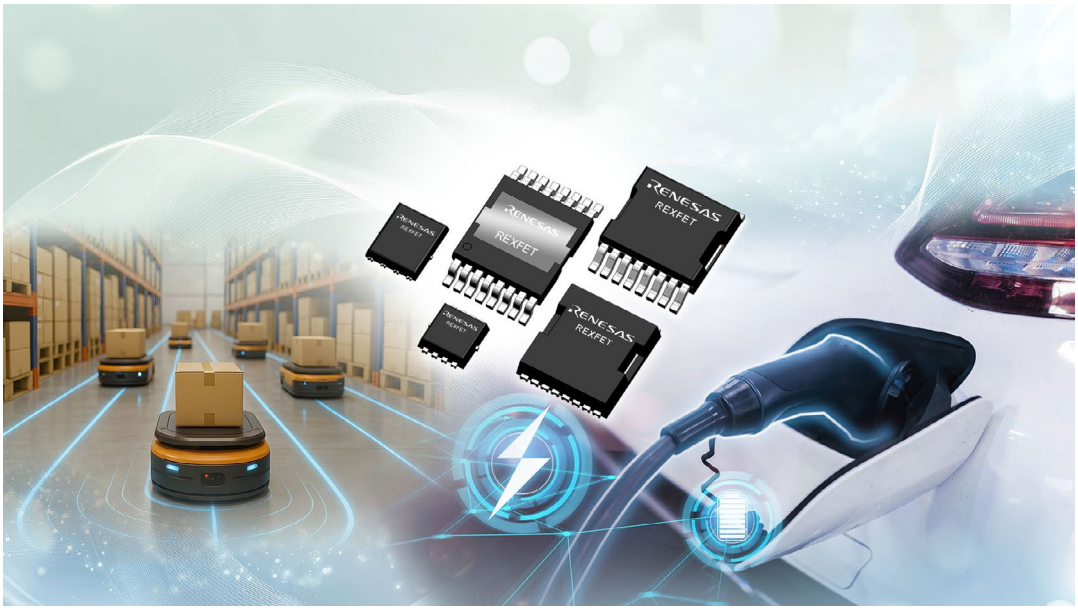
Leveraging Split-Gate Trench Process to Advance MOSFET Performance

Dean Kim, Senior Manager, MOSFET Application Engineering
Renesas Electronics Corporation



Introduction

High-power and high-efficiency systems such as electrical motor drives and battery management systems continue to see rapid growth and increasing power demands. To help meet these requirements, lower on-resistance and improved switching performance are needed. Renesas has designed a new generation of power MOSFETs based on the advanced split-gate trench process in response to these demands. The first-generation REXFET™ MOSFETs portfolio achieves a **30% reduction in specific on-resistance (RSP)** compared to previous generation conventional trench technology, enabling significantly lower Rds(on) devices. This results in higher power density, reduced conduction losses and improved system efficiency.

REXFET-1 devices deliver superior switching performance, reducing switching losses and improved thermal behavior and reliability in demanding systems. To maximize design flexibility for different applications, the portfolio is offered in a wide range of advanced packaging options—from compact footprints (3x3) to thermally robust top-side cooling packages (TOLT).

REXFET Technology Advancements

The core technology challenge of MOSFETs used in high-current applications is achieving low ON-resistance while maintaining excellent switching performance. With the adoption of PWM-based systems and higher switching frequencies in modern power supplies, minimizing both conduction and switching losses has become critical.

The Renesas REXFET-1 process introduces a split-gate trench structure, compared to the previous ANM1 / ANM2 super-junction technologies which concentrate on P column implementation to deliver:

- Improved Ron index of 0.24 (compared to 0.36 in earlier generations)
- Ultra-low on-resistance, leading to reduced conduction losses and lower heat dissipation
- High power density in small packages
- Optimized switching behavior with reduced gate charge (Qg), low gate capacitance

Combined with advanced packaging techniques such as multi-wire and clip bonding, REXFET-1 devices achieve both low resistance and high-speed switching, while meeting stringent automotive reliability standards.

Furthermore, we use a sturdy design that integrates years of experience to ensure our products are very reliable and durable, allowing designers to use them with confidence. The REXFET-1 series (80-150V products) has been specifically designed for BMS and electrical motor applications. Figure 1 shows the evolution of Renesas MOSFET technology advancements.

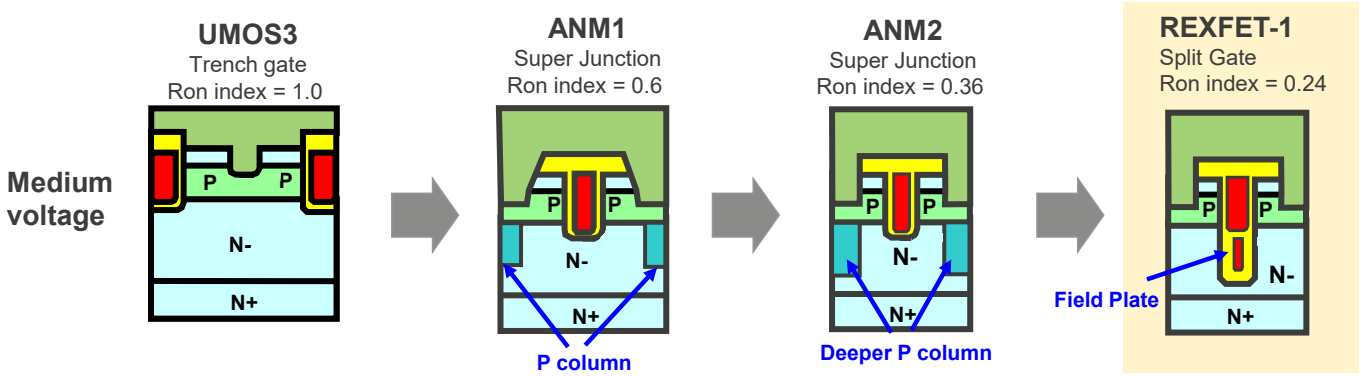
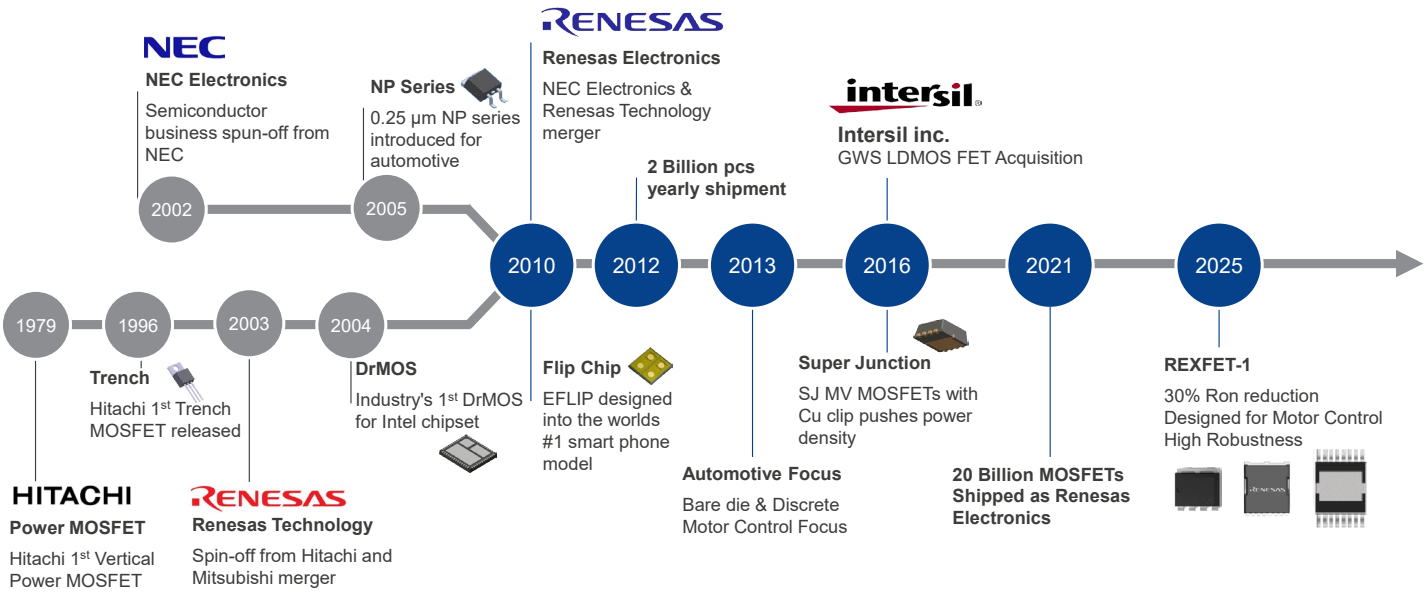


Figure 1: Comparison of Renesas Technology for Power MOSFETs

The development of REXFET-1 is part of Renesas' long history of advancing power MOSFET technology. Starting with Hitachi's first vertical MOSFET in 1979, Renesas has consistently delivered industry firsts, including the first DrMOS for Intel chipsets (2003). Over the following decades, innovations such as super junction technology, flip-chip packaging for smartphones and copper clip structures further improved efficiency and power density. By the mid-2010s, Renesas was shipping billions of MOSFETs annually and by end of the 2020s, nearly 20 billion individual MOSFETs were shipped with best-in-class quality levels (<0.05 DPPM).



Advanced Package Technologies

Renesas offers three major package options in the **TOLx family**, optimized for high-current and high-reliability applications such as electric power steering (EPS), BLDC motor drives, BMS, safety switches, industrial forklifts, e-Bikes, power tools and robotics, among others.

- **TOLL (Leadless):** The basic and most popular package option is ideal for high-power designs requiring low inductance, superior EMI performance, and high thermal efficiency
- **TOLG (Gullwing):** Provides compatibility with TOLL pinouts while adding gullwing leads for improved board-level reliability (2× TCoB performance), especially designed for automotive and other high-reliability applications
- **TOLT (Top-side cooling):** Enables best-in-class thermal dissipation by transferring heat directly through the package top surface

Three packages with high current, small size and better heat dissipation are shown in Figure 2. To get more efficient power density to meet market demands, Renesas packaging continues to improve from legacy packages as shown in Figure 3. Various SMD packages options meet the new package trend from the market:

- Leadless, low-inductance designs for fast switching
- Higher power density through top-side cooling and increased pin counts
- Wettable-flank technology for automated optical inspection (AOI) and enhanced solder joint reliability
- Reduced package size (including height) for lower system cost and compact form factors

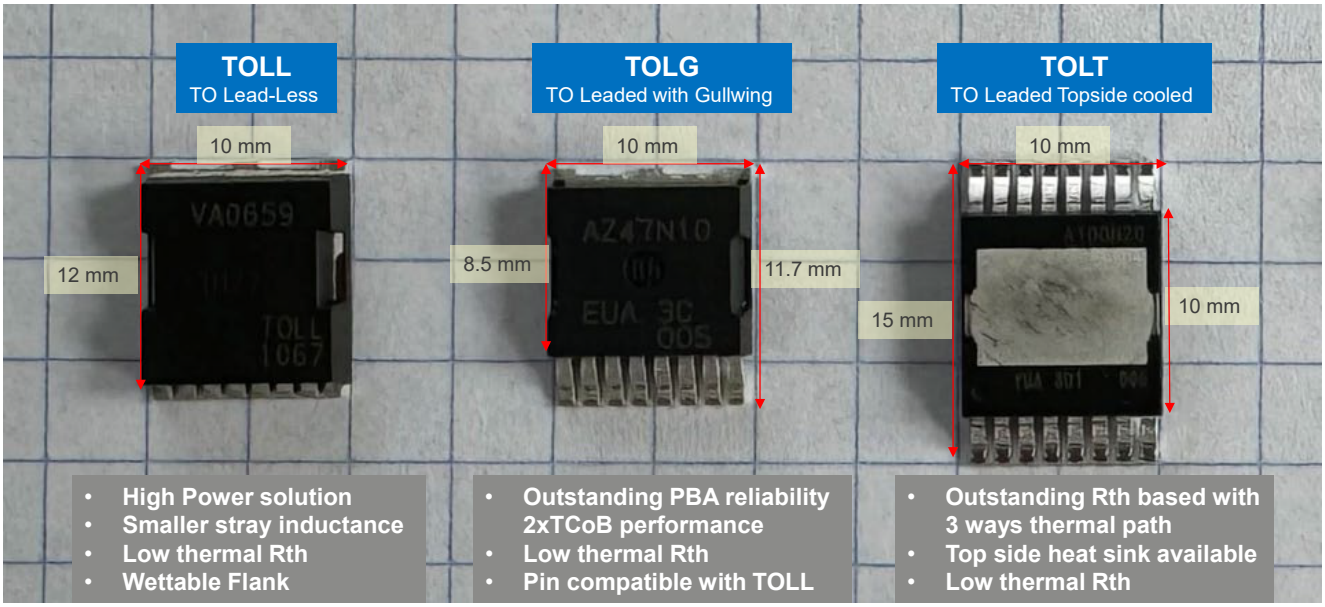


Figure 2: Features of Renesas TOLx Packages

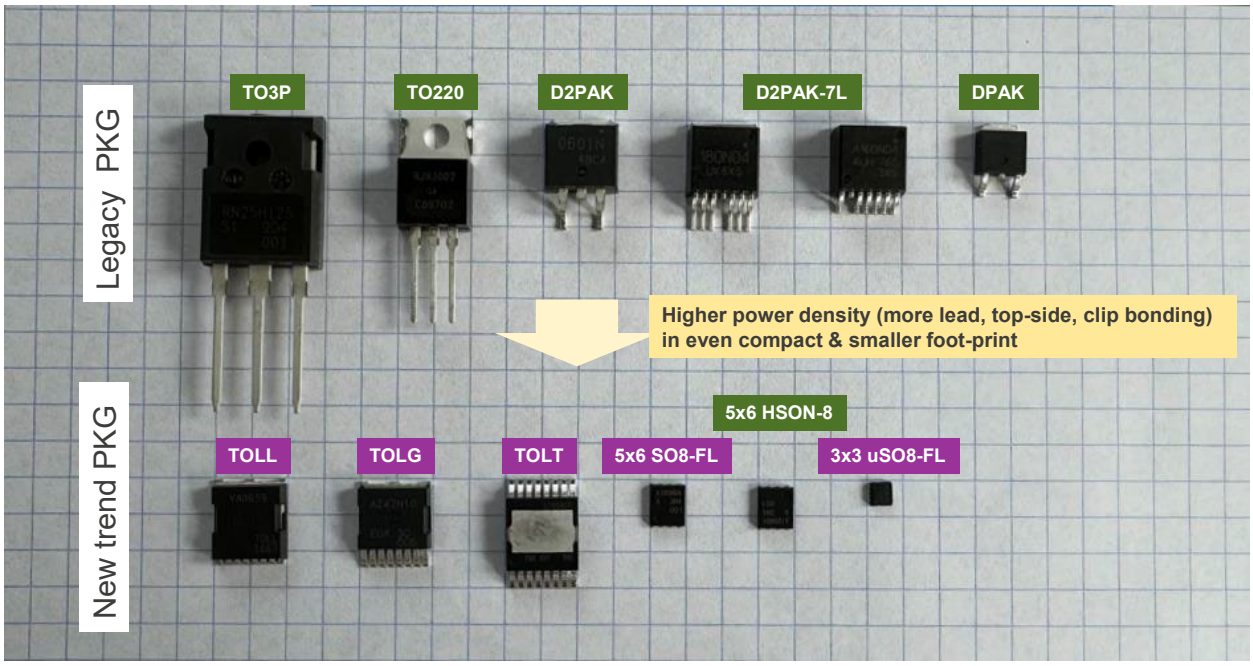
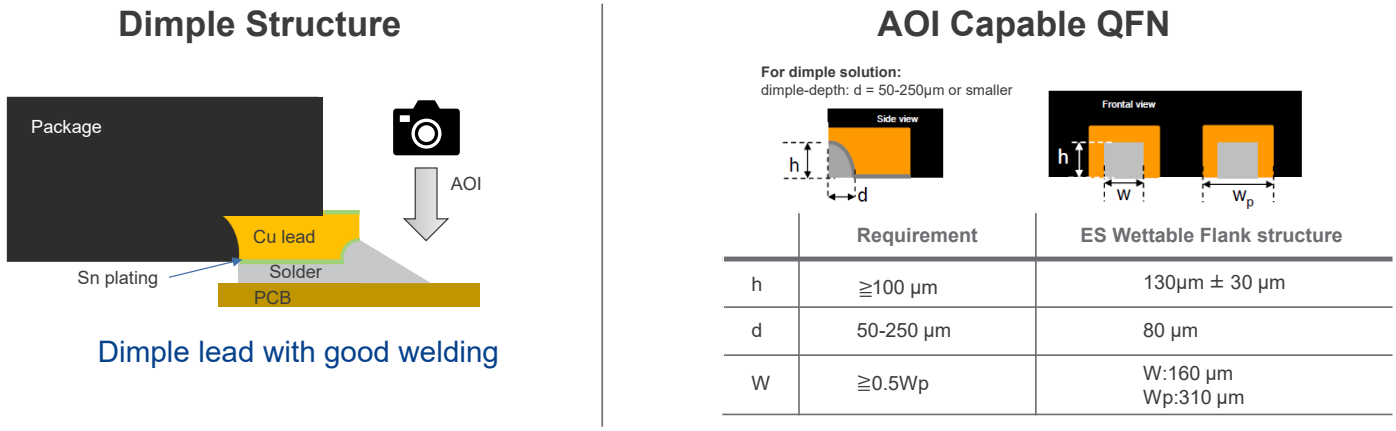


Figure 3: SMD Package Options for REXFET-1 Products

Wettable Flank Packages for Improving AOI Process

For SMD packages, wettable flank structures are increasingly essential for automated optical inspection process. Renesas has adopted a dimpled wettable flank design that not only enables full AOI compatibility (shown in Figure 4) but also improves solder joint reliability in a cost-effective way. This ensures higher assembly yield and long-term robustness for automotive and industrial systems. Wettable flank has been well-adopted in automotive MOSFETs but Renesas also offers this in the industrial MOSFET portfolio.



	Requirement	ES Wettable Flank structure
h	≧100 µm	130µm ± 30 µm
d	50-250 µm	80 µm
W	≧0.5Wp	W:160 µm Wp:310 µm

Figure 4: Wettable Flank with Dimple Structure for REXFET-1 Packages

REXFET System Level Performance

BLDC motor control is popular in both industrial and automotive applications. To validate REXFET-1 performance in real applications, Renesas evaluated the devices in BLDC motor drive systems with both 100V and 150V products in the TOLL package. Figure 5 compares the performance specifications of REXFET-1 100V RBA300N10EANS-3UA02 (industrial version RBE015N10R1SZQ4) and 150V RBA190N15YANS-3UA04 (industrial version RBE039N15R1SZQ4) with key devices on the market.

	Renesas		Competitor "A"	
Products	RBA300N10EANS-3UA02 RBE015N10R1SZQ4	RBA190N-15YANS-3UA04 RBE039N15R1SZQ4	A-100	A-150
Breakdown Voltage	100V	150V	100V	150V
Current Rating @ 25 °C	340A	190A	300A	190A
Rds(on) @ 25 °C (typ./max.)	1.3 mΩ / 1.5 mΩ	3.2 mΩ / 3.9 mΩ	1.3 mΩ / 1.5 mΩ	3.3 mΩ / 3.9 mΩ
Rds(on) @ 125 °C (typ.)	2.2 mΩ	5.8 mΩ	2.1 mΩ	5.6 mΩ
Pd_max @ 25 °C	468W	319W	375W	319W
Package	TOLL			
Rth (j-c)	0.32 °C/W	0.47 °C/W	0.4 °C/W	0.4 °C/W
Vth @ 25 °C (min./max.)	2.0V / 4.0V	2.0V / 4.0V	2.2V / 3.8V	3.0V / 4.6V
Ciss	13000 pF @ 50V	5500 pF @ 75V	12316 pF @ 50V	5900 pF @ 75V
Coss	3300 pF @ 50V	1800 pF @ 75V	1920 pF @ 50V	1500 pF @ 75
Crss	80 pF @ 50V	36 pF @ 75V	84 pF @ 50V	33 pF @ 75
Qg @ 25 °C	170 nC @ 50V, 100A	76 nc @ 75V, 50A	166 nC @ 50V, 100A	78 nC @ 75 , 50
Vsd @ 25 °C (max.)	1.5V @ 100A	1.5V @ 95A	1.3V @ 100A	1.0V @ 50A
Qrr @ 25 °C (typ.)	300 nC @100A, 100 A/us	400 nC @ 50A, 100A/us	220 nC @ 50A, 100A/us	77 nC @ 50 A, 100A/us

Figure 5: Key Parameter Comparisons

As shown in Figures 6 and 7, REXFET-1 and competitor devices were tested up to 60A and compared the average junction temperature. The junction temperature result remained competitive with best competitor device during 10 kHz and 20 kHz switching frequency.

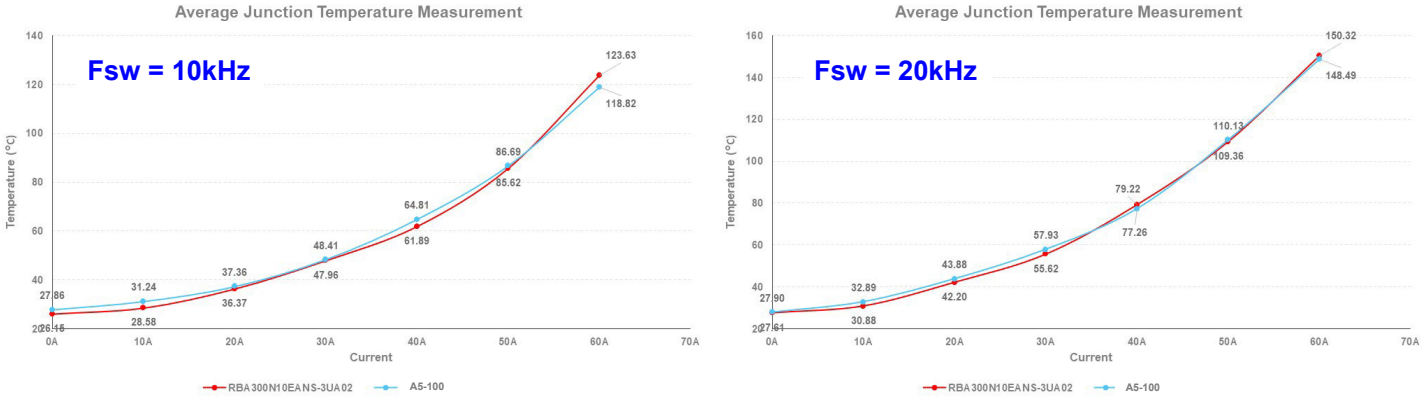


Figure 6: System Evaluation Result with 100V REXFET-1, RBA300N10EANS-3UA02 (RBE015N10R1SZQ4)

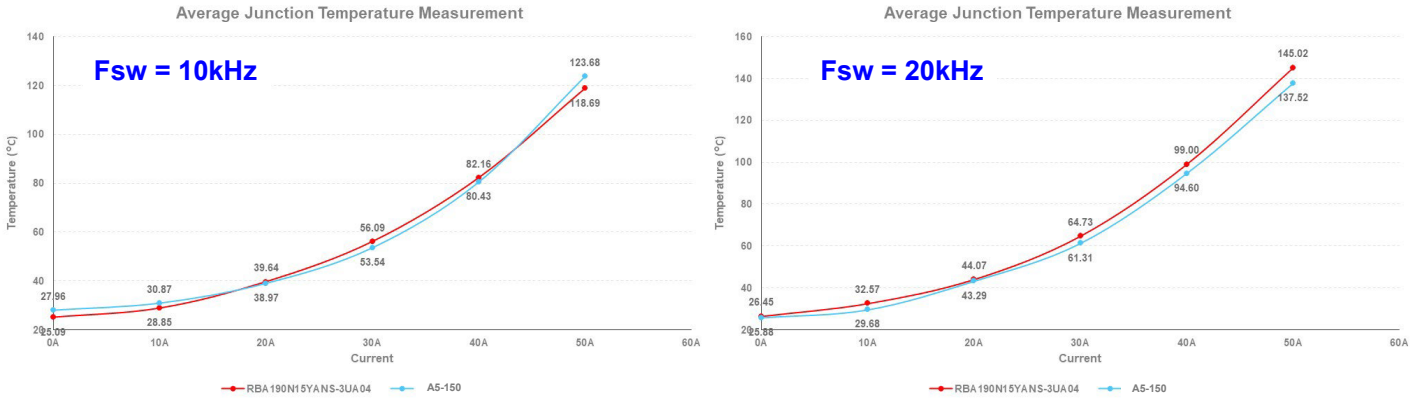


Figure 7: System Evaluation Result with 150V REXFET-1, RBA190N15YANS-3UA04 (RBE039N15R1SZQ4)

As seen in Figures 8 and 9, REXFET-1 devices show lower voltage oscillation and spike during the same system conditions. In motor control applications, higher oscillation and voltage spikes can cause system reliability concerns and high EMI. REXFET-1 devices consistently demonstrate competitive efficiency, thermal stability and reduced EMI-related stress.

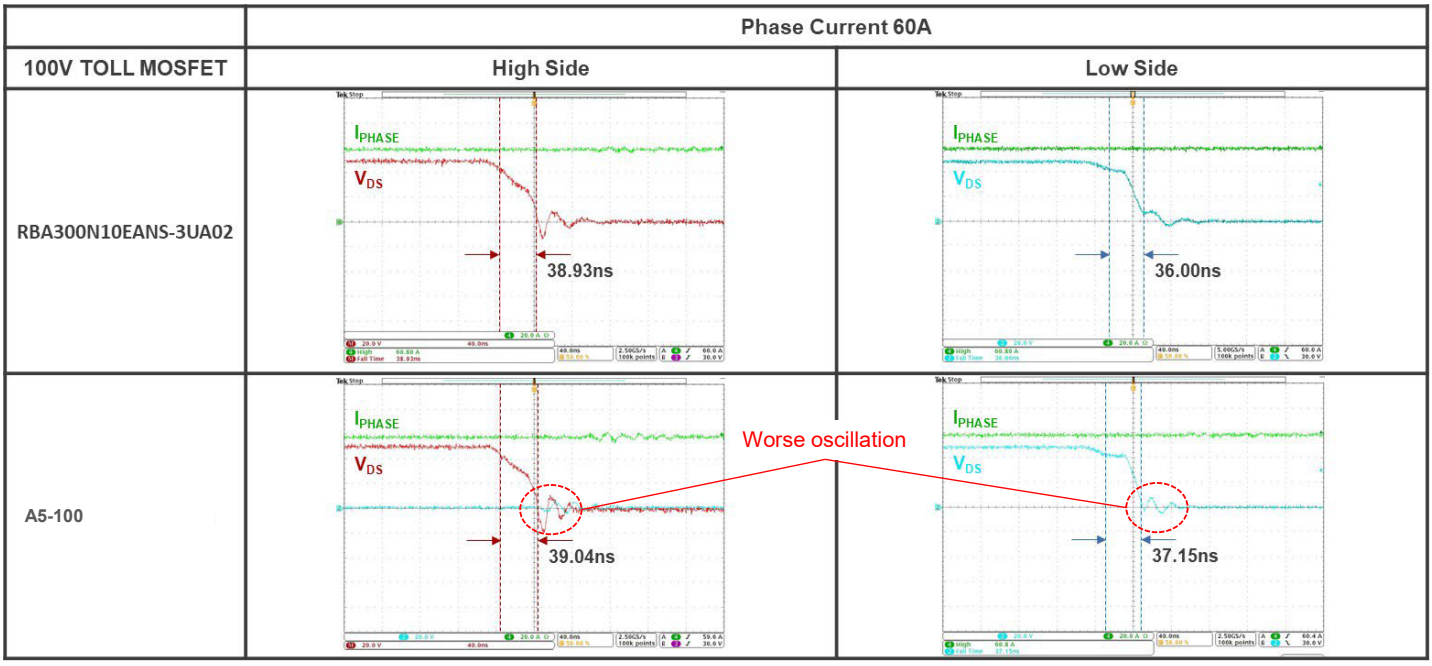


Figure 8: 100V REXFET-1 Turn-on Waveform Comparison

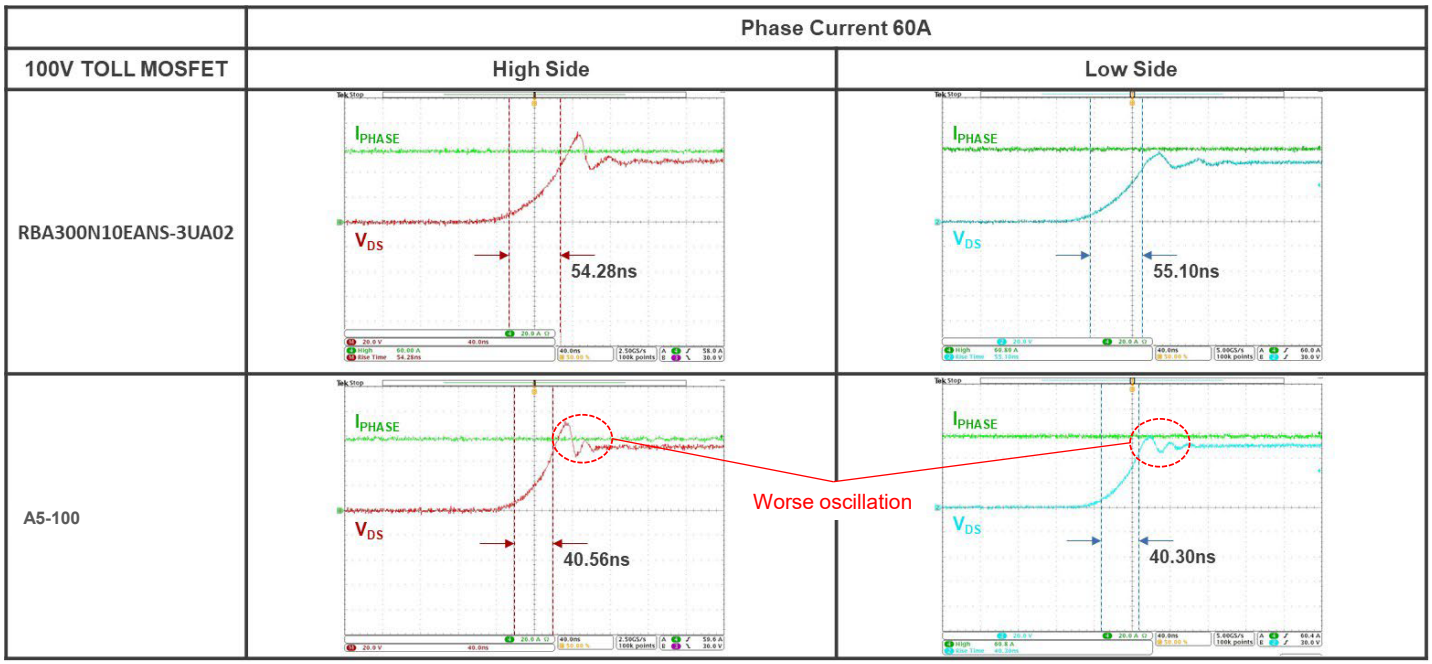


Figure 9: 100 V REXFET-1 Turn-off Waveform Comparison

REXFET™ MOSFET Portfolio

This broad portfolio enables system designers to optimize power density, thermal characteristics and board layout flexibility according to application needs. The high-power density TOLL, TOLG and TOLT packages increase system power density for new applications. Thanks to split-gate technology, REXFET devices deliver improved switching and thermal performance and enable higher power density.

Key package families include:

- **3x3 mm and 5x6 mm bottom-side cooling µSO8-FL / SO8-FL** for space-constrained applications
- **TOLL (leadless), TOLG (gullwing) and TOLT (top-side cooling)** for high-current and high-power designs requiring robust thermal performance

Table 1 provides a basic overview of the REXFET-1 lineup, highlighting the breadth of voltage ratings, Rds(on) options and package technologies available for both industrial and automotive markets. View the complete portfolio and filter options by your key parameter(s).

Breakdown Voltage	On-Resistance	Drain Current	Gate Drive	Qualification	Package
80V	1.06 – 17.2 mΩ	30 – 360A	Standard	Automotive, Industrial	µSO8-FL 3.3x3.3, SO8-FL 5x6 (WF), TOLL, TOLT
100V	1.2 – 21 mΩ	20 – 350A			µSO8-FL 3.3x3.3, SO8-FL 5x6 (WF), TOLL, TOLG, TOLT
150V	3.4 – 3.9 mΩ	190 – 200A			TOLL, TOLT

Table 1: Renesas REXFET-1 Portfolio Lineup

Conclusion

The broad Renesas REXFET-1 portfolio represents a significant advancement in power MOSFET technology. Leveraging split-gate trench wafer processing and advanced packaging, REXFET-1 devices deliver:

- 30% lower RSP vs. previous trench generations
- Excellent conduction and switching loss trade-off
- Robust package reliability with AOI-friendly wettable flank designs
- Range of package options to meet diverse system requirements

These innovations enable designers to achieve higher efficiency, greater power density and improved system reliability in motor drives, BMS and other demanding applications. Renesas will continue expanding the REXFET portfolio with the next generation supporting expanding requirements for high-performance power conversion applications. For more information visit renesas.com/MOSFETs.

Reference Materials

- Application Note: REXFET-1 MOSFET
- Application Note: TOLL 48V Power Line Evaluation Board
- Application Note: Renesas BMS Shunt-less Solution

Corporate Headquarters
TOYOSU FORESIA, 3-2-24 Toyosu, Koto-ku, Tokyo 135-0061, Japan
https://www.renesas.com

Contact Information
For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit:
https://www.renesas.com/contact-us

Renesas Electronics Corporation
www.renesas.com

Doc Number: R16WP0011EU0100