MOSFETs Operate Efficiently at Lower Supply Voltages

By Kevin Turchin, FAE Manager, ROHM Semiconductor | Thursday, March 4, 2010

Low gate drive MOSFETs provide cooler running and longer life for battery-powered "green" products

Portable products increasingly rely on a single 3.7V Li-Ion battery for the energy source. For these and other low-voltage applications, lower gate voltage power MOSFETs improve the efficiency for extended battery life and reduce the heat dissipation involved in switching the loads. In addition, they simplify the design of numerous control functions by allowing direct control / drive. MOSFETs that operate at 1.5V and even 1.2V gate drive provide improved performance over previous 2.5V versions. Changes in processing technology have resulted in comparably sized power MOSFETs having a 90% lower on-resistance at 2.5V gate drive or 75% lower on-resistance at 1.2V. Before investigating the application implications of recently introduced ECOMOS™ MOSFETs, a brief background on the technology is in order.

Applying Advanced CMOS Technology to Discrete MOSFETs

As CMOS technology continues to shrink design geometries for smaller and more cost-effective digital circuits, power MOSFET technology has benefited from the improved finer-pitched processing technology as well. In addition, the ability to form a thinner and consistently uniform gate has taken MOSFETs from the 10V gate drive of the earliest vertical power MOSFETs to the initial 4.5V logic level-rated products in the 80s and more recently to 2.5V. With the recently introduced ECOMOS trench MOSFET family, ROHM Semiconductor's engineers have reduced the gate voltage to 1.5V and even 1.2V.

The proprietary advanced processing, including advanced metallization for internal connections, brings the individual cells in the MOSFET closer together for a lower RDS(on) x active area product. A thinner gate oxide provides a lower gate threshold voltage for the MOSFET, allowing full enhancement at lower voltages. The combination produces a lower on-resistance structure that can be fully ON with lower gate drives. Since the structures can be fabricated consistently, the data sheet can guarantee operation and performance values for voltage levels as low as 1.2V. Lower voltage gate drive has been used for both N-channel and P-channel MOSFET designs.

One of the concerns with thinner gate oxides is electrostatic discharge (ESD) sensitivity. For these low gate drive MOSFETs, an integrated ESD diode from the gate to the source provides an inherent level of protection.

The biggest tradeoff that system designers need to be aware of with lower gate drive MOSFETs is a reduced maximum VGS rating. For most circuits, the restricted maximum should not be a problem. As shown in Table 1, as the nominal gate voltage decreases, the maximum voltage range can decrease from the standard 20V maximum down to 8V for the newest 1.2V products. The maximum level is a value that can vary from manufacturer to manufacturer, so it is a parameter that should be considered in choosing a specific supplier's product.

Gate Design	Gate Voltage (Nom)	Gate Voltage (Max)
Standard N-ch	10V	±20V
Logic Level N-ch	4.5V	16V
Low VGS N-ch	4V	±20V*
Low VGS N-ch	2.5V	±12V*
Low VGS P-ch	1.5V	±10V*
Low VGS N-ch	1.2V	±8V*

*ROHM Semiconductor rating

Table 1. The maximum gate voltage reduces with progressively lower gate drive ratings.

Applications Impact for Portable Designs

Saving space in increasingly smaller portable products drives increased integration in ICs but not necessarily at the expense of discrete devices that control power. For greater efficiency, ease of dissipating the power and the ability to isolate the heat from sensitive ICs, power and even small signal MOSFETs are frequently used in portable designs. Highly efficient, low gate drive MOSFETs extend system designers' capability for using discrete solutions.

Figure 1 shows the extent of the on-resistance reduction from using a higher cell density (finer geometry) process and lower gate threshold. The upper curve is the performance of an earlier generation MOSFET that operates at a VGS of 2.5V. A comparably sized, ECOMOS part has 90% lower on-resistance at 2.5V gate drive. Even at the lower 1.2V gate drive, the on-resistance (1.6Ω) is 75% less than the previous generation. This provides system designers the flexibility to reduce power consumption and obtain much higher efficiency or reduce the package size for space and cost savings.

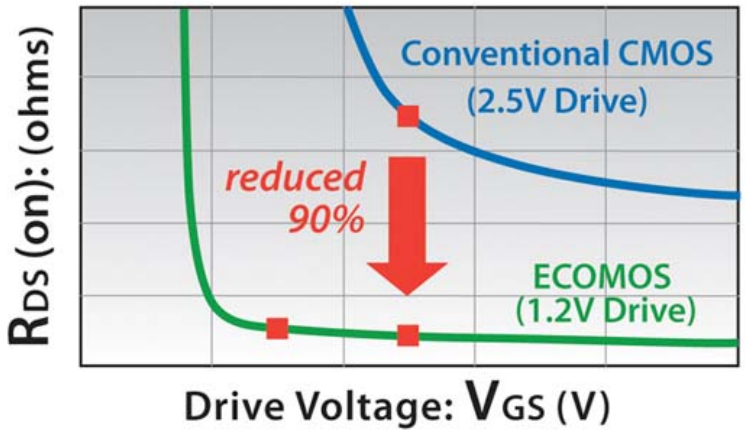

Figure 1. Lower gate drive and higher cell density MOSFETs provide much lower on-resistance and design options.

With highly efficient process technology, packaging provides the design aspect that makes the silicon useful for a wide range of applications. Because of the variety of packages for ECOMOS products, a smaller, lower-profile package size may be used in many applications. Figure 2 shows three examples of new design possibilities. In the first example, maintaining the same on-resistance allows the use of a package that is 30% thinner and 40% smaller. In the second example, both a significant reduction in on-resistance and package size can occur. In the last example, the package footprint is comparable but 20% thinner while achieving 77% less on-resistance. When more complex packaging arrangements such as a dual die and MOSFET with Schottky diodes are considered, efficient discrete products provide continued justification for not integrating the power control function.

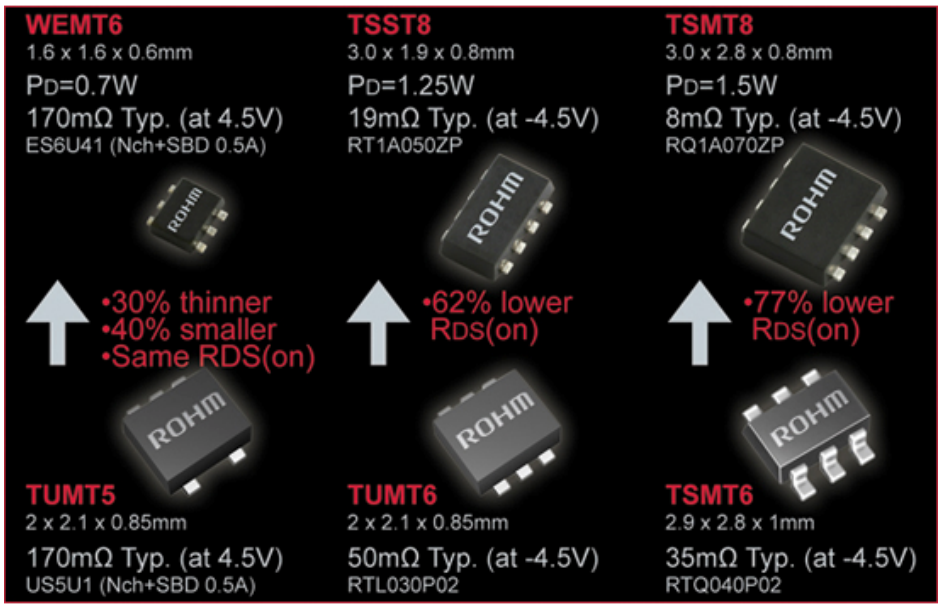

Figure 2. Package size reduction and performance improvements that result from more efficient silicon.

Increased Efficiency for Portables and More

While all embedded systems can benefit from improved efficiency enabled by low-resistance MOSFETs, target markets include mobile phones, portable audio, digital video/still cameras and other portable products. Specific applications for low gate drive MOSFETs in portable products include load switch drive, LED driver, muting circuit, DC/DC converter and charger control circuit as shown in Figure 3. In some of these applications, bipolar transistors continue to be used since they operate at lower voltages. The lower gate drive MOSFETs can easily replace bipolar transistors and achieve improved efficiency. In some instances, the lower gate drive can provide an extra safety margin in applications where MOSFET drive voltages fall off at high temperatures, especially at increased current levels or when the VCC degrades as the battery discharges.

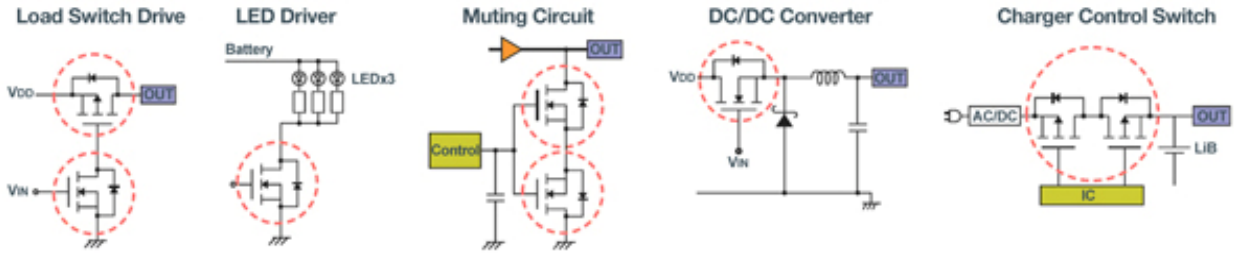

Figure 3. Low gate drive MOSFETs in various P-channel and N-channel configurations can address many different applications.

Lower gate voltage products target portable applications where a maximum drain to source voltage (VDSS) rating of 12 or 20V is more than sufficient and several new devices are rated at 50V. However, other embedded applications, such as personal computers and servers, can benefit from the improved efficiency capability of the ECOMOS design if the maximum drain-to-source voltage rating is not exceeded. For some emerging applications, such as energy harvesting for wireless sensing, low power consumption is essential. Low gate drive MOSFETs could play a key role in enabling this technology.