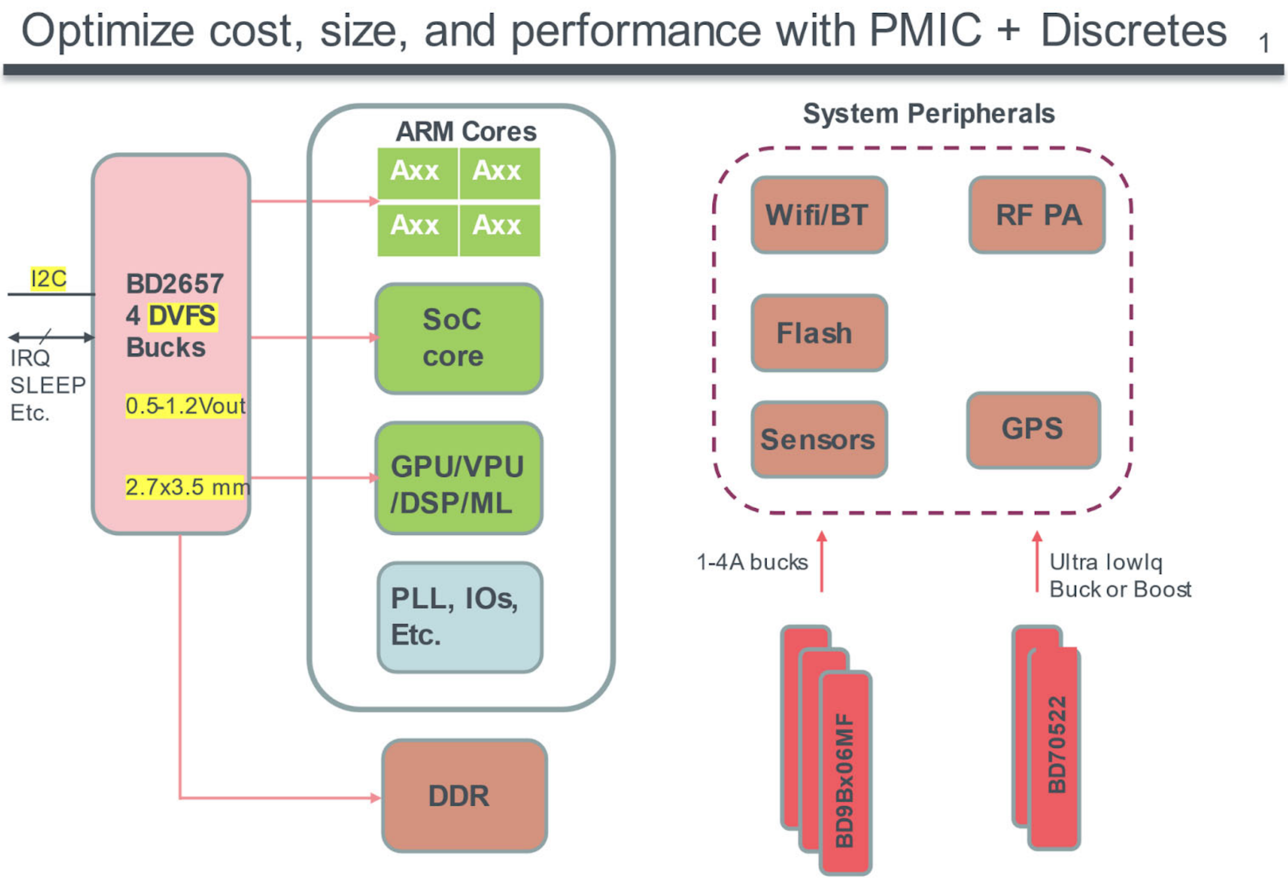
ROHM SEMICONDUCTOR

Optimizing Embedded Systems Power Requirements with Hybrid PMIC Design

White paper



Introduction

Building blocks of modern embedded systems, including processors, SoCs, system DRAM, non-volatile memories, sensors, and connectivity modules, have varied power requirements. On one extreme, a system power management IC (PMIC) integrates all or almost all of the required power rails. On the other hand, individual power rails are implemented using discrete dc/dc and LDOs. Thus, the best approach will depend on particular use cases and users' criteria. PMICs tend to offer better performance and controllability in a smaller footprint, while discrete solutions are more cost-effective. However, there is a "hybrid" approach to achieve the best of both worlds — using 'small' PMICs to implement power rails for performance and programmability, and discretes for everything else. In view, this whitepaper by ROHM Semiconductor will explore the benefits of using this approach.

Overview

The nature of the loads will determine how much power must be delivered and what, if any, special attributes are required from power sources. For example, power supplies to processor cores and hardware accelerators will require a good transient response and support for Dynamic Voltage and Frequency Scaling (DVFS) (i.e., the ability to adjust the voltage and current levels dynamically via software/OS). Conversely, power supplies to EEPROM or flash memories are relatively simple; they only need to supply the correct voltage and current and, perhaps, support low-power standby mode. As another example, power supply to an RF (e.g., Bluetooth or power amplifier (PA)) may require low-noise with ultra-low quiescent current (Iq) when not in use.

Why A Hybrid PMIC Approach is Beneficial

The semiconductor process and circuit design for implementing a low-Iq power supply for a sensor with very low duty cycle generally differs from those needed to produce DVFS power supply for a digital core. For example, the latter must offer software programmability and thus would be better to be implemented on a process which allows designers to economically incorporate digital control logic. The former requires low leakage of larger geometry processes for which on-chip integration does not yield the same cost benefit as in more advanced nodes. It's quite obvious to users that 'dumb' discrete (i.e., those without programmability) generally cost less than their equivalent when integrated into a PMIC. This is due to discretes' much higher volume and much smaller number of functionally equivalent PMICs on the market: the higher the integration, the more 'unique' a part is.

An optimized power solution can be achieved if system designers can use PMIC functionalities and features - e.g., software programmability, DVFS, slew rate control - in subsystems where they are really needed, and use discretes everywhere else. This pay-for-use approach delivers performance as well as low BOM cost. It requires a bit more effort compared to using a PMIC on a reference design but is frequently well justified when low BOM cost is demanded by the volume.

There currently exists a wide range of PMICs and discretes providing various operating voltages and output current. This hybrid approach allows designers to pay for performance and features only when necessary, meaning they are not required to pay for the trade-offs PMIC suppliers inevitably make when they conceive their products for various use cases or applications. The mismatches between PMIC capabilities and utilization is minimized when integration is kept to the most essential.

Cost Considerations

Given that cost is almost always an important consideration when making design trade-offs, system designers would prefer to implement or pay for features only when necessary. Although a high-powered, all-in-one PMIC can save space and simplify hardware power design, it may not be the optimal solution for a particular use case. Unused features and extensive geometry processes required to meet low leakage/Iq requirements are usually cost-ineffective for implementing fine-grained programmability and flexibility in control and power management state machines. All-in-one PMICs also often pose a thermal management challenge due to power losses aggregating onto a single die. Discretes are typically cheaper than PMICs, however, they are less flexible and do not offer specific advanced capabilities, such as I^2C programmability and DVFS. To get the best of both worlds, system designers should pay a premium for advanced features only where needed, e.g. I^2C programmability and DVFS features on rails supplying power to processor cores or hardware accelerators (GPU, VPU, etc.).

Power Management Requirements in Today's Embedded Systems

High-speed digital subsystems, such as CPU and SoC cores, DDR SDRAM, and VPU/GPU/ML hardware cores require power rails with moderate to high current levels, lower output voltages, small resolution (5-10 mV), good transient response, DVFS, and software programmability.

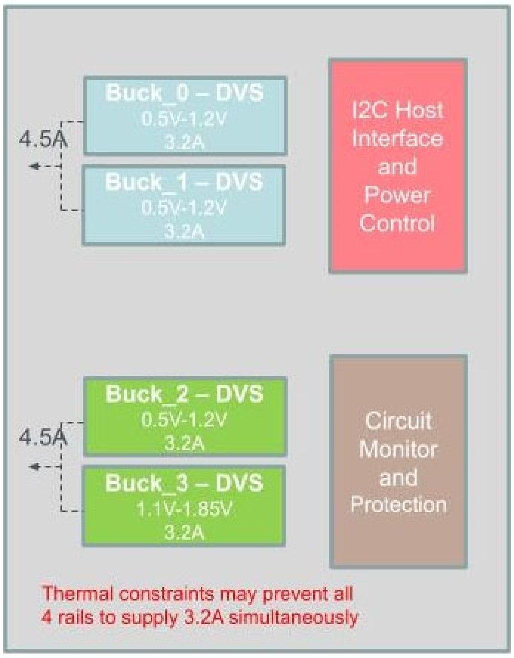
Transient Response Considerations

Rapidly expanding power requirements in today's embedded systems require high peak currents to be delivered instantaneously at low voltages to enhance the system efficiency and minimize power dissipation. The transient response refers to the response of a circuit to any change from its steady state. Voltage drops typically occur when the transient response is not fast enough, resulting in power loss and higher emissions with rapid changes in dynamic high-current loads. Given that the power source is sized correctly, a DC/DC converter and an output capacitor will be essential components for providing a good transient response. Typical converters achieve transient responses of a few milliseconds and a voltage drop greater than 50 mV with output capacitance. However, high-speed load transients induce parasitic elements on the transient response, and including output capacitors, can increase the overall size, weight, and cost.

ROHM's BD9B305QUZ is a synchronous DC/DC buck converter with built-in on-resistance power MOSFETs capable of providing an output current of up to 3A. It offers ultra-fast transient responses (within nanoseconds) via a constant on-time control system with no output capacitance required. The resulting voltage drop is up to four times smaller (less than 15 mV) than standard solutions. The BD9B305QUZ provides Power Good function for sequence control and light-load mode (LLM) control for enhancing the efficiency in standby/light-load conditions by reducing the power consumption. The device performs switching operation in PWM (Pulse Width Modulation) control at heavy load and offers high power density in a small footprint package for an ideal balance between performance size, weight, and cost.

Dynamic Voltage and Frequency Scaling (DVFS) and Programmability

The latest embedded systems utilize ultra-high clock frequencies to enhance system performance and increase processing power. Also, the speed of a circuit corresponds linearly to the supply voltage. However, when the system is not required to run at its highest performance, the supply voltage and clock frequency must be scaled down. DVFS functionality is essential for adjusting these parameters to lower active power consumption while preserving functionality. Additionally, it improves thermal performance by reducing self-heating in processor chips. DVFS uses software feedback to dynamically adjust the clock frequency based on the workload and subsequently ramps down the voltage to achieve power savings. Since the minimum supply voltage required is programmed into each IC, a PMIC can read this value and adjust the supply voltage accordingly. Similarly, by integrating in-circuit digital programmability/configurability for output voltages, complex system sequencing can be significantly simplified.



ROHM's BD2657 PMIC is ideal for use in battery-powered systems and offers input voltages from 0.5V to 1.2V to support the latest processors. The device provides 4 buck converters and DVFS and offers programmable output voltage, sequencing, and power state control. It comes in a small-footprint QFN-28 package which significantly lowers parasitic resistance and inductance and heat dissipation. The BD2657 also provides two general-purpose outputs and a power button support, and can power SoC CPUs and SoC cores, GPU/VPU subsystems, and DDR (to fine-tune memory performance). ROHM's fault protection capabilities include overvoltage, overcurrent, undervoltage lockout (UVLO), and thermal shutdown.

Best of Both Worlds: The Hybrid Solution

A proposed hybrid solution for power management in embedded systems incorporates two PMICs; a high input voltage PMIC for single-stage buck conversion from a 12V intermediate bus to supply higher power loads that require the highest efficiency, including processor cores, DDR, and VPU/GPU/ML, and a highly integrated 5V PMIC to supply other low-power system components. For example, using a 2-stage conversion process from a 12V source to a 1V rail with ninety percent (90%) efficiency at each stage would result in an eighty-one percent (81%) efficiency overall. If the power rail delivers 15A at 0.85V, the power loss is nearly 3W. This could cause a temperature rise in the parts between 10 and 20C. This is where a single-stage PMIC converter would be extremely useful to reduce the power wasted and converted to heat.

For lower current rails that draw only a few amps, the difference in power lost between 2-stage and single-stage converters is less significant. Hence, it may be a worthwhile trade-off to use a smaller and lower-cost PMIC, such as ROHM's BD2657 for lower current rails. This allows for a smaller footprint while addressing higher performance and efficiency requirements of the core rails and adequate performance for the lower current rails. The BD2657 integrates only DC/DC for these capabilities and costs less than equivalent implementation using a discrete solution. A DC/DC buck converter with an I2C interface can easily cost twice as much as one without.

Conclusion

This ROHM whitepaper suggests a hybrid approach for power architecture in embedded systems that combines PMICs and discretes to achieve higher performance and greater flexibility while reducing costs. The two products that were introduced are ROHM's BD2657 PMIC and BD9B305QUZ. The BD2657 offers broad programmability, sequencing, and DVFS to support a wide range of SoCs, processor units, memory components, and more. The BD9B305QUZ, while also programmable, offers an ultra-fast transient response, high power density, light-load mode control, and Power Good output for enhancing efficiency in standby mode while lowering the power consumption. By incorporating ROHM PMICs, engineers and designers can optimize performance, lower power consumption, and reduce costs in a host of embedded systems for numerous applications.

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