ROHM's SBD Lineup Contributes to Greater Miniaturization and Lower Loss in Automotive, Industrial, and Consumer Equipment

White Paper

1. Introduction

Recent years have seen a steady increase in the number of semiconductors installed in applications as electrification in the automotive, industrial, and consumer sectors continues to advance. Among these, ROHM boasts a strong track record for medium voltage diodes used in rectification and protection circuits in a range of applications, from smartphones to EV powertrains. (Fig. 1)

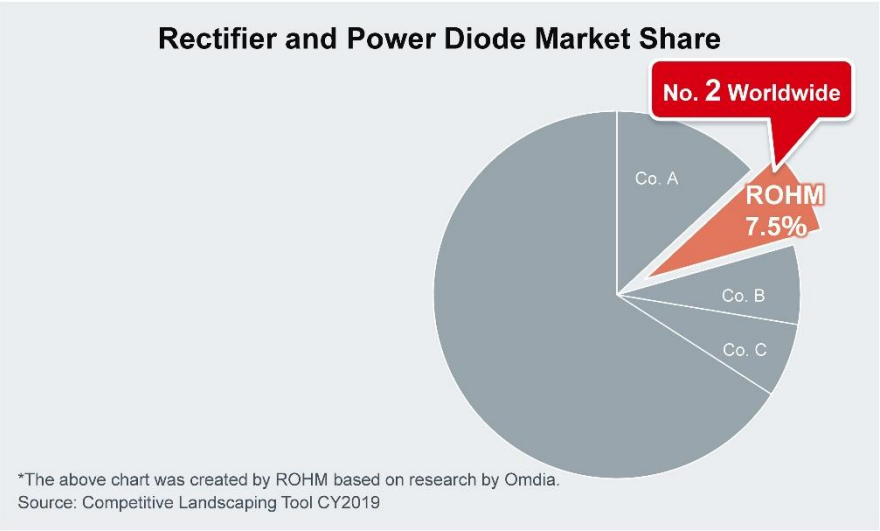

Figure 1. ROHM's Market Share for Rectifier and Power Diodes

Key performance indicators for diodes include V_F (forward voltage) and I_R (reverse current) that lead to power loss when applied in the forward and reverse directions, respectively. The 'ideal diode' is one with zero V_F and I_R (no power loss at all) capable of rectification and switching. However, this ideal cannot be achieved in semiconductors involved with electron transfer. Also, V_F and I_R are generally in a trade-off relationship, making it difficult to improve both. And in an actual diode, some power loss also occurs when the diode is turned OFF during switching (due to current flow in the reverse direction for a time trr).

As Schottky barrier diodes (SBDs) achieve low losses in rectifier and switching circuits due to lower V_F and trr than other types of diodes, their high I_R often causes heat generation that exceeds the amount of heat dissipated, so there is concern about the risk of thermal runaway that can eventually lead to destruction. (Fig. 2)

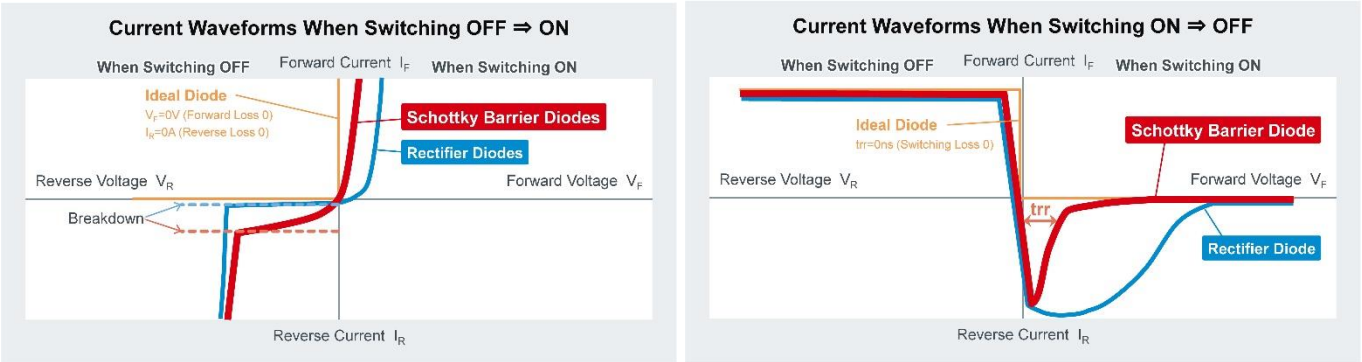

Figure 2. Comparing V_F and I_R in a Rectifier Diode and SBD During Switching

In response, ROHM developed a broad lineup of SBDs that allows users to select the ideal model according to whether V_R or I_R is a priority based on application requirements. ROHM is also developing a new series closer to the 'ideal diode' by improving both V_R and I_R characteristics while delivering the industry's highest trr for SBDs. This paper will outline ROHM's SBD initiatives and the features of each series.

(See below for detailed technical articles related to SBDs)

Advantages of PMDE Compact Package with High Heat Dissipation for Automotive Schottky Barrier Diodes

Advantages of YQ Series: Compact and Highly Power Conversion Efficiency Schottky Barrier Diodes for Automotive

2. Trends and Performance Required of SBDs

As an example of market conditions surrounding SBDs, Fig. 3 shows the number of ECUs installed in a typical vehicle. The continuing evolution of ADAS (Advanced Driver Assistance Systems) and automated driving is increasing the number of ECUs required per vehicle, which is expected to lead to significantly higher demand for diodes.

In cars, since power cannot be supplied beyond the capacity of the battery and alternator (generator), manufacturers are requiring diodes with low loss (low V_F), accelerating the adoption of SBDs with excellent V_F and trr characteristics. At the same time, circuits around the engine in gas-powered vehicles and batteries and motors in xEVs are exposed to high temperatures, so the risk of thermal runaway for SBDs with high I_R can become a major problem that directly relates to reliability. Therefore, when selecting an SBD it is important to find a balance between V_F and I_R, which are in a trade-off relationship.

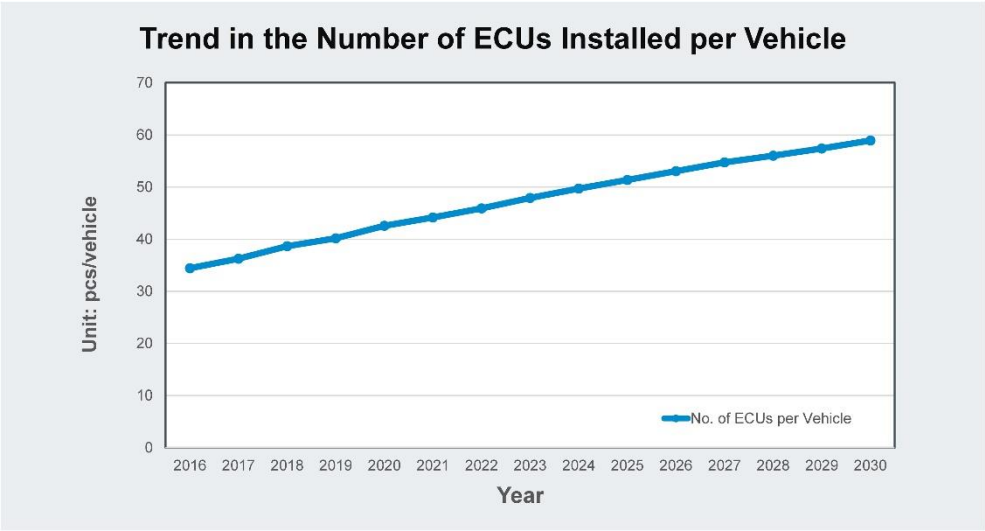

Figure 3. Trend in the Number of ECUs Installed per Vehicle (ROHM study)

In the consumer sector, the increasing multifunctionality of applications is leading to higher density boards than in automotive systems, which in turn requires compact, ultra-low-loss (ultra-low V_F) SBDs. At the same time, like vehicle applications, industrial equipment requires high reliability along with long-term stable supply due to long model life. As a result, although SBDs are general-purpose components, trends can vary greatly depending on the sector and application, prompting many manufacturers to establish opposing characteristics during product development, such as combining low loss with high reliability or miniaturization together with high current. To meet these wide-ranging needs, ROHM is continuing with development by establishing a vertically integrated system that ensures stable, long-term supply. The next section introduces ROHM's considerable SBD lineup.

3. ROHM's SBD Family

ROHM's current lineup consists of five series that allow users to select the ideal product depending on the importance placed on V_F or I_R. (Fig. 4) Each series also offers an extensive package lineup with a choice of smaller form factors to meet performance requirements. (Fig. 5) From the next page, the features of each product will be introduced.

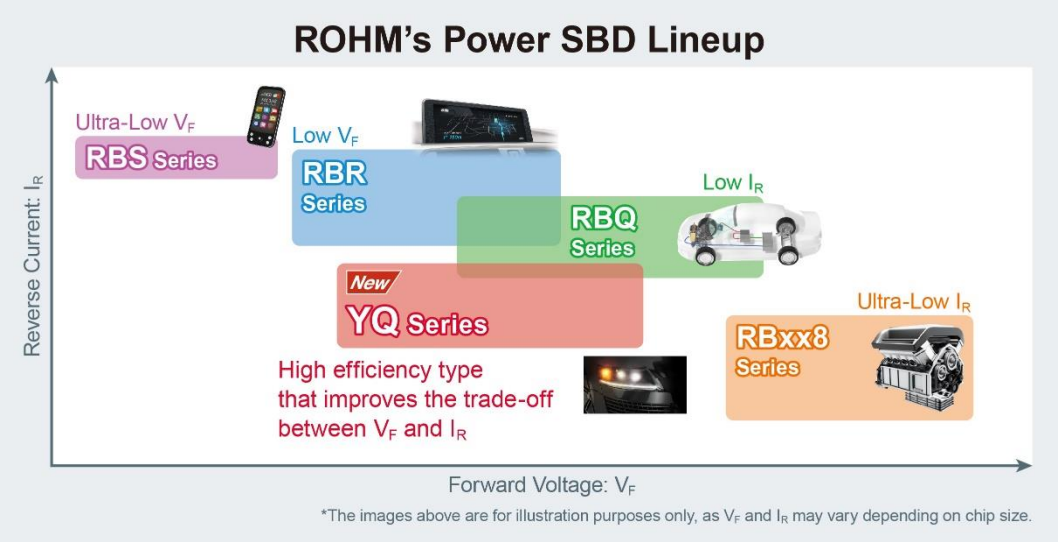

Figure 4. ROHM's Product Family

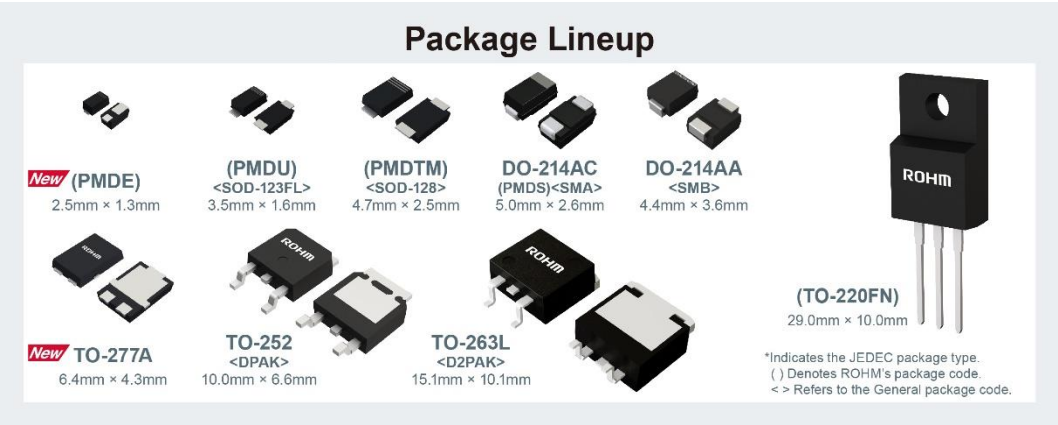

Figure 5. ROHM's SBD Package Lineup

3-1. RBS Series: Ultra-Low V_F (20V Withstand Voltage)

The series with the lowest V_F, enabling significantly lower losses in circuits used mainly in the forward direction. Ideal for rectification applications in portable battery-powered low-voltage devices such as smartphones.

Target applications: Laptops, portables, etc.

3-2. RBR Series: Low V_F (30V/40V/60V Withstand Voltage)

This general-purpose series reduces V_F by approximately 25% over ROHM conventional products of the same size. As it delivers the lowest forward loss in automotive applications, this series boasts a good track record as protection diodes for car infotainment and vehicle LED lamps where high efficiency is required. In August 2021 the smallest automotive-grade PMDE package was added to the lineup, making it possible to respond to market demands for smaller sizes.

Target applications: Car infotainment, vehicle LED lamps/ECUs, laptops, etc.

3-3. RBQ Series: Low I_R (45V/65V/100V Withstand Voltage)

This series utilizes proprietary barrier formation technology to achieve an optimum balance between V_F and I_R. Compared to ROHM/s conventional products, reverse power loss is reduced by 60%. This minimizes the risk of thermal runaway, making it ideal for rectification applications in engine ECUs that operate in high temperature environments, protection circuits for high power LED headlamps, and power supplies in industrial equipment with large current flow.

Target applications: xEVs, engine ECUs, high power LED headlamps, power supplies for industrial equipment, etc.

3-4. RBxx8 Series: Ultra-Low I_R (30V/40V/60V/100V/150V/200V Withstand Voltage)

Ultra-low I_R characteristics reduce the risk of thermal runaway, enabling suitability for rectification applications in battery and motor peripheral ECUs for xEVs along with engine/transmission ECUs in gas-powered vehicles that operate at high temperatures. Models up to 200V are offered, allowing designers to replace rectifier and fast recovery diodes normally used in the withstand voltage regime, resulting in significantly lower V_F (approx. 11% less vs FRDs) and, ultimately, power consumption.

Target applications: xEV battery management systems, engine ECUs, industrial equipment inverters, etc.

4. New Products: YQ Series

The YQ series adopt new technologies in the form of an original trench MOS structure that reduces both V_F and I_R compared with conventional planar-type products. Both series feature improved trr, which structurally deteriorates in a general trench MOS structure, achieving best-in-class characteristics equivalent to conventional planar products. This minimizes switching losses along with the likelihood of thermal runaway, enabling support for applications requiring high-speed switching, such as drive circuits for automotive LED headlamps and DC-DC converters in xEVs which tend to generate heat.

Target applications: Automotive LED headlamps, xEV DC-DC converters, power supplies for industrial equipment, lighting, etc.

4-1. Improves both V_F and I_R vs Conventional Products

The YQ series utilize a unique trench MOS structure to decrease V_F by approx. 15% compared to conventional products with the same withstand voltage and current, resulting in less power loss when used in the forward direction in rectification applications. At the same time, 60% lower I_R vs conventional planar products significantly reduces the risk of thermal runaway, which is the biggest concern for SBDs, ensuring compatibility with automotive applications exposed to high temperatures and other severe conditions.

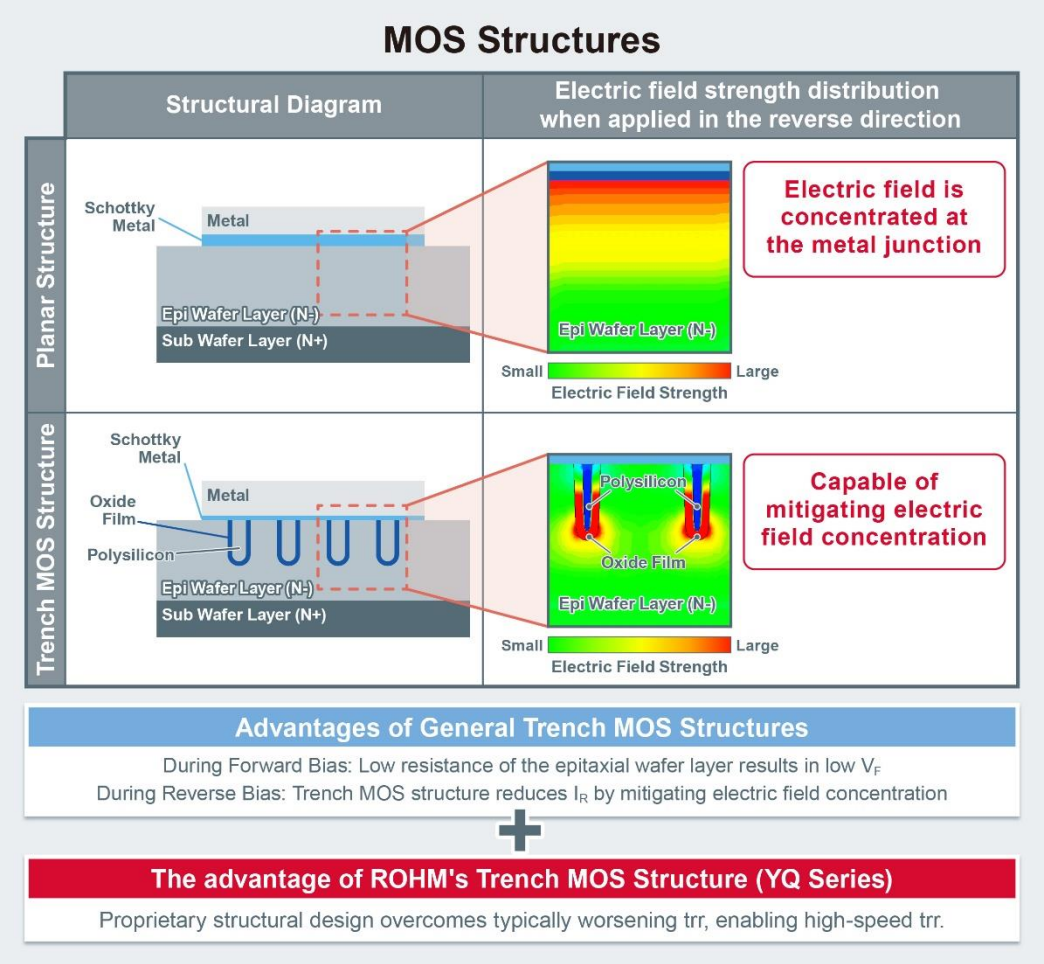

Figure 6. Comparing SBD MOS Structures

4-2. Achieves Class-Leading trr

In a typical trench MOS structure, trr is worse than in planar types due to larger parasitic capacitance (resistance component in the device). In contrast, the YQ series not only minimize both V_F and I_R, but also achieve equivalent trr as planar structures by optimizing proprietary technologies and materials. As an example, Fig. 7 shows a comparison of switching loss when evaluated on an actual device using an LED headlamp evaluation board. During switching the loss ratio from V_F and trr is normally high, but the YQ series reduce loss from trr alone by about 37%, and when combined with the lower V_F, overall switching loss can be decreased by about 26%. This contributes to lower power consumption in applications requiring high-speed switching, such as drive circuits for automotive LED headlamps and DC-DC converters in xEVs.

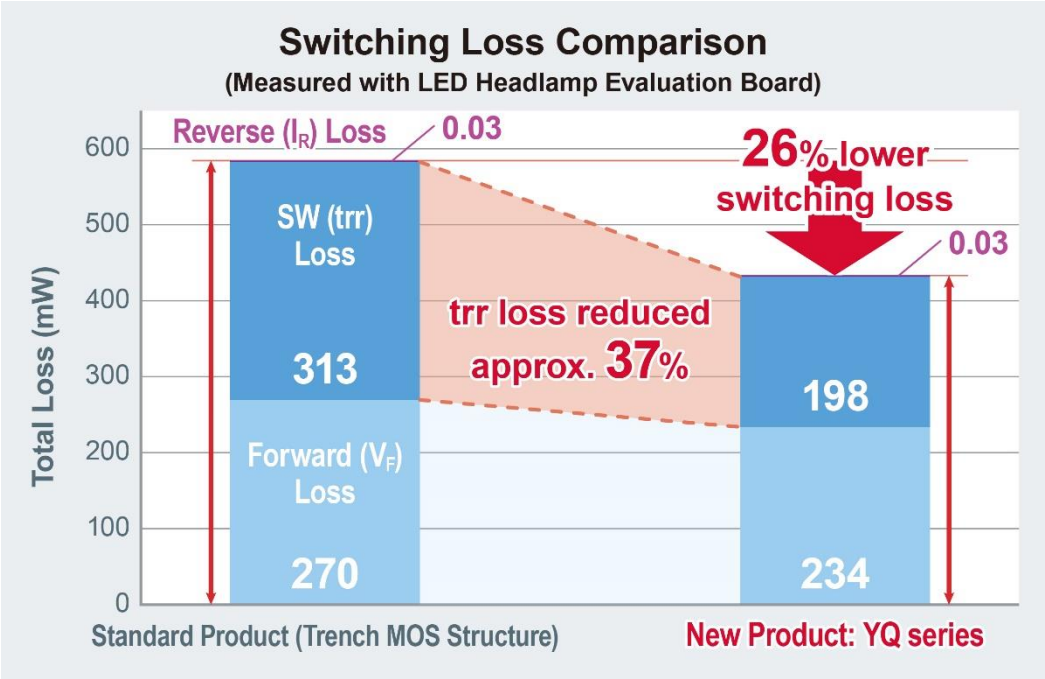

Figure 7. Switching Loss Comparison in Actual Equipment

5. Future Developments

The number of diodes installed per application is expected rise due to the continuing evolution of applications in a variety of fields, including multi-functional home appliances in the consumer sector and sensor modules for achieving autonomous driving in vehicle systems. What's more, as motors for industrial equipment and xEVs become more sophisticated, circuit current will increase, requiring a full lineup of high-current products.

ROHM is proceeding with development in anticipation of the demand for contradictory characteristics that are difficult to balance, such as higher current in a smaller size or high performance with low loss. For example, ROHM is strengthening its lineup by starting mass production of compact high current TO-277 package (6.5mm × 4.6mm) products to meet future needs. ROHM is also developing new 200V withstand voltage products for xEV inverters and onboard chargers that are garnering significant attention, with the aim of bringing them to market by the end of FY2022.

Going forward, ROHM will continue to expand its lineup to meet a wide range of market requirements while contributing to greater functionality and lower power consumption in evolving next-generation vehicle applications.

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