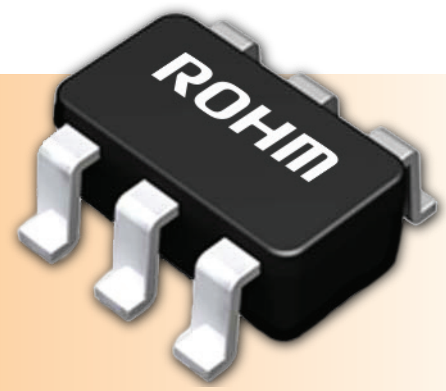
ROHM SEMICONDUCTOR

Innovations Embedded

Switching Regulator Advances Enable Compact, Efficient Power Management Design



White Paper

Introduction

Efficient power management is an important design element enabling systems developers to overcome increasing demands for compact size, low-power operation and improved functionality. In addition, many electronics systems require low multiple power rails and supply solutions that need to address the few milliamps needed for standby supplies as well as the over 100A requirements for application-specific integrated circuit (ASIC) voltage regulators. Low-voltage processors, digital signal processors (DSPs), and double data rate (DDR) memories also impose stringent requirements on the power supply.

Taking on these challenges, sophisticated power management technologies that make a huge impact to the overall solution with advances in direct current DC-to-DC regulator technology are being adopted. In the past, designing power management has been a complicated endeavor, challenging designers new to this area. Key technologies in switching mode regulators are making it easier to meet these requirements while delivering tremendous power savings and maintaining alternating current (AC) performance. To achieve the most optimum, efficient regulator design a number of factors must be considered when selecting power management architecture and technology. Understanding an application's demands such as output regulation, high operating voltage, extended temperature, and fast transient response in terms of efficiency needed, system footprint constraints and component budget are important evaluation points that should be taken in the first design steps.

This paper will present the benefits of incorporating a device from ROHM Semiconductor's expanded DC-to-DC switching regulator line that delivers enhanced efficiency compared to competitive and older generation voltage regulators. It will also illustrate how ROHM's new switching regulators enable designers to reduce the number and size of components on the printed circuit board (PCB). Features of these new regulators will be discussed in detail to demonstrate their technological advantages that include integrated protection circuitry, pulse frequency modulation (PFM), pulse width modulation (PWM), ROHM's SoftStart. Application examples where ROHM's new switching regulators are best suited will also be presented.

Power Supply Technology

Portable electronic systems are pervasive in both the industrial and consumer markets. Battery-powered devices, secondary point of load (POL), and distributed power supplies are a few areas that regularly require power supplies. These include:

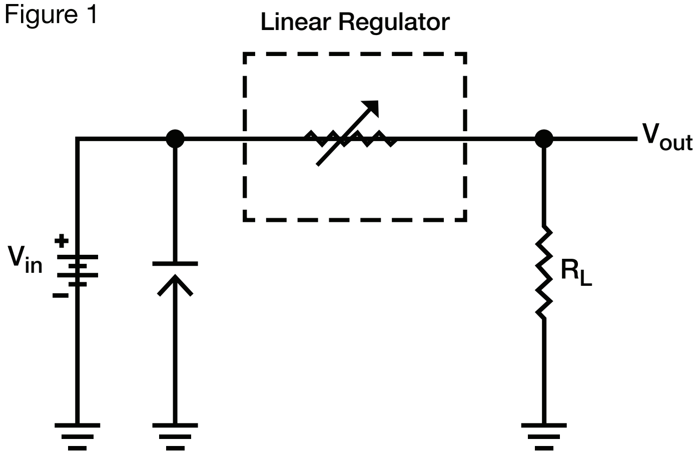
- Internet of Things (IoT) Gateways, Routers
- Streaming Media Players, Set-Top Boxes, HDMI Media Sticks
- LCD TVs, Gaming Equipment
- Broadband/Communications Equipment

- Notebook/Tablet PCs, Servers, Printers
- Storage Devices (HDDs, SSDs)

Consumer systems such as those listed typically use high operating voltages driven by 12-14V 2S and 3S battery configurations in order to achieve longer battery life. Higher power applications require faster processors, which in turn necessitate larger currents. And given the huge variety of components requiring power, a distributed power rchitecture is commonly employed, consisting of several DC-to-DC power modules that convert the high bus voltage to lower supply voltage rails. However, this type of isolated configuration poses challenges in meeting the requirements of many of the most common loads. Low voltage processors, DSPs, ASICs, and DDR memories place unwavering demands on the power supply to provide very fast transient response, high efficiency and low-voltage rails in a compact footprint.

In many distributed power designs, a linear low dropout (LDO) regulator is used to convert a low common voltage rail down to the lower supply required for the core and input/output (I/O) voltages for ICs on the PCB. The linearity in these circuits will indicate the power loss experienced in the conversion as well as the amount of power that is dissipated in the LDO. For example, a common 5V rail supplying a 3.3V to the DSP drops 1.7V in the LDO, which is equivalent to a 35% power loss. Such high loss of power leads to inefficiency that is inacceptable, especially with multiple components and varying core and I/O voltages to maintain. The figure below illustrates the concept of a linear regulator.

Figure 1



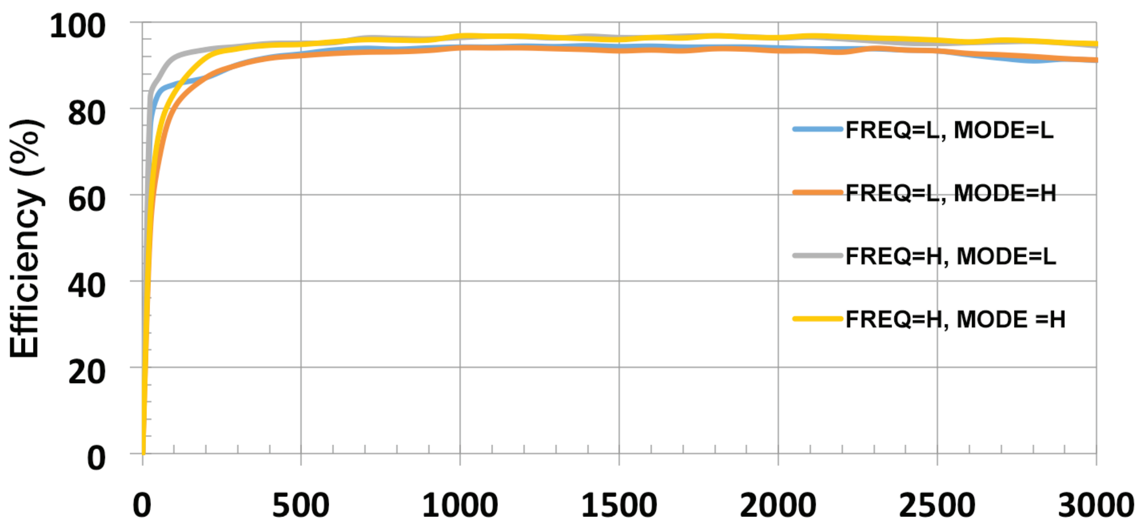
As shown in Figure 1, a linear regulator is nothing more than a variable resistor whose resistance varies based on the output load resistance in order to provide a constant voltage.

On mixed signal PCBs, the digital portion has numerous rails that can be used for components while the analog portion has fewer. The availability of multiple voltages on the digital side of a mixed signal circuit board allows the LDO to use a lower supply rail to meet circuit needs. Narrowing the gap between the supply rail and the output as described reduces linear loss and increases efficiency by about 50% on the digital side. Analog portions of the PCB have limited supply rail options with sufficient AC performance, which makes conversion design more difficult and demands a regulator option other than LDO. A switching regulator is a good alternative to an LDO, since it inherently provides superior power savings because its efficiency is not measured by the difference in the supply rail and output.

Switching Regulator Basics

Transistors in a switching mode power supply (SMPS) operate in switching mode, as opposed to the linear mode employed in LDOs, and can be used for step-up and step-down applications. With PWM implementation, a current switch with constant frequency and variable duty-cycle controls the output of an SMPS. The semiconductor transistor in the SMPS behaves like an ideal switch, minimizing voltage drop when conducting current (on state), and virtually eliminating current through its path when not conducting (off state). Advantages of this low loss implementation compared to more lossy LDO are evident in high current designs. For example, a synchronous buck step-down supply with 12 Vin and 2.5 Vout loses less than 10% with a SMPS and more than 75% with an LDO. Switching frequencies of a few kilohertz (kHz) to a few hundred kHz are typical, with a trend toward higher frequency operation to reduce the energy per switching cycle and the size of the energy storage components. Some switching regulators employ pulse width modulation (PWM) mode and pulse frequency modulation (PFM) mode control for switching based on whether duty-cycle or frequency is more efficient for the application loads.

Figure 2

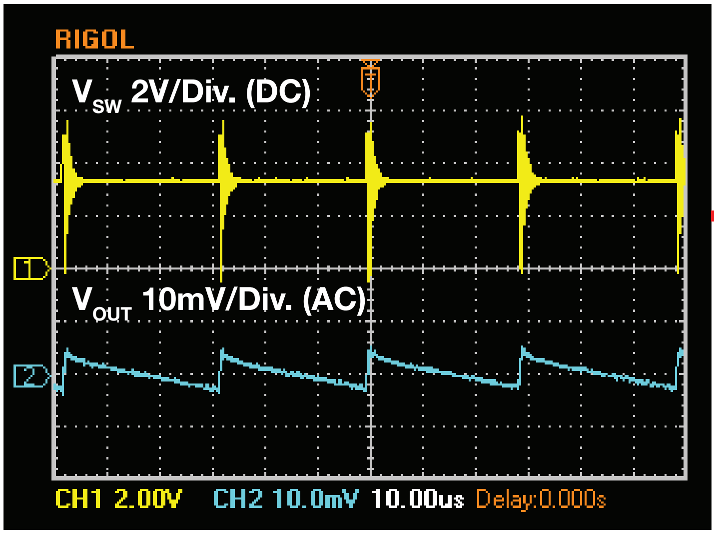


Efficiency Curve for the BD9B300MUV (V_{in} = 5V, V_{out} = 3.3V)

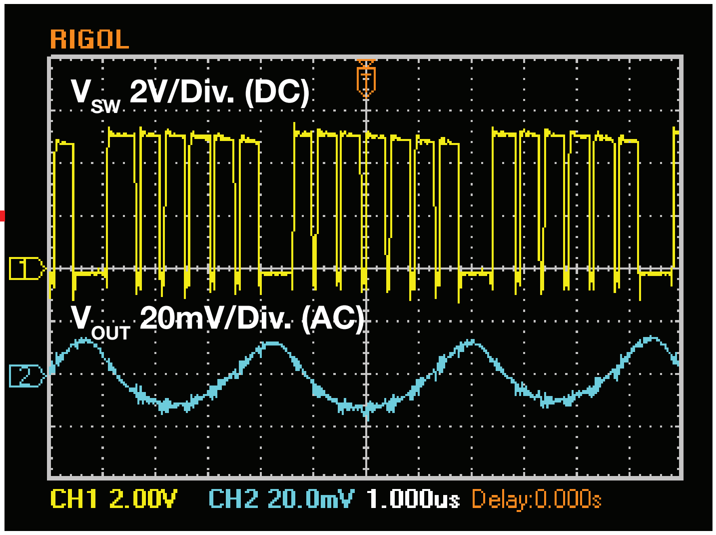
Newest Generation of Regulators

Control over power supply implementation differentiates the newer generation of SMPS power regulators. Features such as PWM, PFM, protection modes, and SoftStart reduce the complexity of design while increasing reliability and efficiency. PWM, the most common control for SMPS, provides a constant switching frequency over a broad range of loads - though it is more efficient at higher loads. Lighter loads may be better suited for PFM control, which switches the transistors at varying frequencies only when required by the load to maximize efficiency.

Figure 3: Switching Node and Ripple Output Waveforms for ROHM's BD9B300MUV.



V_{in} = 5V, V_{out} = 3.3V, I_{out} = 0A, PFM Mode



V_{in} = 5V, V_{out} = 3.3V, I_{out} = 3A, PWM Mode

Various protection modes are built into today's regulators to help protect the device and act as a soft fuse, resetting when the conditions that triggered them are cleared. For example, overcurrent protection (OCP) ensures the chip shuts down when a load exceeds expectations. Similarly, under voltage lock out (UVLO) protects the device when the input voltage falls below the lower limit. A thermal shutdown function monitors the regulator die temperature and shuts down the chip if an environmental or other condition causes it to overheat. Each of these mechanisms work to protect the device and prevent damage from common threats. ROHM developed and integrated its SoftStart as a flexible feature for a variety of applications that prevents harmful in-rush current at startup. During startup, the frequency reacts to the voltage detected on the frequency fold back, and the SoftStart time varies the DC-to-DC comparator output voltage based on the application's specific start conditions.

Integrated Solutions Address Challenges

Even with these advances, switching regulators are not without challenges, including the amount of development time devoted to testing, external circuitry to support operation, PCB space constraints, and proper board layout. Field effect transistors (FETs) are required at the voltage input and have to be carefully chosen based on the ratings, size, configuration, and resistance characteristics of the application and regulator. However, ROHM has made tremendous advancements in power management integrated circuits (ICs) to make this portion of design easier. Following the trend to integrate system components to maximize cost effectiveness, reliability, and PCB real estate, some of the required DC-to-DC functional blocks such as FETs are now incorporated into ROHM's switching regulator products.

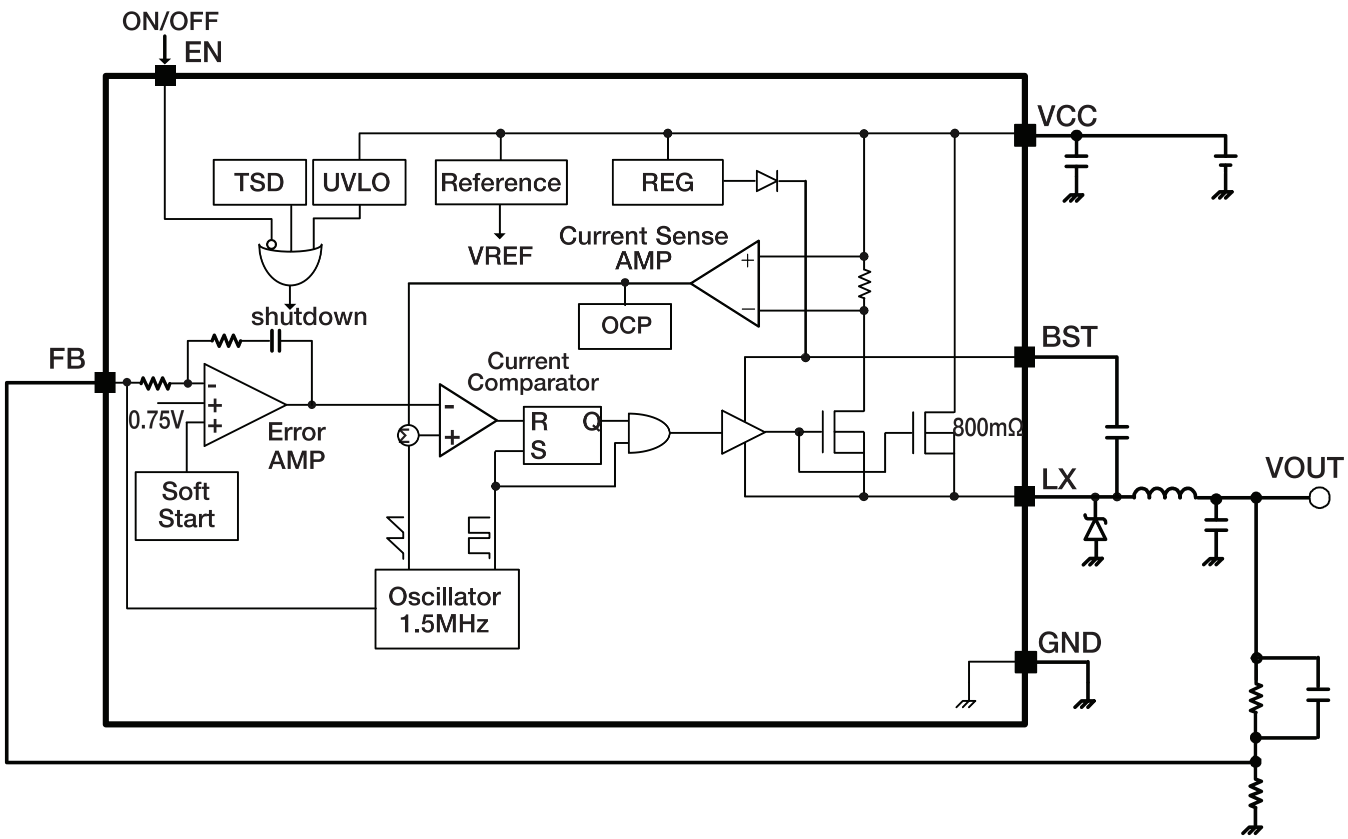
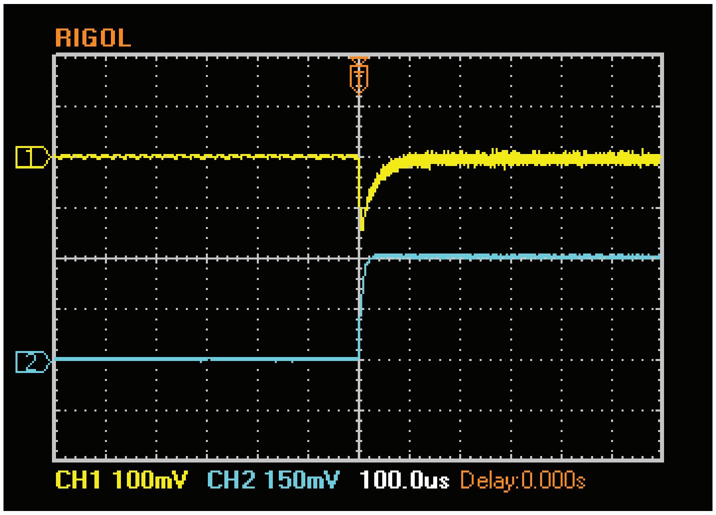
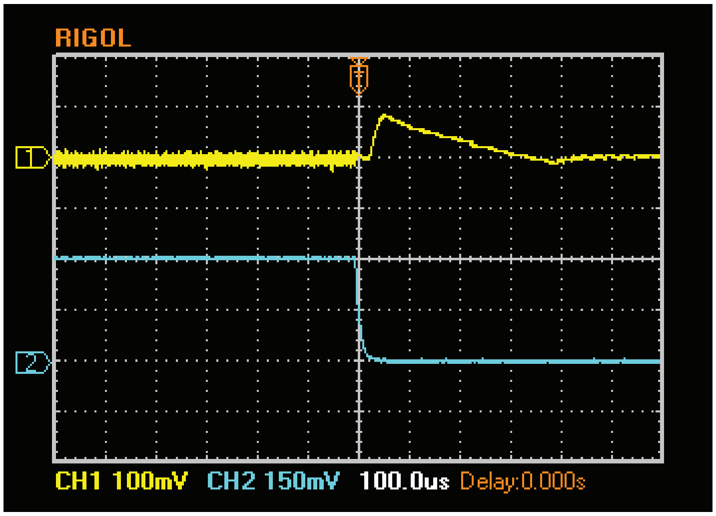


Figure 4: Block Diagram of ROHM's BD9G101G Step-Down Switching Regulator with Built-In Power MOSFETs

Perhaps the most significant challenge addressed by integrated solutions is board layout, including power stage layout, grounding schemes, capacitor placement, and the proximity of power and analog traces on a typical board. Integrating functional blocks such as FET power staging and current sensing reduces the number of discrete components required outside the regulator. ROHM has also eliminated several PCB interconnects to reduce the likelihood of layout mistakes and provide design freedom in component placement while also simplifying the grounding scheme. With an integrated SMPS, the parasitics and PCB trace capacitance previously associated with the external components is minimized, making higher switching frequencies and faster load-transient response possible. The external capacitors, inductors, and filters required are physically smaller, which, when combined with the reduced number of external components, help to minimize PCB space. An integrated SMPS regulator is accompanied by tested and proven board layout guidelines that reduce the time spent on the design cycle and layout revisions, thus speeding up time-to-market.

Figure 5: Fast Transient Response Characteristics of ROHM's BD9B300MUV





(V_{in} = 5V, V_{out} = 3.3V, I_{OUT} = 0A » 3A » 0A, FREQ=L, MODE=L).

Applications that Can Take Advantage of Latest Switching Regulators

ROHM offers a comprehensive range of industrial, consumer, automotive, and battery-powered equipment power supplies. The portfolio continues to grow as more compact power supply applications evolve and users demand increased performance. ROHM BD9G101G DC-to-DC converter features a wide input voltage range of 6-42V with an internal high-side 42V power MOSFET and 0.5A DC output. Additional features of this PWM SMPS converter include an extended temperature range of -40° to +105°C, fixed 1.5MHz operating frequency, an integrated high-efficiency power block, and compact form factor (SOT23 package). In addition, a voltage feedback pin, along with overcurrent protection, UVLO, and thermal shutdown are included to ensure safety and reliability.

Given its PWM output, the BD9G101G is ideal for use in higher load applications such as industrial distributed power, automotive, and battery-powered equipment. For applications with smaller loads, including portable electronics, smartphones, and universal serial bus (USB) accessories, a PFM-capable semiconductor such as ROHM's BU90002GWZ is an optimal choice. This regulator features an input voltage range of 4-5.5V and an ultra-low current PFM mode to provide up to 1A load current. And to maximize efficiency for a range of loads, the BU900002GWZ switches automatically between PFM and PWM modes based on the load. It also gives designers the option to override and force it to remain in 6 MHz PWM operation. The feature-rich switching regulator incorporates SoftStart and protection functions such as UVLO, overcurrent protection, thermal shutdown and a fast transient response -- all in an ultra-compact UCSP35L1 package.

ROHM Semiconductor also offers two very different SMPS regulators in its BD9G101G and BU900002GWZ models. Both products integrate protection and proprietary SoftStart functions.

Recommended external components are listed in the online datasheets, and layout support is provided to ensure consistency with tested configurations. Applications with higher loads and high, wide voltage rails, and extended temperature requirements will find the B9G101G ideal, while the BU900002GWZ, which provides efficient operation for a variety of loads, is better suited for lower voltage, lower load applications.

These integrated solutions also help OEMs achieve design goals for greater miniaturization, cost-effectiveness, improved reliability, and lower total cost of ownership required for a growing range of applications. These make them well-suited for the distributed power requirements of modern telecom boards, which demand smaller, multiple point-of-load power supplies that can accommodate excellent transient response to dynamic loads.

Deploying ROHM SMPS Regulators

ROHM's new switching regulators deliver today's in-demand integrated features and smaller sizes in cost-effective solutions, allowing designers to reduce space by more than 20%. With increased power efficiency and wide voltage input capabilities, OEMs can implement reduced power and energy saving features that improve system reliability for a broader range of applications. In addition, next-generation designs can benefit from noise optimization and move away from less efficient LDOs. Integrated solutions with wide voltage input capabilities are able to reduce the overhead of designing external circuits to support power supplies. Combining these advances enable efficient power management designs to finally be within reach of even designers whose specialty is the power sector.

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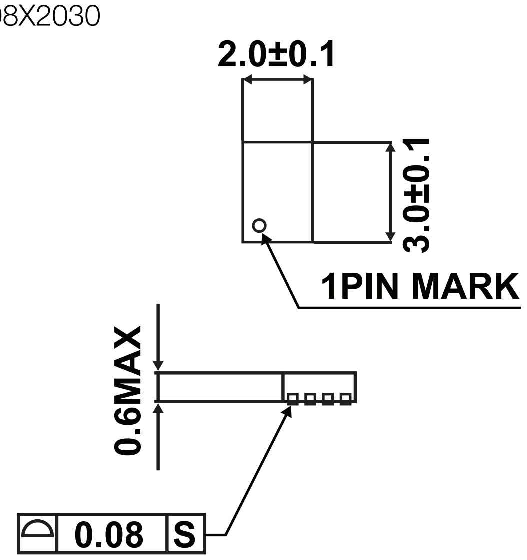

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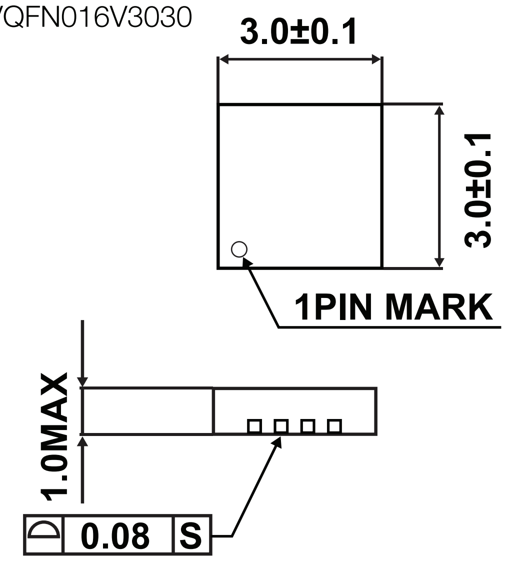

Figure 6: Examples of Small Packages Offered in ROHM's DCDC Switching Regulator Lineup

ROHM Semiconductor is an industry leader in system LSI, discrete components and module products. ROHM's proprietary production system, which includes some of the most advanced automation technology, is a major factor in keeping it at the forefront of the electronic component manufacturing industry. In addition to electronic components, ROHM has developed its own production system which enables it to focus on specific aspects of customized product development. ROHM employs highly skilled engineers with expertise in all aspects of design, development and production. This allows ROHM the flexibility to take on a wide range of applications and projects and the capability to serve valuable clients in the automotive, telecommunication and computer sectors, as well as consumer OEMs.

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