StrongIRFET™ 2 N-channel power MOSFET 30 V

Product description, design guide, and application performance

About this document

Scope and purpose

This application note provides an in-depth look at the advantages and technical details of Infineon's latest 30 V N-channel MOSFET products, featuring the latest StrongIRFET™ 2 technology. The purpose of this document is to present a detailed perspective on these products within their standard applications.

Intended audience

This document is primarily designed for design engineers, technicians, and power electronic system developers, who work on electronic systems that necessitate the use of 30 V MOSFETs. These systems include, but are not limited to:

- Motor drives in power and gardening tools
- Uninterruptible power supplies (UPS)
- DC/DC converters
- Other applications that necessitate the use of 30 V MOSFETs

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1 Product description

Infineon's StrongIRFET™ 2 family offers a range of general-purpose discrete power MOSFETs designed for ease of use and flexibility, with superior price-performance optimization. The 30 V N-channel MOSFET lineup is the latest addition to the StrongIRFET™ 2 series, which also encompasses 40 V, 60 V, 80 V, and 100 V variants aimed at diverse uses.

The 30 V N-channel MOSFET portfolio offers an array of standard package options, primarily employed in motor drives, power tools, gardening equipment, and battery management systems. Its key applications also extend to offline UPS and other cost-sensitive application domains.

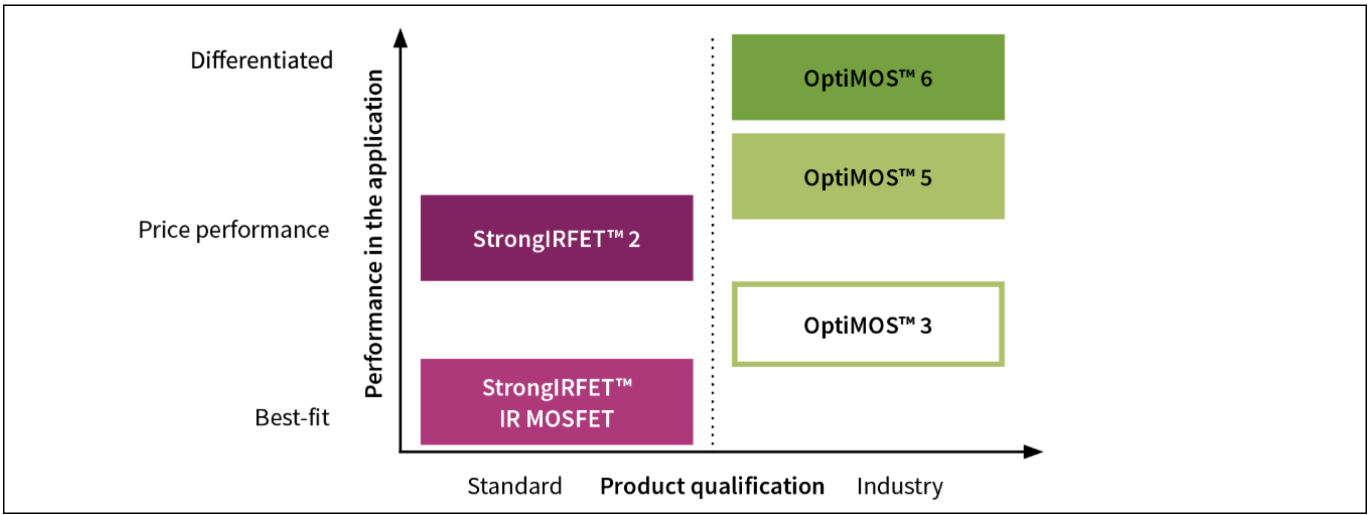

Figure 1 **StrongIRFET™ 2 N-channel power MOSFET 30 V product positioning**

1.1 Product features and benefits

The StrongIRFET™ 2 power MOSFET has been a forerunner in the multisource market, prioritizing the price-to-performance ratio and high reliability. It played a vital role in shaping today's power electronic devices. The release of the StrongIRFET™ 2 generation in 30 V marks a significant advancement, introducing an upgraded technology that brings numerous improvements to the existing portfolio.

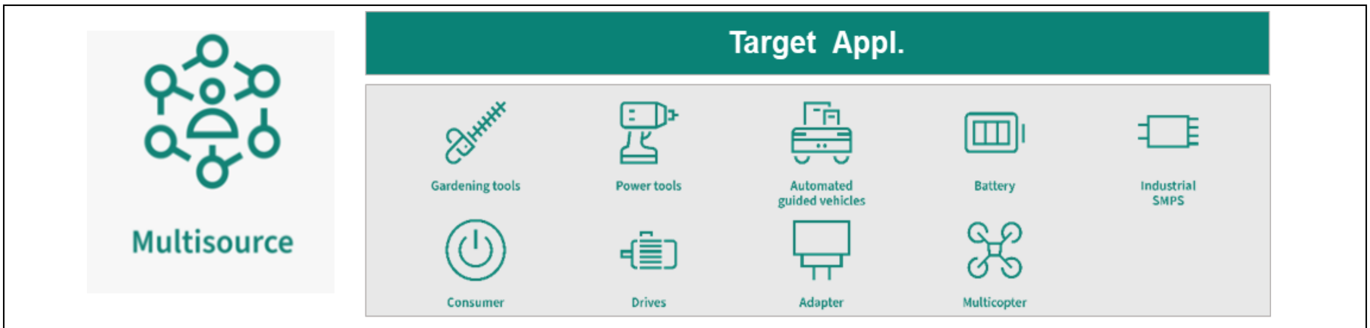

Figure 2 **StrongIRFET™ 2 N-channel power MOSFET 30 V target applications**

The StrongIRFET™ 2 MOSFETs are tailored for a wide spectrum of applications, as shown in Figure 2, showcasing their suitability for various target uses. With their widespread availability and outstanding price-to-performance ratio, they are the ideal choice for designers seeking ease in selection and procurement.

Figure 3 StrongIRFET™ 2 N-channel power MOSFET 30 V product portfolio

This comprehensive portfolio ensures that the StrongIRFET™ 2 devices cater to the mass market's needs by providing design flexibility, ease of selection, and convenient purchasing options for customers, as shown in Figure 3.

1.2 Technology improvements

The latest advancements in technology have led to a significant breakthrough in the new StrongIRFET™ 2 devices, resulting in an impressive 40% reduction in $R_{DS(on)}$ and a substantial 60% decrease in Q_g, when compared to their StrongIRFET™ predecessors. This significant enhancement not only boosts power efficiency but also elevates the overall system performance. Furthermore, the improved current ratings enhance the devices' current handling capabilities, which means there is no longer a need to use multiple devices in parallel, resulting in a reduction of both the bill of materials (BOM) costs and the required board space.

The underlying technology of the StrongIRFET™ 2 series is characterized by these substantial improvements in $R_{DS(on)}$, Q_g, input capacitance ratio, and avalanche ruggedness as detailed in Figure 4. The key technological figures of merit (FOMs) have been markedly improved from the previous generation, leading to systems that are not only more efficient and robust but also offer superior power efficiency.

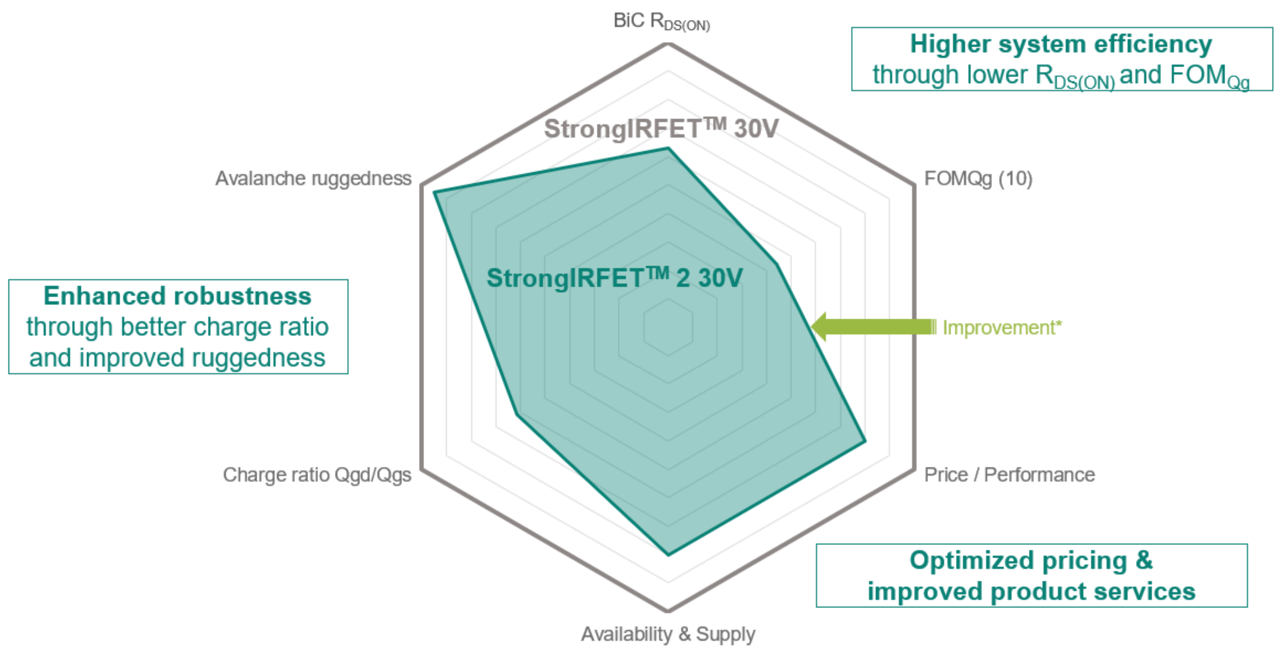

Figure 4 Technology improvements of StrongIRFET™ 2 vs. previous StrongIRFET™ generation

When selecting the optimal MOSFET for a specific application, it is essential to understand its advancements over previous technologies. Therefore, it is important to exa006Dine the key electrical characteristics of the StrongIRFET™ 2 N-channel power MOSFET 30 V that are relevant for targeted applications. The StrongIRFET™ 2 N-channel power MOSFET 30 V is designed to replace the StrongIRFET™ N-channel power MOSFET 30 V, its previous generation in switched-mode power supply (SMPS) applications, providing enhanced performance at a more cost-effective price point.

Table 1 provides a comprehensive comparison for the key datasheet values between StrongIRFET™ N-channel power MOSFET 30 V, and StrongIRFET™ 2 N-channel power MOSFET 30 V. It is important to note that the values of the electrical parameters provided in the datasheet of typical MOSFETs are often specified at different test conditions, thus preventing a fair comparison.

Table 1 Parametric comparison of StrongIRFET™ N-channel power MOSFET 30 V and StrongIRFET™ 2 N-channel power MOSFET 30 V

Parameter	Symbol	Unit	StrongIRFET™ IRLB3813PbF	StrongIRFET™ 2 IPP018N03LF2S
Drain-source on-state resistance	$R_{DS(on)}$	mΩ	1.6	1.55
Drain-source voltage	$V_{(BR)DSS}$	V	30	30
Gate threshold voltage	$V_{GS\ (th)}$	V	1.9	1.85
Switch charge	Q_{sw}	nC	25.7	23
Threshold gate charge	$Q_{GS\ (th)}$	nC	16	12
Total gate charge	$Q_{G\ (10V)}$	nC	120	95
Transconductance	g_{fs}	S	140	130
Single pulse avalanche energy	$E_{AS\ at\ (50\ A)}$	mJ	520	896

Key features of StrongIRFET™ 2:

- Broad availability from distribution partners
- Excellent price-to-performance ratio
- Ideal for high and low switching frequencies
- Industry standard footprint through-hole package
- High current rating

Key benefits of StrongIRFET™ 2:

- Increased security of supply
- Right-fit products
- Supports a wide variety of applications
- Standard pinout allows for drop-in replacement
- Increased product ruggedness

2 Design guidelines

Improving efficiency is a key consideration for SMPS designers. As the performance of silicon MOSFETs continues to improve, their intrinsic capacitances reduce, enabling faster switching speeds when used as plug-and-play replacements. While this has the benefit of reducing switching losses, it also increases the Electromagnetic Interference (EMI). Hence, designers must pay special attention to fast-switching MOSFETs to ensure EMI compliance testing.

This section discusses the impact of components and parasitic involved with the switching transitions of the MOSFET and how to control MOSFET switching to improve the EMI signature. Low-power designs tend to be the most challenging for EMI, as they often lack a metal enclosure or shielding, and are subject to high cost pressures, making it difficult for any additional EMI mitigating components. In these designs, the hard switching totem pole converter such as in full-bridge or motor control is still the dominant topology. So, this will be the primary focus, but the principles can be applied to other topologies. Later sections provide design guidelines for transitioning from the existing generation of StrongIRFET™ devices to new StrongIRFET™ 2 devices.

For this, two MOSFET part numbers are selected as illustrative examples of design guidelines. IRLB3813PbF is selected as a representative from the existing StrongIRFET™ lineup, while the IPP018N03LF2S is selected for the new StrongIRFET™ 2 series. The key parameters of these two MOSFETs are shown in Table 1.

The switching behaviors of these two example parts are evaluated using a double pulse tester with the test circuit shown in Figure 5.

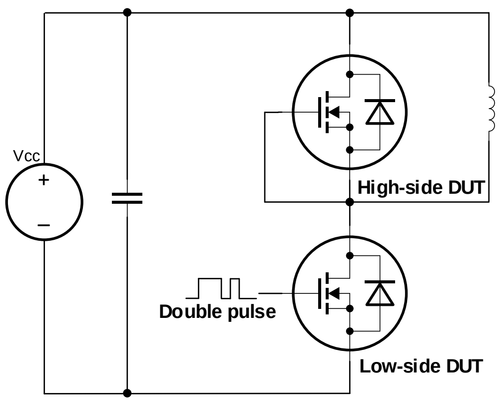

Figure 5 Double pulse test circuit

As listed in Table 1, the gate charge parameters of IPP018N03LF2S are lower than IRLB3813PbF. For instance, the $Q_{GS(th)}$ of IPP018N03LF2S is 25% lower than IRLB3813PbF, and the Q_{sw} of IPP018N03LF2S is about 10.5% lower than IRLB3813PbF. Therefore, to achieve similar V_{DS} slew-rate, the low-side (LS) device-under-test (DUT) gate resistors of IPP018N03LF2S and IRLB3813PbF are tuned with the value:

- IPP018N03LF2S: $R_{G\text{-}on}$ = 162 Ω and $R_{G\text{-}off}$ = 16 Ω
- IRLB3813PbF: $R_{G\text{-}on}$ = 75 Ω and $R_{G\text{-}off}$ = 7 Ω

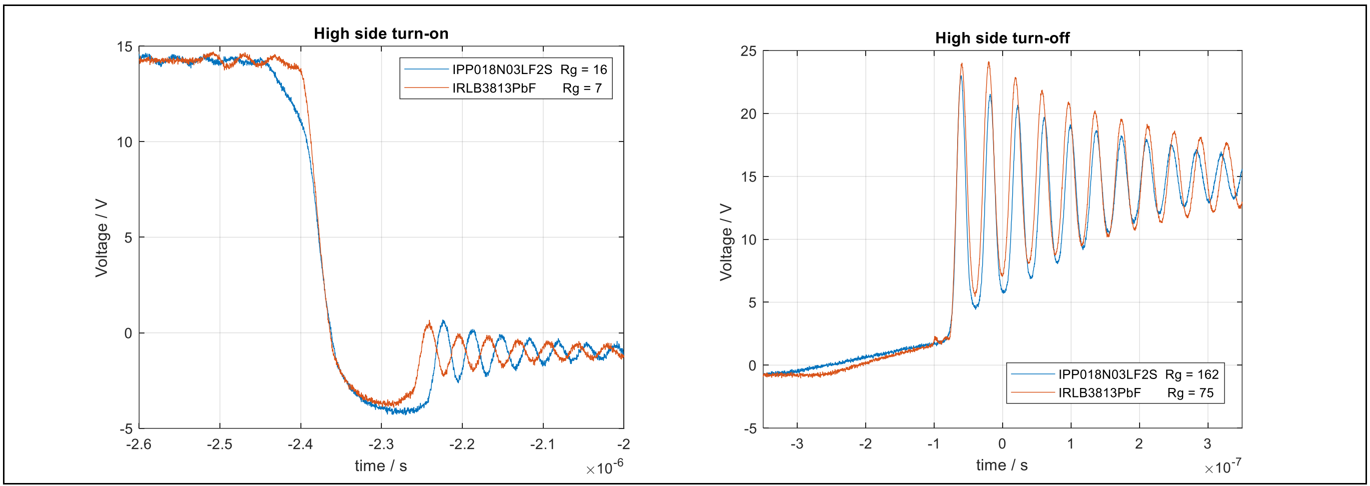

Figure 6 **Double-pulse test waveform of IRLB3813PbF and IPP018N03LF2S with similar V_{DS} slew rate**

The V_{DS} slew-rates of high-side (HS) DUTs are:

- IPP018N03LF2S: Turn-on dV/dt = -428 MV/s, Turn-off dV/dt = 1.56 GV/s
- IRLB3813PbF: Turn-on dV/dt = -448 MV/s, Turn-off dV/dt = 1.55 GV/s

The high-side (HS) DUT switching waveforms of IRLB3813PbF and IPP018N03LF2S are shown in Figure 6. A notable difference between the two devices is the severity of ringing observed in the IRLB3813PbF waveform, despite both devices exhibiting similar slew rates. In a follow-up test is shown in Figure 7. The switching behaviors of the IRLB3813PbF and IPP018N03LF2S power MOSFETs were evaluated using the same gate resistor values with RG-on and RG-off of 180 Ω and 47 Ω, respectively.

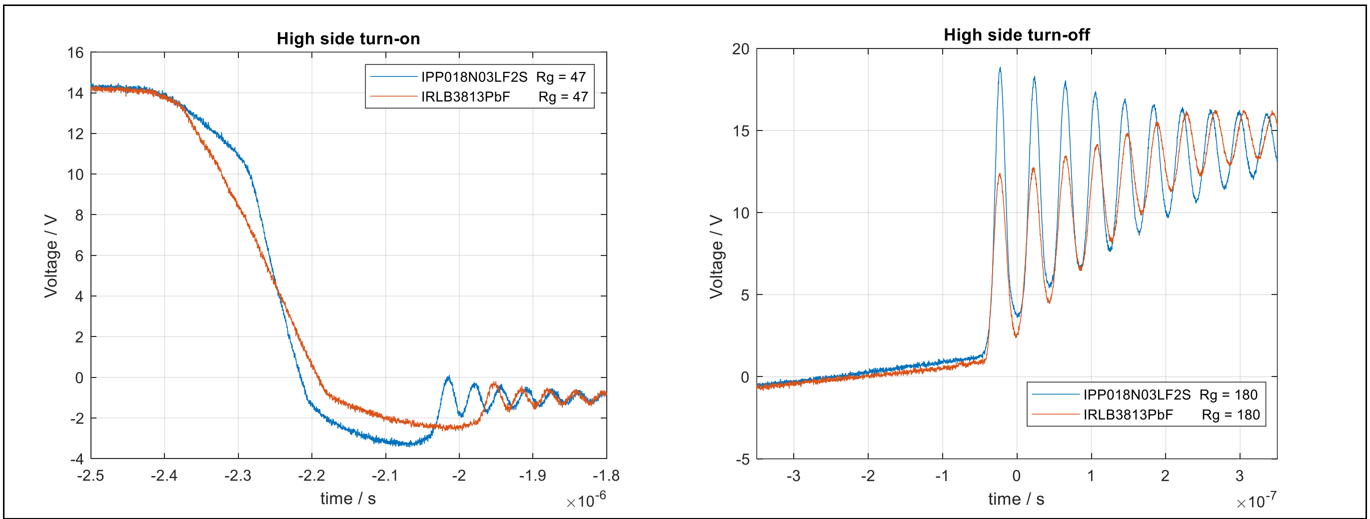

Figure 7 **Double-pulse test waveform of IRLB3813PbF and IPP018N03LF2S with same gate resistors**

The V_{DS} of HS DUT slew-rates while using the same gate resistors are:

- IPP018N03LF2S: Turn-on dV/dt = -151 MV/s, Turn-off dV/dt = 1.43 GV/s, and
- IRLB3813PbF, Turn-on dV/dt = -80 MV/s, Turn-off dV/dt = 0.87 GV/s.

These test results indicate that redesigning the gate resistors is necessary to achieve similar switching behaviors when replacing a StrongIRFET™ device with a StrongIRFET™ 2 device. A practical example of tuning gate resistors in real-world applications is discussed in Section 3.1.

3 Application evaluations

StrongIRFET™ 2 N-channel power MOSFET 30 V are designed for a wide array of applications. To assess the benefits of this technology, evaluations were conducted for specific use cases, including:

- Motor drives for power tools and gardening tools
- SMPS applications like offline UPS systems and battery management systems (BMS)

For the motor drive system and high current pulse tests, the StrongIRFET™ 2 (ISC009N03LF2S and ISC012N03LF2S) parts were selected for performance analysis. Their results were benchmarked against StrongIRFET™ (IRFH5300PbF), which is considered the equivalent class to ISC012N03LF2S.

For SMPS applications, StrongIRFET™ 2 (IPP011N03LF2S and IPP018N03LF2S) parts were tested within full-bridge hard-switching circuits. Their performance was compared against StrongIRFET™ (IRLB3813PbF), which is also classified within the same class as IPP018N03LF2S.

The specifications of the selected devices are outlined in the tables provided below.

Table 2 Key parameters of the devices for motor drive application test

Parameter	**Symbol**	**Unit**	**StrongIRFET™ 2** ISC009N03LF2S	**StrongIRFET™ 2** ISC012N03LF2S	**StrongIRFET™** IRFH5300PbF
Drain-source on-state resistance	$R_{DS(on)\text{-}max}$	mΩ	0.9	1.28	1.4
Drain-source voltage	$V_{(BR)DSS}$	V	30	30	30
Gate threshold voltage	$V_{GS\ (th)}$	V	1.85	1.85	1.8
Switch charge	Q_{sw}	nC	21	16	23
Threshold gate charge	$Q_{GS\ (th)}$	nC	12	8.6	12
Total gate charge	$Q_{G\ (10V)}$	nC	95	69	120
Transconductance	g_{fs}	S	115	95	190
Single pulse avalanche energy	$E_{ASat\ (50\ A)}$	mJ	896	473	420

Table 3 Key parameters of the devices for SMPS application test

Parameter	**Symbol**	**Unit**	**StrongIRFET™ 2** IPP011N03LF2S	**StrongIRFET™ 2** IPP018N03LF2S	**StrongIRFET™** IRLB3813PbF
Drain-source on-state resistance	$R_{DS(on)\text{-}max}$	mΩ	1.05	1.60	1.95
Drain-source voltage	$V_{(BR)DSS}$	V	30	30	30
Gate threshold voltage	$V_{GS\ (th)}$	V	1.85	1.85	1.9
Switch charge	Q_{sw}	nC	49	23	25.7
Threshold gate charge	$Q_{GS\ (th)}$	nC	28	12	16

Parameter	Symbol	Unit	StrongIRFET™ 2 IPP011N03LF2S	StrongIRFET™ 2 IPP018N03LF2S	StrongIRFET™ IRLB3813PbF
Total gate charge	$Q_{G\ (10V)}$	nC	224	95	120
Transconductance	g_{fs}	S	200	130	140
Single pulse avalanche energy	$E_{AS\ at\ (50\ A)}$	mJ	5028	896	520

3.1 3-phase motor drive application test

In this test setup, the devices under test (DUTs) are integrated into a 3-phase motor drive system, powering a 12 V brushless DC motor (BLDC) coupled with a controllable load. The input power levels are varied at 200 W, 150 W, and 100 W, with the motor speed at 12,000 RPM. Table 4 lists the main parameters of the test condition.

Table 4 Test conditions of 3-phase motor drive application

Parameter	Symbol / unit	Value
Input voltage	V_{in}/V	12
Switching frequency	f_{sw}/Hz	10,000
		20,000
Input power	W_{in}/W	200
		150
		100
Motor speed	RPM/ -	12,000

To ensure comparable switching behavior, three different devices , IRFH5300PbF, ISC009N03LF2S, and ISC012N03LF2S, are each placed into the same BLDC system, with distinct gate resistors.

The tuned gate resistors values are:

- IRFH5300PbF: $R_{g\text{-}on}$ = 43 Ω and $R_{g\text{-}off}$ = 1 Ω
- ISC009N03LF2S: $R_{g\text{-}on}$ = 75 Ω and $R_{g\text{-}off}$ = 1 Ω
- ISC012N03LF2S: $R_{g\text{-}on}$ = 91 Ω and $R_{g\text{-}off}$ = 1 Ω

As an illustrative example of the switching behavior discussed in Section 2, the switching transient of IRFH5300PbF and ISC012N03LF2S in the BLDC systems are shown in Figure 8.

During high-side turn-on transient, the V_{DS} overshoot of low-side devices is controlled, which is lower than 80% of the break-down voltage ($V_{(BR)DSS}$). The induced voltage on low-side gate (CdV/dt) is another factor that needs designers' attention. The waveforms of channel 2 (purple) is CdV/dt, and its maximum value should be below 1 V to prevent any false-turn-on.

During high-side turn-off transient, the V_{DS} overshoot of high-side devices must be lower than 80% of the $V_{(BR)DSS}$.

The waveforms of these two devices exhibit similarities due to the tuned gate resistors design.

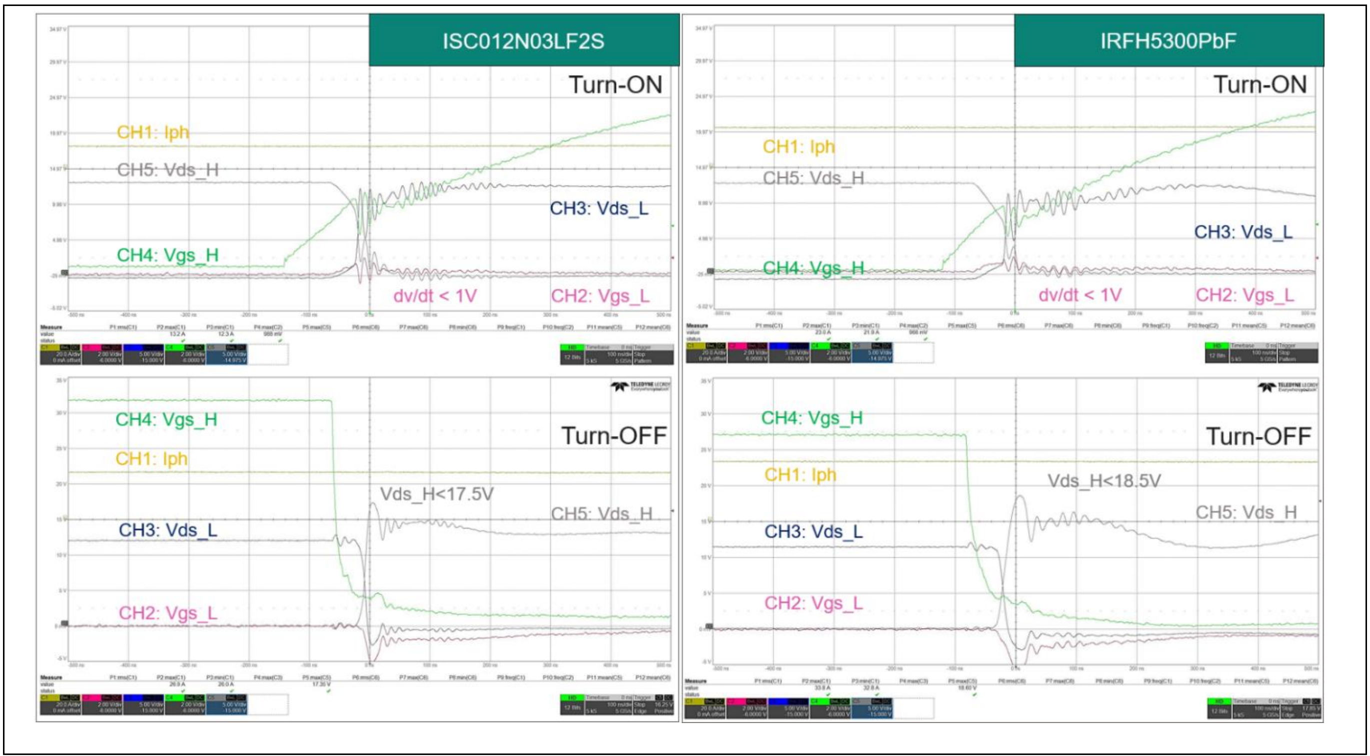

Figure 8 Switching transient waveforms

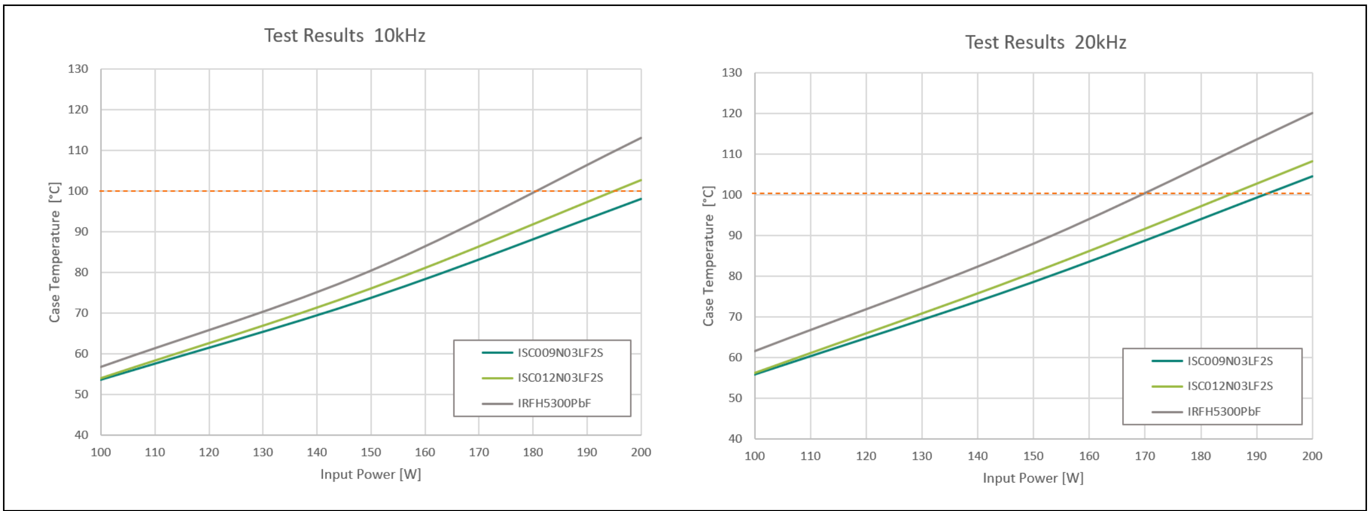

Figure 9 Test results – MOSFET case temperature vs. input power

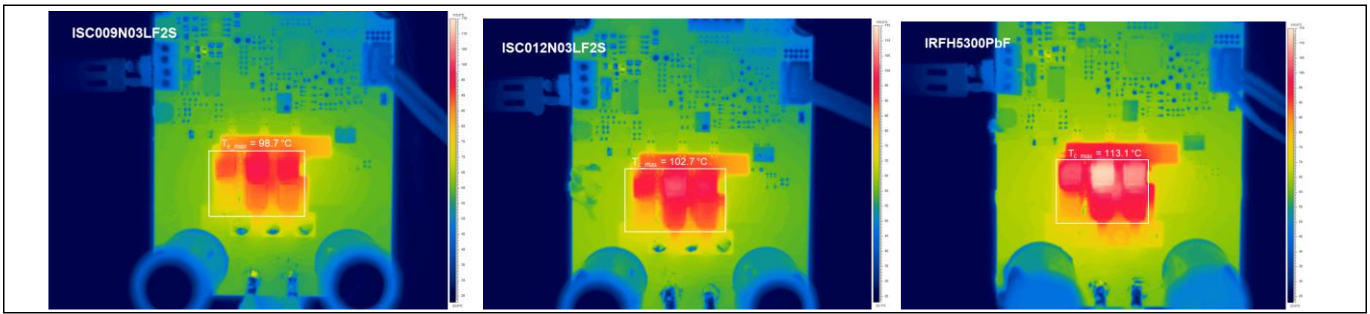

Figure 10 Thermal images for MOSFET case temperature at 200 W output power with 10 kHz switching frequency

Figure 9 shows the case temperature (T_C) vs. the input power curves. With 10 kHz switching frequency, T_C of IRFH5300PbF is about 5°C higher than ISC012N03LF2S at 100 W input power level. This temperature difference increases to around 10°C at an input power level of 200 W. With 200 W input power and 10 kHz switching frequency, ISC012N03LF2S results about 5°C higher T_C than ISC009N03LF2S.

For detailed information on temperature distribution, thermal images of the tests under 200 W input power and 10 kHz switching frequency are shown in Figure 10.

As a conclusion of the 3-phase motor drive test: StrongIRFET™ 2 devices can easily replace StrongIRFET™ devices in motor drive applications with performance improvement.

3.2 High current pulse (HCP) test

The HCP test is widely used to evaluate the current conducting capability of a device, especially in motor drive systems under locked rotor scenarios. The HCP test consists of three distinct parts:

- Single-pulse test : In this test, a 100 A pulse has been injected into the DUT
- DC test: A sequence of incrementing DC current is injecting into the DUT until T_C reaches 120°C, and each step lasts 10 minutes
- Multi-pulse test: A sequence of incrementing pulse current groups is injected into the DUT until T_C reaches 120°C

Each pulse current group consists of 20 square pulses with 58% duty cycle at 0.6 Hz. Figure 11 shows the example waveform of the HCP test.

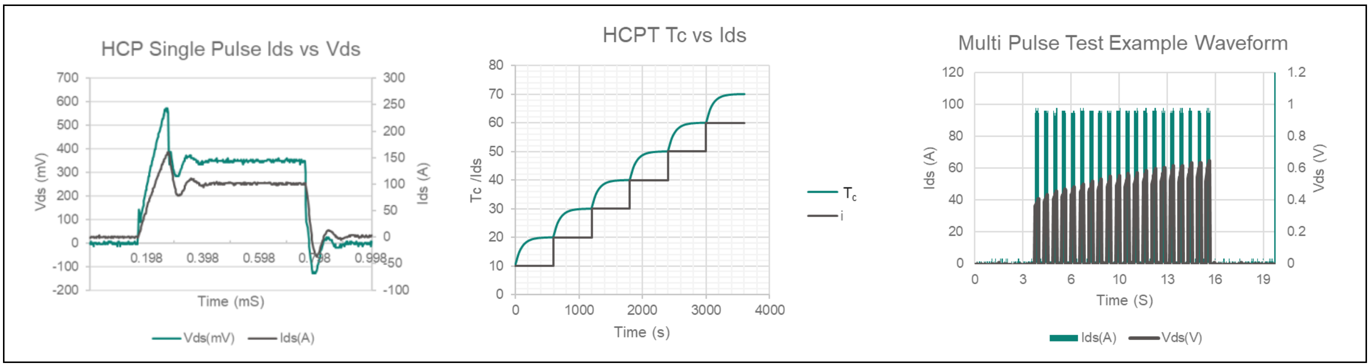

Figure 11 Example waveforms of HCP test

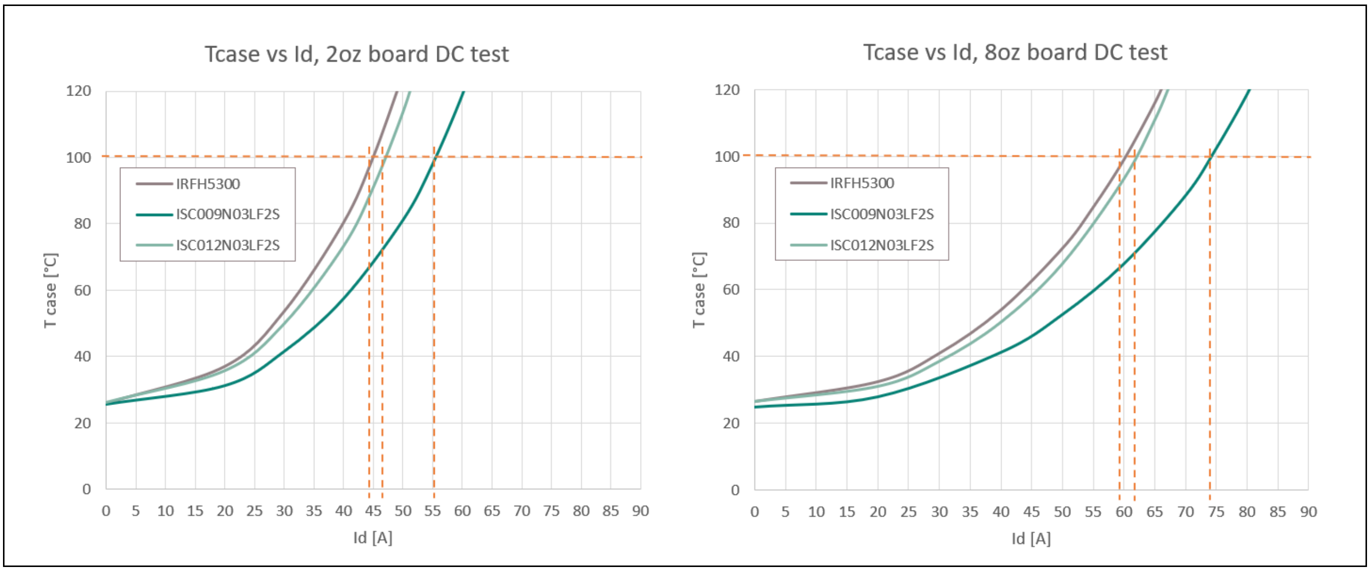

Figure 12 **Test results of HCP DC test**

The DC test has been performed on IRFH5300PbF, ISC009N03LF2S, and ISC012N03LF2S with a 2oz 2-layer board and an 8oz 2-layer board to evaluate their conduction current capability in locked-rotor condition. The test results are shown in Figure 12. On the 2 oz. 2-layer board, ISC009N03LF2S was able to carry 59 A with a case temperature (T_C) of 100°C. With the same T_C, ISC012N03LF2S conducted 50.5 A current, and IRFH5300PbF achieved 48 A. On the 8 oz board, with 100°C T_C, ISC009N03LF2S was able to carry 74 A, while ISC012N03LF2S carries 62 A, and IRFH5300PbF carries 60.5 A.

It is important to note that ISC012N03LF2S exhibits slightly higher current conducting capability than IRFH5300PbF. The best-in-class device ISC009N03LF2S has the best DC current conducting capability.

3.3 Full-bridge application test

The full-bridge application test targets evaluating the performance of the devices in SMPS applications such as offline UPS. IRLB3813PBF, IPP011N03LF2S, and IPP018N03LF2S were placed in a full-bridge system as shown in Figure 13. The full-bridge was operated with an open loop 50% duty cycle control, and an electrical load controls the output current. The test conditions are listed in Table 5.

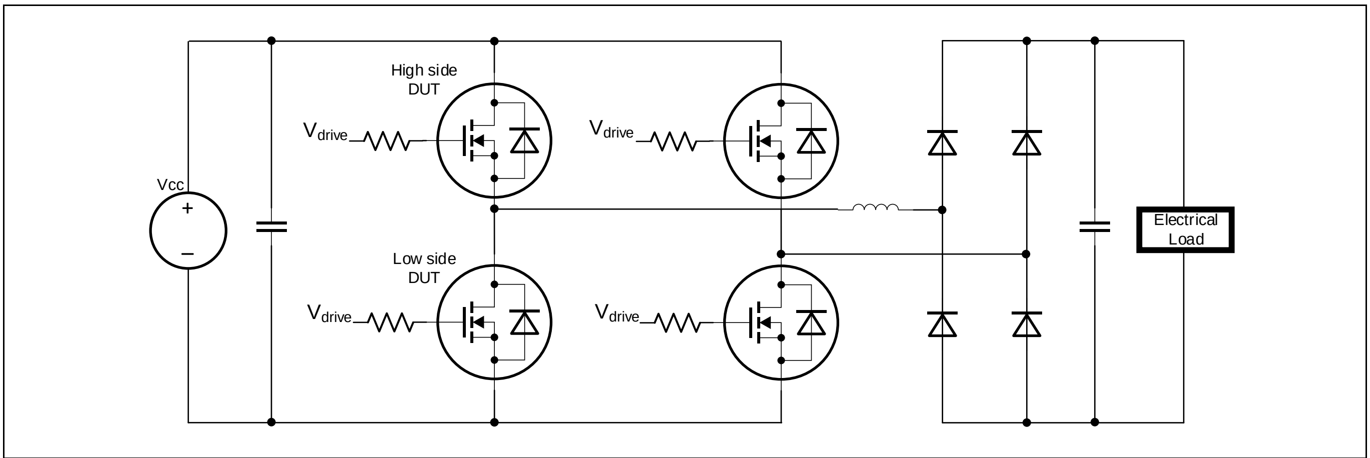

Figure 13 **Methodology for full-bridge application test circuit**

Table 5 Test conditions of full-bridge application

Parameter	Symbol / unit	Value
Input voltage	V_{in} / V	15
Load current	I_{load} / A	35
Switching frequency	f_{sw} / Hz	200
Open loop duty cycle	D / -	50%
Turn-on gate resistor	R_{g_on} / Ω	100
Turn-off gate resistor	R_{g_off} / Ω	16

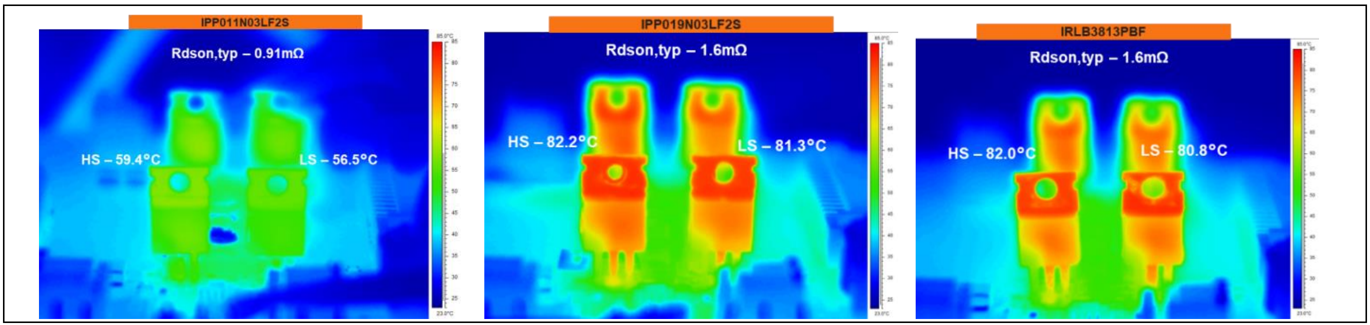

Figure 14 Full-bridge test results

Table 6 Case temperature of the DUT

Device part number	High-side DUT temperature [°C]	Low-side DUT temperature [°C]
IPP011N03LF2S	59.4	56.5
IPP018N03LF2S	82.2	81.3
IRLB3813PBF	82.0	80.8

The temperature results with 10 minutes operating time are listed in Table 6, and the detailed information on temperature is shown in Figure 14.

IPP018N03LF2S achieved similar thermal results when compared to IRLB3813PBF. The best-in-class device IPP011N03LF2S results in about 20°C lower temperature compared to IRLB3813PBF. Therefore, StrongIRFET™ 2 devices can be used to replace StrongIRFET™ devices in the applications with full-bridge topologies.

4 Conclusion

StrongIRFET™ 2 power MOSFETs are optimized for a broad range of applications like SMPS, motor drive, battery powered applications, battery management, UPS, and more. Featuring broad availability and excellent price/performance ratio make these right-fit products an easy choice for designers interested in convenient selection and purchasing. The StrongIRFET™ 2 N-channel power MOSFET 30 V portfolio is offered in diverse packaging options.

This document assesses the performance of these devices across various applications. The 3-phase BLDC motor drive application test results indicate that ISC012N03LF2S can replace IRFH5300PbF in real applications with performance improvement, as well as other SMD devices in the family. The full-bridge tests prove that IPP018N03LF2S can replace IRLB3813PBF in various systems such as offline UPS, as well as other through-hole devices in the family.

StrongIRFET™ 2 device family can replace the devices of the StrongIRFET™ family with minimal design changes, as their wide portfolio provide the choices for various applications.

Revision history

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