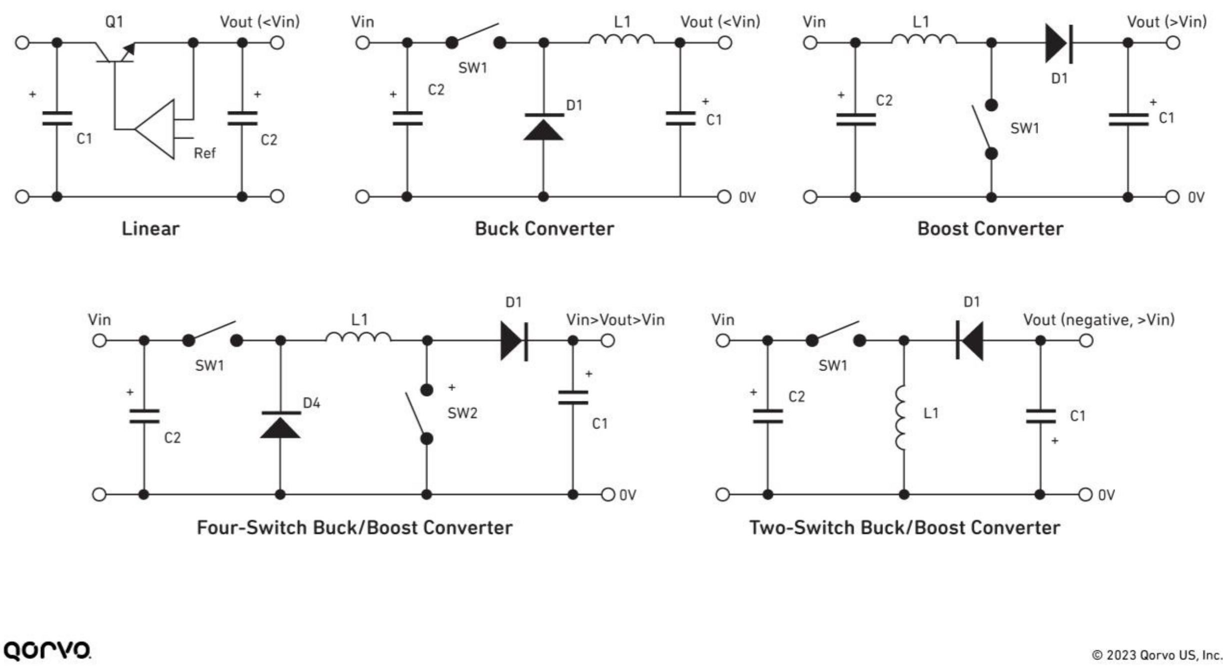

Figure 2: The basic DC/DC conversion arrangements: linear, buck, boost, four-switch buck/boost and two-switch buck/boost.

LDO linear regulators find their niche in situations where the input-output voltage difference is relatively small. For instance, when deriving 1.5V from 1.8V, they can achieve a reasonable efficiency of 83.3%. These regulators offer rapid responses to load changes and maintain very low output noise levels, making them invaluable in specific applications. However, it is worth noting that LDOs often lack advanced control features like adjustable outputs or shutdown pins. They are compact, three-terminal devices in their simplest form, making them straightforward to work with.

On the other hand, LDO linear regulators that are not designed for low-drop scenarios typically require a headroom voltage of more than 2V to function. These regulators are commonly employed in low-current applications where system-level efficiency takes a back seat.

Buck regulators, a type of switched-mode converter, step down the input voltage and can achieve high efficiencies, often exceeding 95%. They are versatile and function well with a wide range of input-to-output voltage differentials. However, they require an inductor and may exhibit slower dynamic responses compared to linear regulators. Additionally, some level of switching noise is usually present in their outputs.

Boost converters share similar characteristics with buck converters but instead increase the input voltage.
The four-switch buck/boost converter steps up or down the input as needed to maintain the desired output voltage. It is frequently used with battery inputs due to a battery's wide operating voltage range. This converter starts in buck mode when the battery is fully charged and transitions to boost mode as the battery discharges below the required output voltage. This dynamic operation allows the buck/boost converter to maximize energy extraction from the battery and extend runtime. A simpler two-switch version of the buck/boost converter serves to provide voltage inversion, such as generating -5V for an analog interface.

System DC/DC Converters Need to be Controllable and Compatible

FPGAs, DSPs and ADCs often demand a specific sequence for powering up and down their supply voltages. Even when not strictly necessary for functionality, one advantage to sequencing power rails includes reducing inrush current during startup. Plus, various types of system voltage regulators, supplied by different manufacturers, may offer sequencing capabilities through an enable input and a "Power Good" output signal that confirms when a voltage is stable and ready for the next step in the sequence. Sequencing can also be accomplished through communication buses like I^2C or PMBus®. However, the diverse range of control voltages, thresholds and communication protocols can make the task of sequencing separate regulators quite complex, sometimes necessitating the use of a separate microcontroller.

Given the complexities and potential problems of implementing a power tree with discrete regulators, a better solution is to use a power management integrated circuit (PMIC) which integrates multiple regulators into one package with guaranteed interoperability.

PMICs – The Small Flexible Solution

A PMIC sourced from a reputable provider, capable of generating all required system power rails with minimal external components, holds significant appeal. This is especially true during times of component shortages when the unavailability of a single part within a complex network of discrete converters can bring a production line to a halt. The idea is not new, and there are already PMICs on the market with multiple outputs. The drawback of many PMICs, however, is their inflexibility and inability to modify their default functionality. This often confines a PMIC to a narrow range of operational conditions.

In a discrete design, a simple adjustment of resistor values might suffice to fine-tune a voltage level, but in the case of a PMIC the high degree of integration can restrict modifications from the factory defaults. Additionally, various end products can leverage different combinations of the same stock of discrete regulator components, whereas a PMIC may be ideally suited for a specific product's power architecture with voltage requirements, rendering it unsuitable or overly expensive for other applications.

Different PMIC SKUs can be used for different designs, but this increases stocking costs and reduces buying power. Under the right conditions, the PMIC approach can yield dramatic improvements in size, assembly and parts cost, plus guaranteed operability, with a reduced supply chain reliance on discrete components, “dialing down” the production risk. As an example, consider implementing the power tree in Figure 1 using discrete regulators.
Figure 3 (left) shows the result with 57 components occupying 142 mm^2. If implemented with a Qorvo® **ACT88329** PMIC (right), the footprint reduces by a factor of five to 28.05 mm^2 and the component count drops to 14.
The size reduction alone opens opportunities to add functionality and value to space-constrained portable or wearable devices.

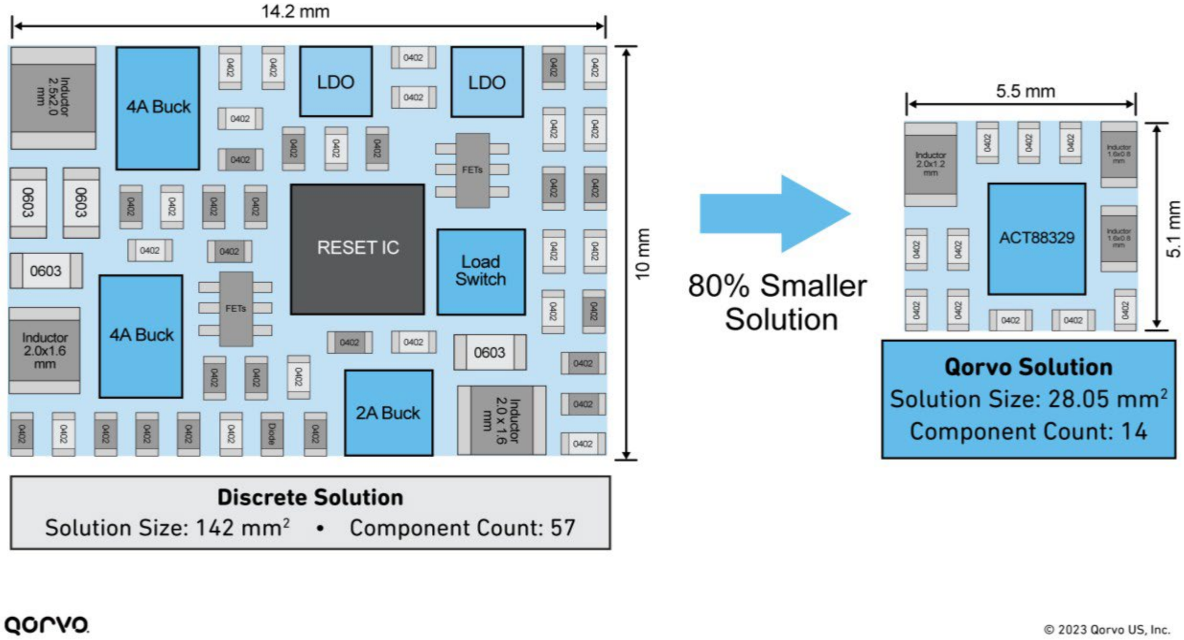

Figure 3: Reduction in parts count and footprint comparing a discrete DC/DC module solution (left) with a Qorvo PMIC solution (right) for the power tree of Figure 1.

Qorvo's Programmable PMICs and Supporting Systems Add Flexibility

The case for PMICs for cost and size reduction is compelling. When Qorvo PMICs are used, the issue of flexibility is also addressed by their range of multi-time configurable devices. Uniquely, these parts can be user-configured without any special software or firmware, via an I²C bus using the Qorvo ActiveCiPS™ USB dongle (**Figure 4**) connected to a Qorvo-supplied evaluation board. The ActiveCiPS GUI is intuitive and enables the user to preset and save a wide variety of default parameters to meet a specific application. When the system is proven, the user can upload the configuration to Qorvo, then Qorvo ships pre-programmed ICs with the required default functionality.

It is not just output voltages that can be configured. Qorvo's PMICs support can configure and optimize the following headline parameters that can be set through the ActiveCiPS dongle:

- Power-up/down sequencing
- Sequencing on-and-off delay times
- GPIO configurations
- Buck/LDO soft start time
- IC undervoltage lockout (UVLO) and overvoltage lockout (OVLO) thresholds
- Over-temperature shutdown
- Dynamic voltage scaling configurations
- Switching frequency
- LDO and buck configuration as a regulator or load switch

Figure 4: The Qorvo ActiveCiPS USB dongle for PMIC configuration.

The dongle provides a versatile means to modify a range of additional parameters, both directly through the I^2C communication interface within the application. These adjustments encompass fault thresholds, functional settings, sleep and low-power modes, enabling or disabling specific blocks and masking interrupt signals. Qorvo PMICs come equipped with configurable GPIOs, enabling straightforward digital control tasks like driving LEDs, initiating resets, monitoring power status and managing external DC/DC converters to synchronize their operation with the PMIC converters. Notably, Qorvo's distinctive three-state GPIOs offer three different configurations for each GPIO, and these parameters can be dynamically adjusted during operation using the I^2C bus. For instance, a user can implement dynamic voltage scaling (DVS) to adapt processor voltage levels based on the current processor load, achieving power efficiency gains and extending battery life in portable devices. Qorvo provides a diverse array of PMICs optimized for high- and low-power applications.

For example, the Qorvo **ACT81460** is optimized for power-sensitive applications such as wearables with very low quiescent consumption, typically down to 7µA. It is targeted for IoT, consumer or medical devices including wearables (**Figure 5**) and provides ten output rails: two bucks, one buck/boost, one boost (up to 20V) and a variety of linear regulators. The part is typically powered from a battery at 2.7V-5.5V in the end-product with two low-power modes, or from an external DC input, in which case the ACT81460 also acts as a battery charge controller.
The ACT81460 also has four GPIOs for programmable functions. All this is achieved in a 49-ball 3.3mm x 3.3mm WLCSP form factor.

For applications requiring medium power levels, the Qorvo **ACT88420** stands out in terms of cost-effectiveness and versatility (Figure 5). This device boasts an array of features to meet various power management needs. Its key specifications include four buck converters, one of which can be optionally configured as a load switch, and another as an LDO with current ratings of 4A and 2A, respectively. In addition to these, the ACT88420 includes two more LDOs, each with a rating of 400mA. Any of these LDOs can be conveniently configured to function as a load switch, offering flexibility and adaptability in diverse power management scenarios.

One of the standout features of the ACT88420 is its quiescent current, measuring only 12µA. This minimal power draw, combined with an input voltage range spanning from 2.7V-5.5V, makes it the best choice for applications where power efficiency and extended battery life are paramount concerns.

In terms of physical packaging, the ACT88420 is designed with space constraints in mind, measuring just 2.66 mm x 2.66 mm. Despite its compact size, it does not compromise on functionality. This device incorporates eight configurable GPIOs that can be tailored to operate as edge or level-triggered inputs, providing flexibility for integrating it into various systems and designs.

The Qorvo ACT88420 finds its sweet spot in a wide range of applications. Its capabilities make it ideal for powering solid-state drives, ensuring stable and efficient energy delivery in storage solutions. Moreover, its versatility extends to Internet of Things (IoT), where power management efficiency is important for prolonged device operation and reliability. Whether addressing power management challenges in a compact IoT device or in medium-power applications, the ACT88420's cost-effective price point, impressive current ratings, low quiescent current and flexible GPIO configurations make it a compelling option to consider.

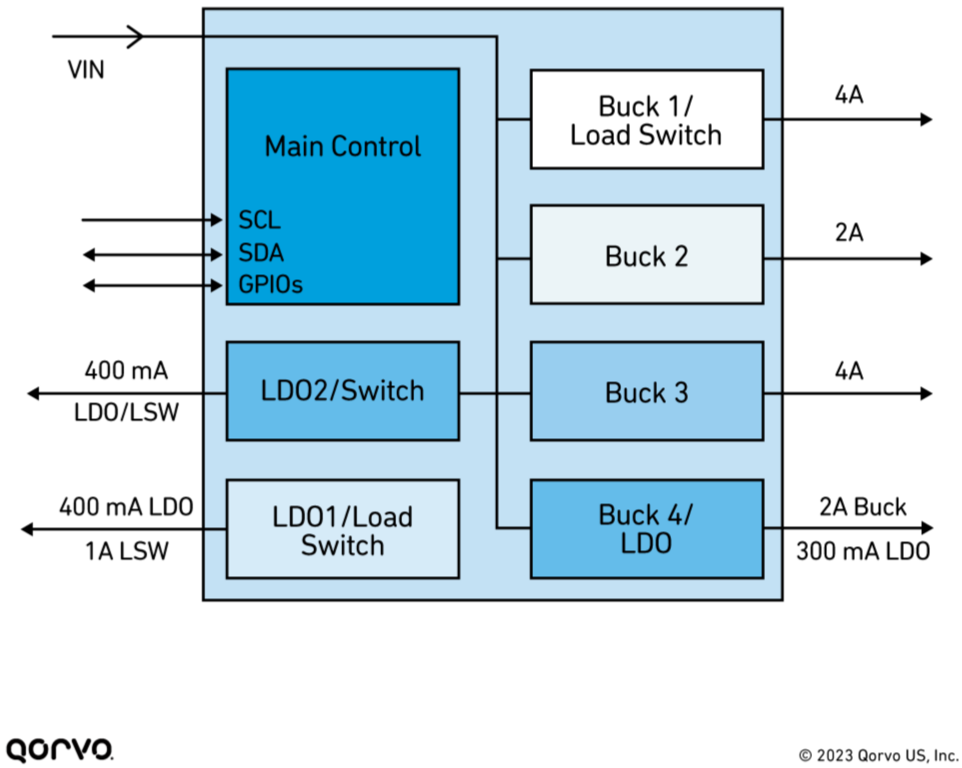

Figure 5: The Qorvo ACT88420 in a 2.66 mm x 2.66 mm chip-scale package.

The Qorvo PMIC offering also includes the **ACT85610** (**Figure 6**), an integrated circuit with high-voltage power loss protection and power management, which has a wide input range from 2.7V-14V with inrush protection using back-to-back FETs to isolate the input voltage during fault conditions. The ACT85610 provides backup power in the event of an input failure. It does this with an integrated boost that charges a storage capacitor up to 31V during normal operation. When the input power fails, the integrated boost is reconfigured to buck, which powers the system with a regulated voltage from the capacitor. Because energy is stored at a high voltage, significant hold-up time is achieved with a relatively small capacitor. The ACT85610 provides three buck outputs at 4A (6A peak), one at 1A (3A peak), one boost to 12V at 1A, and one buck at 100mA with a 20mA LDO. Six configurable GPIOs are included, and the part features a 12-bit ADC for system monitoring.

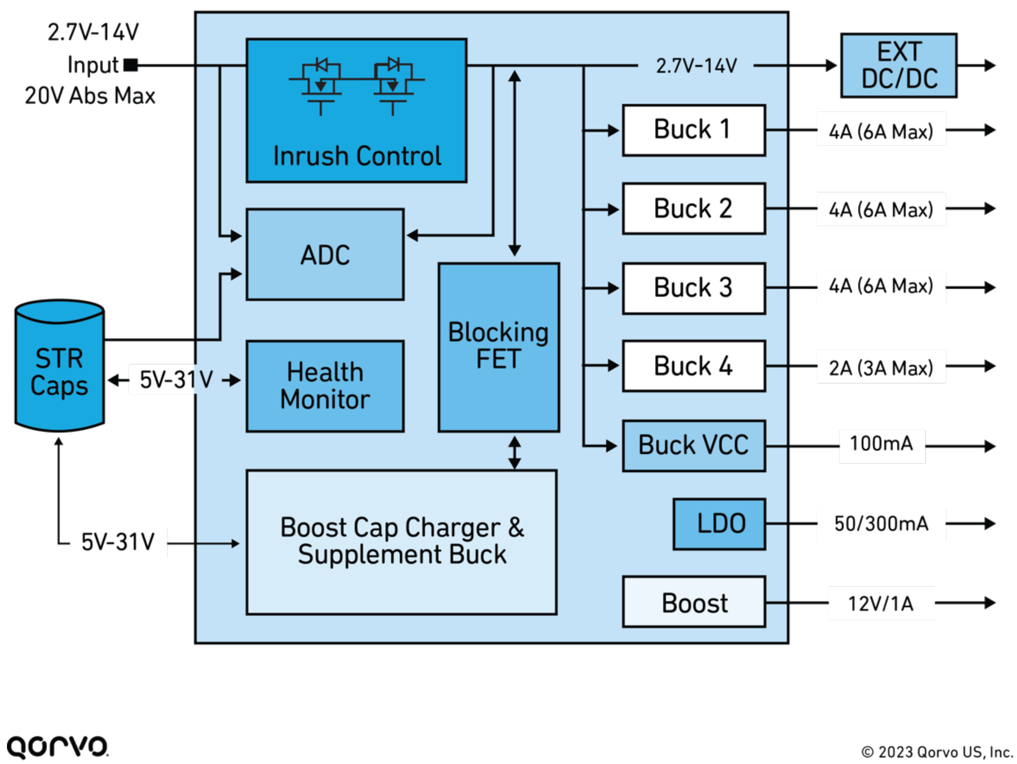

Figure 6: The Qorvo ACT85610 with a connected capacitor for extended hold-up time.

Conclusion

Product designers now have the best of all worlds: The power of the latest-technology processors can be harnessed to provide rich product functionality in a wide range of applications with all power rails provided by PMICs which occupy little to no space.

Qorvo's PMICs can generate an array of up to 13 distinct power rails, which the user can dynamically program in real-time. Alternatively, they can be configured with default settings before the PMICs are shipped, precisely tailored to meet the user's specifications. This level of adaptability means that a single high-performance PMIC can serve as the linchpin for a multitude of product variants or different product lines. The use of a single PMIC across various product iterations or within different product families creates a higher level of ecosystem efficiency. Assembly processes are streamlined, inventory and procurement costs are significantly reduced, and only one vendor is needed for different power management solutions. Moreover, valuable real estate on the PCB is liberated to accommodate additional functionality or features, further enhancing the product's capabilities.

Qorvo's PMICs empower product designers to capitalize on the full potential of modern processors while maintaining a lean and efficient design footprint. This not only translates into cost savings but fuels innovation, reduces complexity and accelerates the journey from concept to market, ultimately benefiting both manufacturers and end-users alike.