OptiMOS™ 7 motor-drive-optimized N-channel MOSFET 40 V

Product description 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 40 V N-channel MOSFET products, featuring the latest OptiMOS™ 7 motor-drive-optimized technology. This document presents a detailed description of these products within their standard applications.

Intended audience

This document is intended for design engineers, technicians, and power electronic system developers, who work on electronic systems that use 40 V MOSFETs.

Keypoints

- Explains design considerations for motor-drive systems using OptiMOS™ 7 MOSFETs in power and gardening tools
- Describes key technology improvements including lower $R_{DS(on)}$, enhanced immunity, wider SOA, and optimized gate characteristics
- Demonstrates switching performance evaluation through double-pulse tests and comparative analysis with OptiMOS™ 6 and competitor devices
- Provides practical insights on thermal behavior and efficiency benefits in 3-phase motor-drive applications
- Highlights packaging options such as dual-side-cooled designs for improved thermal management and reliability

About this product family

Product family

Infineon's OptiMOS™ power MOSFETs provide best-in-class performance with increase in efficiency, power density, and cost-effectiveness. Their ultra-low $R_{DS(on)}$ and low charge enable high switching frequency, making them an excellent choice for high-performance designs.

Target applications

- Industrial drives
- Server
- Telecom
- Battery management systems (BMS)
- Information and communication technologiesn
- Energy storage systems trusted semiconductor solutions for light electric vehicles (LEV)

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1 Introduction: OptiMOS™ 7 motor-drive-optimized MOSFET

Infineon's OptiMOS™ 7 motor-drive-optimized MOSFET family presents "drive-optimized" discrete power MOSFETs, ideally suited for power and gardening tool applications.

The 40 V motor-drive-optimized MOSFETs portfolio offers low on-state resistance ($R_{DS(on)}$) with standard package options, including SuperSO8 5x6 (PG-TDSON), PQFN 3.3 x 3.3 (PG-TSDSON), and SuperSO8 5x6 dual-side-cooled (PG-WSON-8). Figure 2 shows the full portfolio.

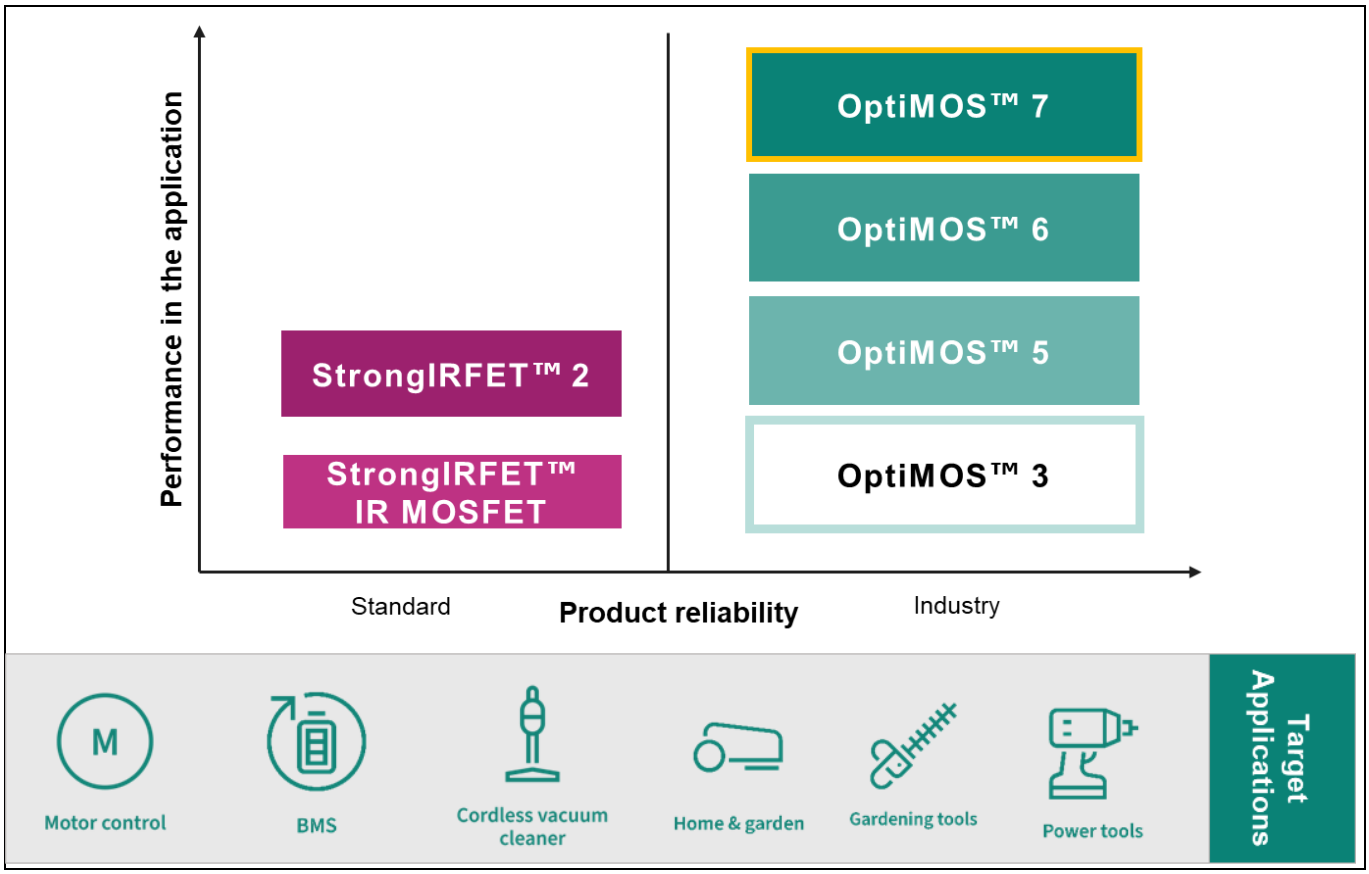

Figure 1 Product positioning of OptiMOS™ 7 motor-drive-optimized MOSFET

Product Name	R_{Dson} max. @10V [mΩ]	Package
ISCH54N04NM7V	0.54	SuperSO8 5x6
ISCH69N04NM7V	0.69	SuperSO8 5x6
ISCH99N04NM7V	0.9	SuperSO8 5x6
ISC011N04NM7V	1.1	SuperSO8 5x6
ISC012N04NM7V	1.2	SuperSO8 5x6
ISC016N04NM7V	1.6	SuperSO8 5x6
ISZ015N04NM7V	1.5	PQFN 3.3x3.3

Packages

SuperSO8 5x6

PQFN 3.3x3.3

Product Name	R_{Dson} max. @10V [mΩ]	Package
ISCH57N04NM7VSC*	0.57	SuperSO8 5x6 DSC
ISCH75N04NM7VSC*	0.75	SuperSO8 5x6 DSC
ISCH92N04NM7VSC*	0.92	SuperSO8 5x6 DSC

Packages

SuperSO8 5x6 DSC

*Product in development stage – Portfolio, parameters and timelines subject to change

Figure 2 OptiMOS™ 7 motor-drive-optimized MOSFET portfolio

1.1 Motor drives in power and gardening tools

A motor drive system is a crucial component in power and gardening tools. The engineers of these products are always working hard to improve:

- Efficiency
- Precise torque control
- Wide speed range
- Lifespan
- Dynamic performance
- Cost-performance balance

Figure 3 [1] shows the block diagram of a typical drive system in a cordless power tool. The power source of the system is a pack of rechargeable battery, followed by a 3-phase inverter (power stage) powering an electric motor. As these have been developed for decades, the brushless DC motor (BLDC) becomes the first choice for a drive system.

Introduction: OptiMOS™ 7 motor-drive-optimized MOSFET

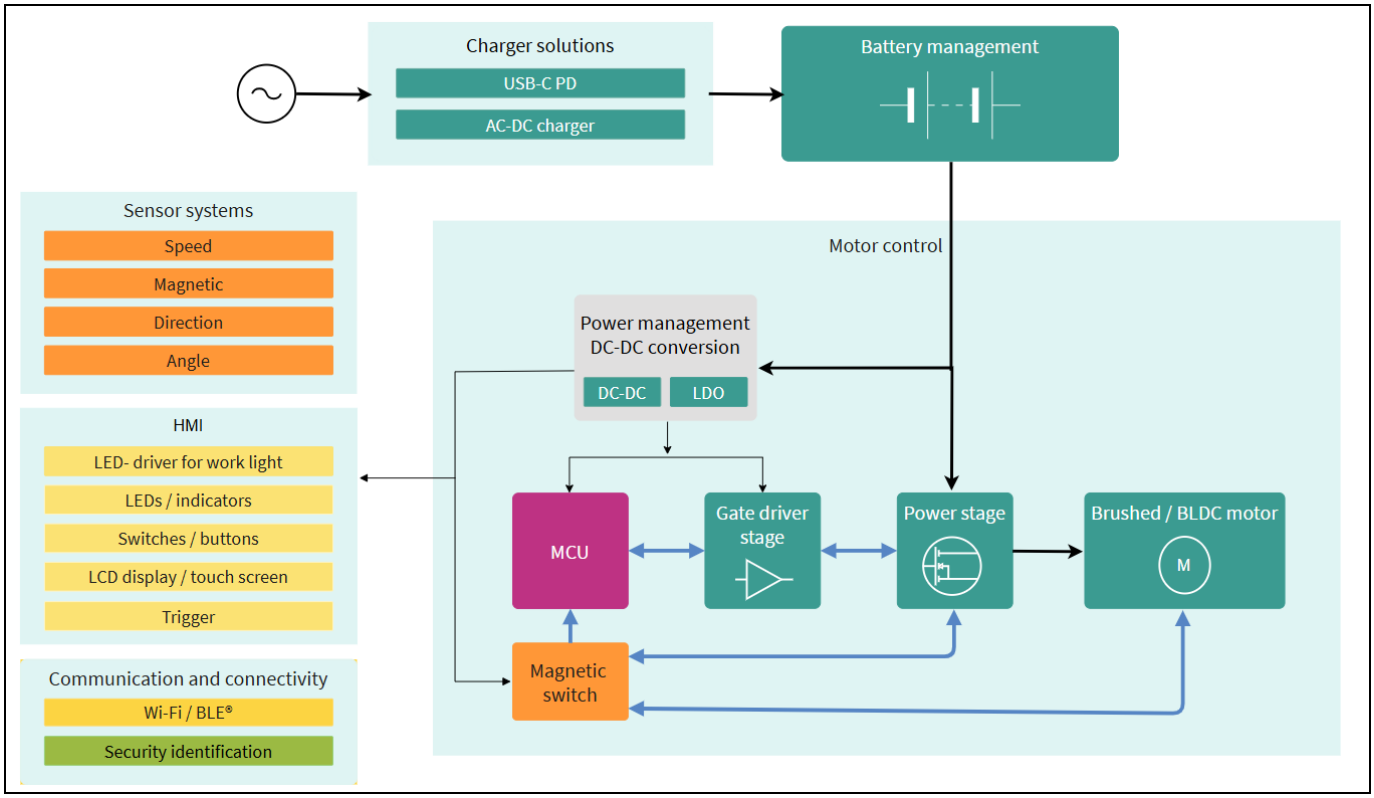

Figure 3 System diagram of battery-powered tools

A good algorithm and electronics of the BLDC drive system are critical to ensure optimum drive system performance. Block commutation control methods are widely used in the drive system. However, compared to block commutation, field-oriented control (FOC) with a proper design has the following advantages:

- Higher efficiency
- Smooth and precise torque control
- Wider speed range
- Better performance at low-speed range
- Faster dynamic response

These benefits require the hardware for FOC support with the following features:

- High-accuracy current sense on 2 or 3 phases
- Accurate rotor position sensing instead of Hall sensing
- More powerful MCU
- Faster feedback and control
- Optimized MOSFETs

As increasingly power and gardening tools are implementing FOC, the demand for the related electronics products is increasing. Infineon's OptiMOS™ 7 motor-drive-optimized MOSFETs are introduced to fulfill the demand.

1.2 Specifications of OptiMOS™ 7 motor-drive-optimized MOSFET 40 V

Infineon's OptiMOS™ 7 motor-drive-optimized devices are designed to fulfill the demand of MOSFETs that fit for higher-power-density systems motor drive systems based on the FOC algorithm. The major improvements are highlighted in Figure 4.

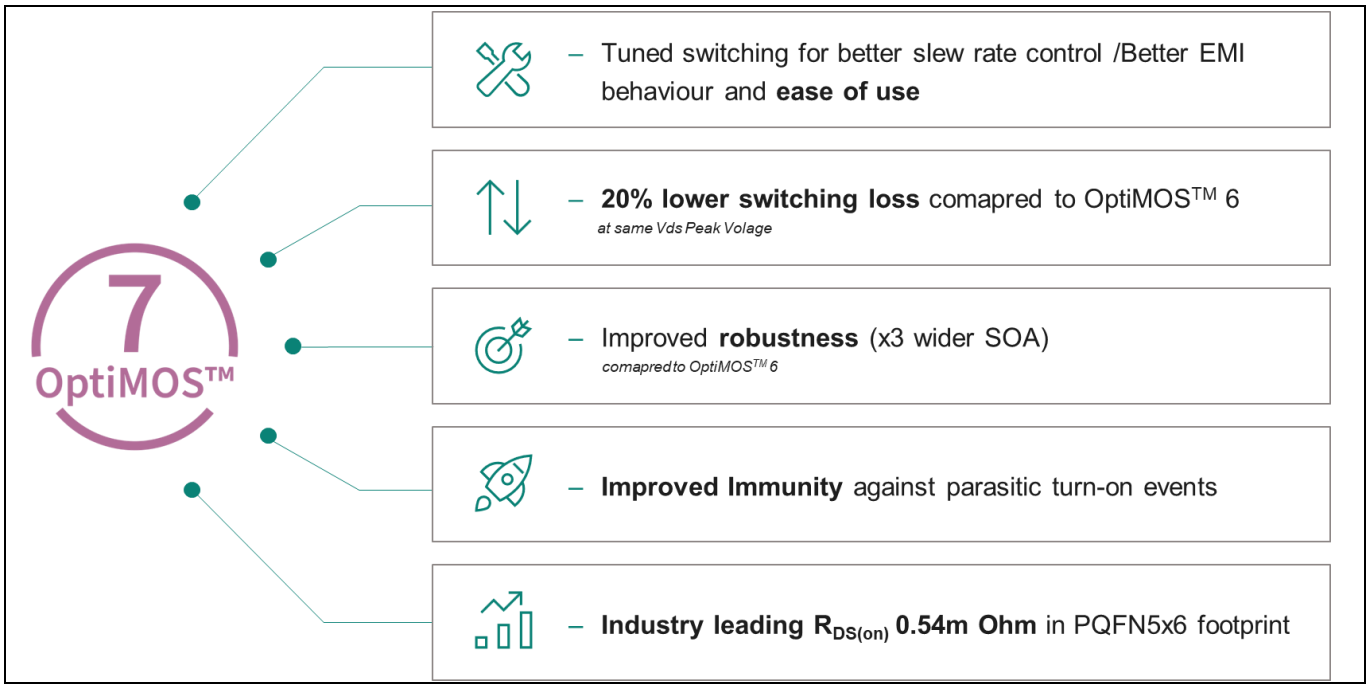

Figure 4 Technology improvement of OptiMOS™ 7 motor-drive-optimized MOSFETs

1.2.1 Superior $R_{DS(on)}$

The losses of a MOSFET in 3-phase inverter of a motor drive can be divided into three parts:

- Conduction loss
- Switching loss
- Body-diode conduction loss

Conduction loss is dependent on many factors, such as phase current, duty cycle, and $R_{DS(on)}$ of the MOSFET. However, for the MOSFET itself, $R_{DS(on)}$ is the only factor that affects the conduction loss. The lower $R_{DS(on)}$, the lower conduction loss if other conditions remain the same.

OptiMOS™ 7 power MOSFET 40 V family provides superior $R_{DS(on)}$: $R_{DS(on)\text{-}max}$ of the best-in-class MOSFET in the OptiMOS™ 7 family with SUperSO8 5x6 package is 0.54 mΩ. Compared to the same-in-class MOSFET of the OptiMOS™ 6 family, the OptiMOS™ 7 MOSFET has up to 20% lower $R_{DS(on)}$.

1.2.2 Improved immunity

The value of induced voltage on the gate (induced V_{GS}) of a MOSFET is a critical factor for false-turn-on in motor drive applications. As shown in Figure 5, during the high-side turn-on transient, the V_{DS} of the low-side MOSFET rises from zero to the bus voltage. The fast-increasing V_{DS} causes a current flow through C_{GD} (I_{CGD}). The current I_{CGD} flowing through R_G and V_{GS} will consequently increase.

A MOSFET with a higher threshold voltage ($V_{GS(th)}$) has a higher immunity to induced V_{GS}.

The threshold voltage ($V_{GS(th)}$) of OptiMOS™ 7 motor-drive-optimized MOSFETs is 2.8 V (typical), which is higher than that of OptiMOS™ 6 MOSFETs.

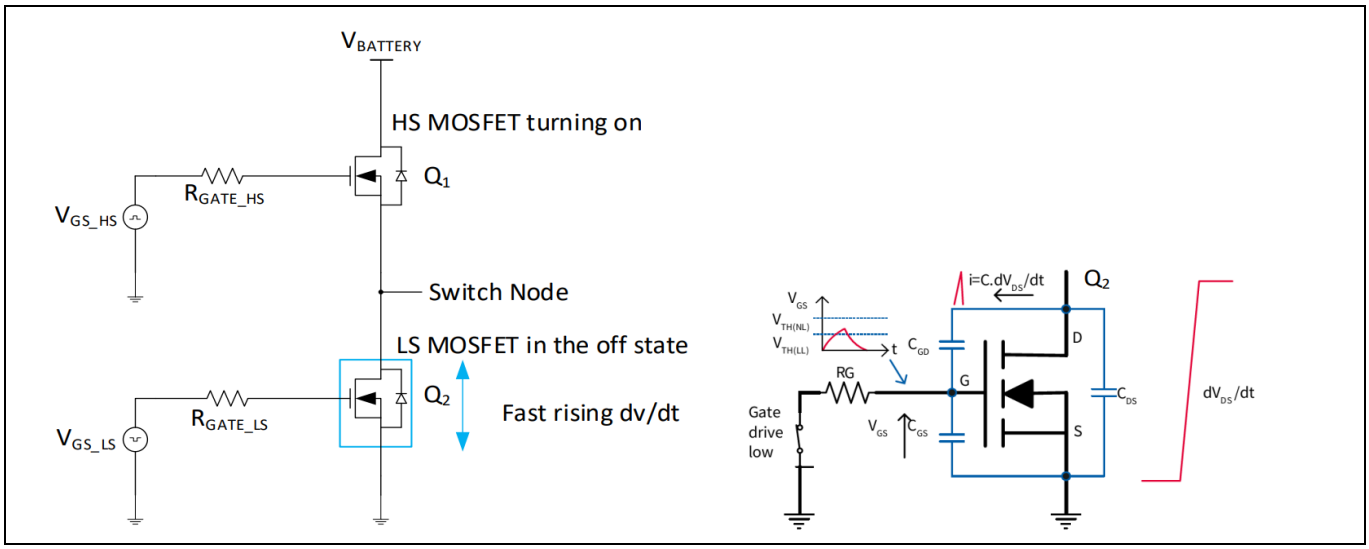

Figure 5 Mechanism of induced gate voltage

1.2.3 3x wider safe operating area

The safe operating area (SOA) is a critical attribute of a MOSFET in a motor drive. The SOA diagram defines the allowed maximum current-voltage range of a MOSFET.

In motor drive applications, a wider SOA provides a higher current capability and better reliability, especially during low-speed, high-torque scenario and locked-rotor scenario.

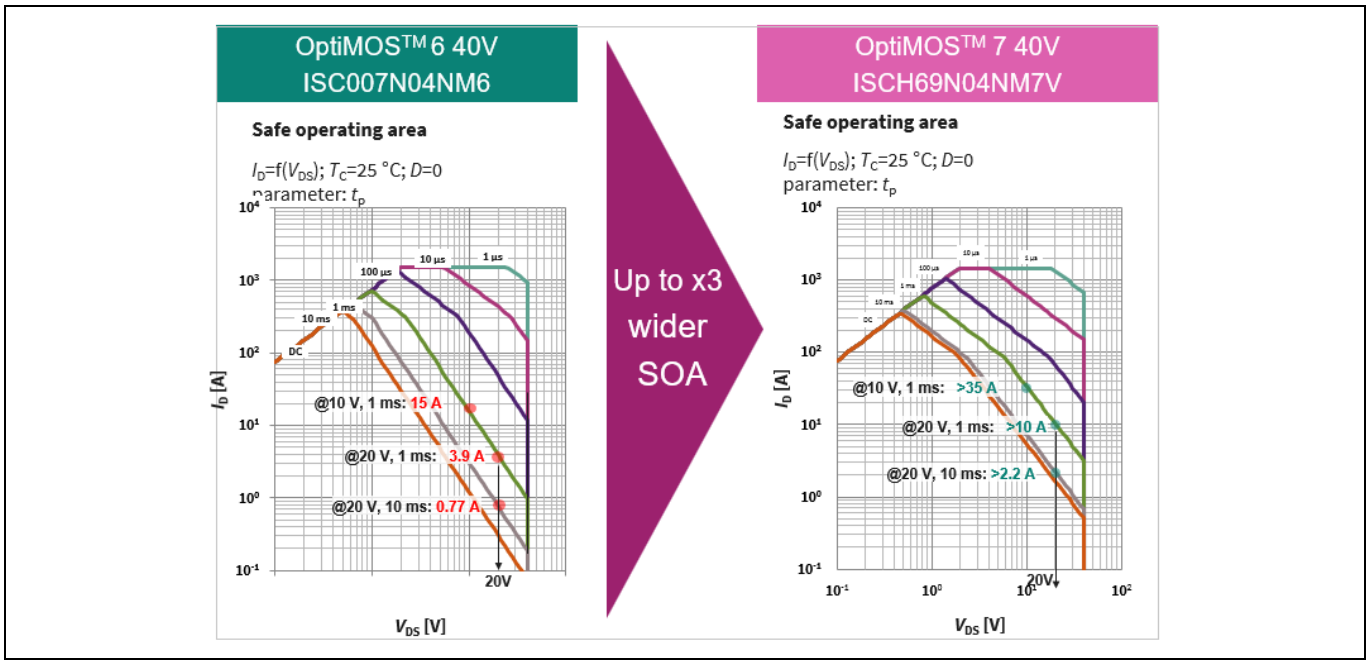

Figure 6 SOA graphs of OptiMOS™ 7 and OptiMOS™ 6

As shown in Figure 6, the SOA of the OptiMOS™ 7 ISCH69N04NM7V MOSFET is up to three times wider than that of a same-in-class OptiMOS™ 6 ISC007N04NM6 MOSFET.

1.2.4 Optimized gate characteristics

Gate-source charge (Q_{GS}), gate-drain charge (Q_{GD}), and other gate charge characteristics are important parameters for the switching behavior. The switching performance is also highly dependent on the gate driver circuit design.

Transconductance (g_{fs}) is another fundamental parameter of a MOSFET, representing the relationship between the input gate-source voltage (V_{GS}) and the output current (I_D).

With optimized gate charges and transconductance, the switching losses of OptiMOS™ 7 motor-drive-optimized MOSFETs are about 20% lower than OptiMOS™ 6 devices at the same V_{DS} peak voltage.

1.2.5 Dual-side-cooled (DSC) package

Infineon's OptiMOS™ 7 motor drive optimized family provides the options of dual-side-cooled (DSC) devices. Equation 1 shows the typical values in the datasheets of the three different packaging technologies. The formula to calculate the combined thermal resistance of DSC package is shown in Equation 1. As shown in the formula, the low thermal resistance from the junction to top provides benefits.

$$R_{th} = \frac{(R_{thJC(top)}+R_{thTA})*(R_{thJC(bot)}+R_{thBA})}{(R_{thJC(top)}+R_{thTA})+(R_{thJC(bot)}+R_{thBA})}$$

Equation 1 Combined thermal resistance of the DSC package

Table 1 Comparison of thermal resistances for different packaging technologies

Package	$R_{thJC(top)}$-typ [K/W]	$R_{thJC(bot)}$-typ [K/W]	Definition
SO8	15	15	
SuperSO8 5x6	15	1	Bottom-side-cooled
SuperSO8 dual-side-cooled 5x6	0.7	1	Dual-side-cooled

2 Switching behavior of OptiMOS™ 7 motor-drive-optimized MOSFET

2.1 Double-pulse test

Double-pulse tests are widely used for power device switching behavior evaluations. The schematic of the tester used in this application note is shown in Figure 7.

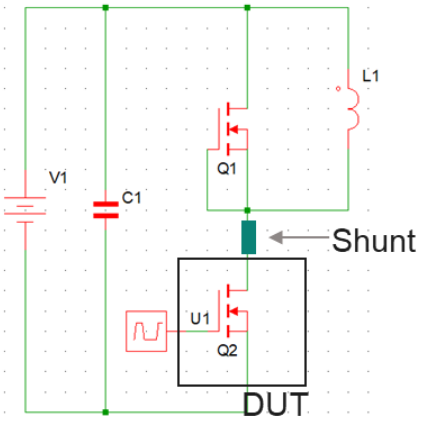

Figure 7 Double pulse tester circuit

All the voltage measurements refer to the low-side DUT (Q2), and the DUT current is measured via the shunt voltage. The high-side switch (Q1) is always off and conducts current through the body diode while the low-side DUT turns off.

Figure 8 shows the double-pulse test setup.

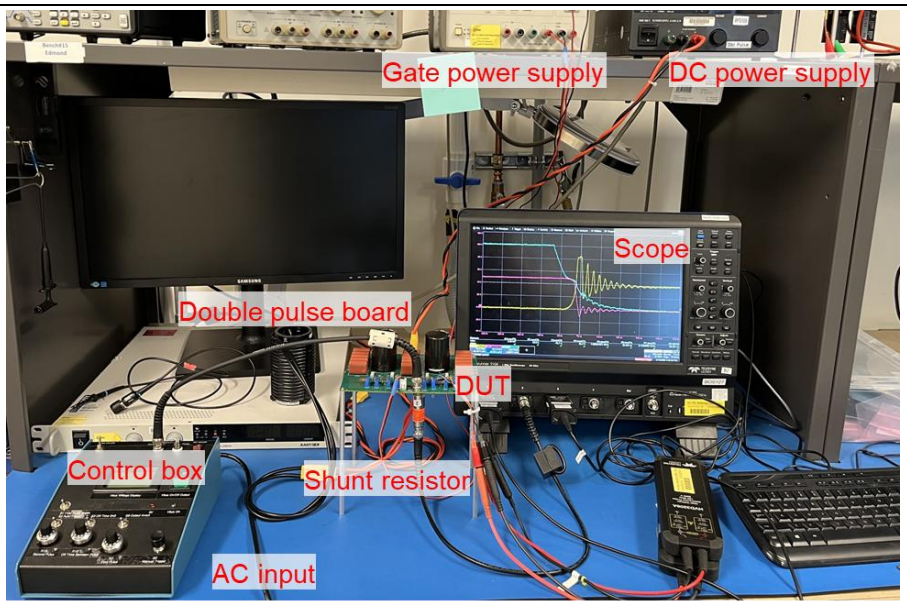

Figure 8 Double-pulse test setup

2.2 Switching behavior of different MOSFETs

Double-pulse tests are performed on an OptiMOS™ 7 motor-drive-optimized MOSFET, OptiMOS™ 6 MOSFET, and MOSFETs from other vendors for analysis and comparison of switching behavior.

ISC011N04NM7V has been chosen as the representative of Infineon's OptiMOS™ 7 motor-drive-optimized MOSFET. ISC010N04NM6 is an OptiMOS™ 6 MOSFET with similar $R_{DS(on)}$. The other three parts are from other vendors with a similar market position and are selected for comparison.

The key parameters are listed in Table 2.

Table 2 Key parameters (in datasheet) of the devices of double-pulse test

Parameter	Drain-source on-state resistance	Output charge	Reverse recovery charge	Total gate charge	Gate threshold voltage
Symbol	**$R_{DS(on)\text{-}max}$**	**Q_{OSS}**	**Q_{rr}**	**Q_G @ V_{GS} = 10 V**	**V_{th}**
Unit	**mΩ**	**nC**	**nC**	**nC**	**V**
ISC011N04NM7V	1.1	73	198	58	2.75
ISC010N04NM6	1.0	73	152	67	2.3
Vendor part A	1.1	100	60	72	3.0
Vendor part B	1.2	56	44	62	2.5
Vendor part C	1.05	82	77	50	3.0

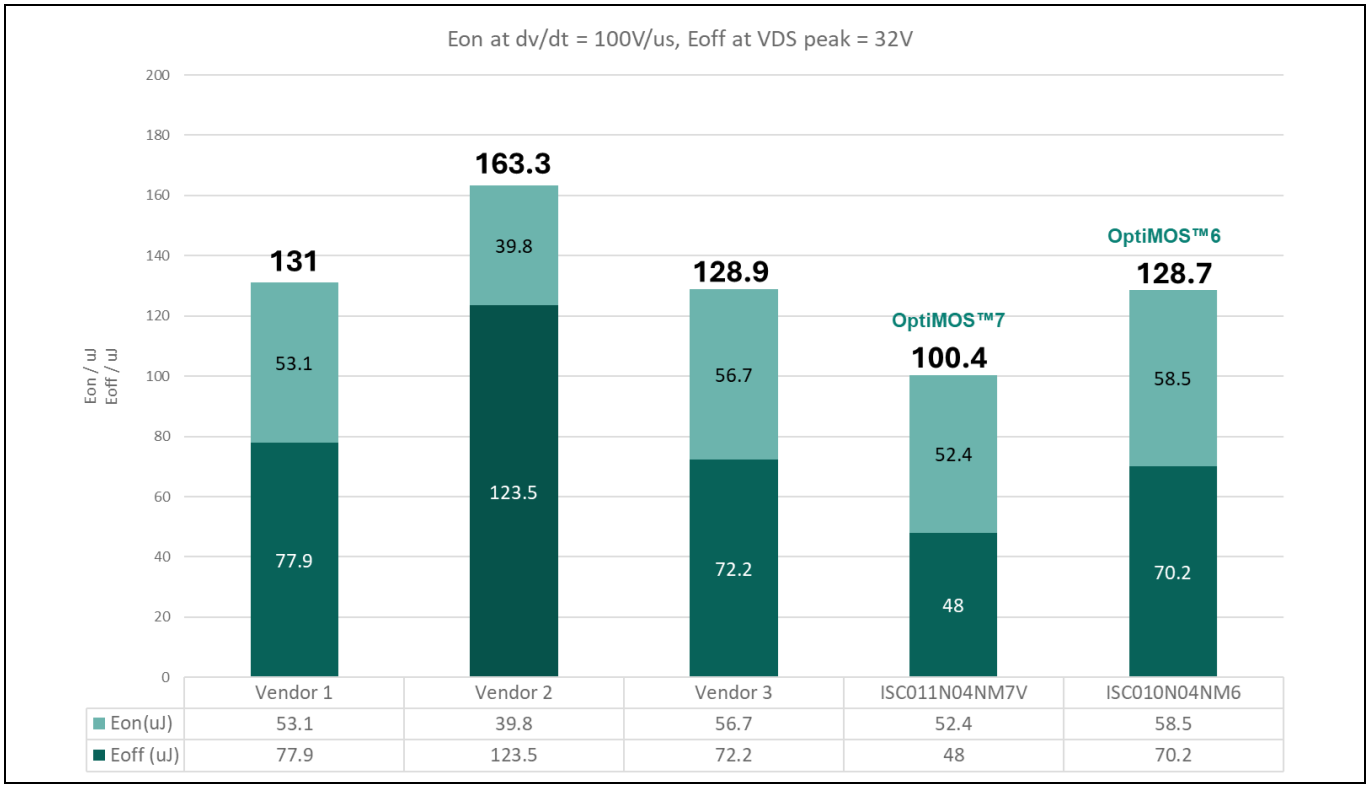

Figure 9 Double-pulse test results, energy losses at V_{DS} peak (turn-off) = 32 V and V_{DS} dv/dt = 100 V/µs

Switching behavior of OptiMOS™ 7 motor-drive-optimized MOSFET

For each test, the turn-off gate resistor values are optimized so that the V_{DS} peak = 32 V (80% of the breakdown voltage), and the turn-on gate resistor are tuned at dV/dt = 100 V/µs.

The double-pulse test results are shown in Figure 9. The switching losses of devices from other vendors are 190.1 µJ, 251.3 µJ, and 159.3 µJ, respectively. The OptiMOS™ 6 ISC010N04NM6 device achieves 128.7 µJ switching losses. OptiMOS™ 7 motor-drive-optimized MOSFET has the lowest switching losses, which is 100.4 µJ.

3 Performance of OptiMOS™ 7 motor-drive-optimized MOSFET in motor drive applications

Motor drive is one of the main target applications of Infineon's OptiMOS™ 7 motor-drive-optimized MOSFET family. The performance of the MOSFET family is evaluated in this section.

The comparison between ISCH54N04NM7V (OptiMOS™ 7 motor-drive-optimized MOSFET) and ISC007N04NM6 (OptiMOS™ 6) is discussed in Section 3.2. Section 3.3 compares ISC011N04NM7V (OptiMOS™ 7 motor-drive-optimized) and devices from other vendors.

3.1 Test setup and conditions

To perform fair tests for comparison, the test setup (in Figure 10) and conditions (in Table 3) remain the same for the tests in Section 3.2 and Section 3.3.

Table 3 Test conditions

Parameter	Symbol	Unit	Value
Input voltage	V_{in}	V	20
Motor speed	-	RPM	2500
Gate voltage	V_{GE}	V	10
Switching frequency	f_{sw}	Hz	20k
Operating time	-	Minutes	12

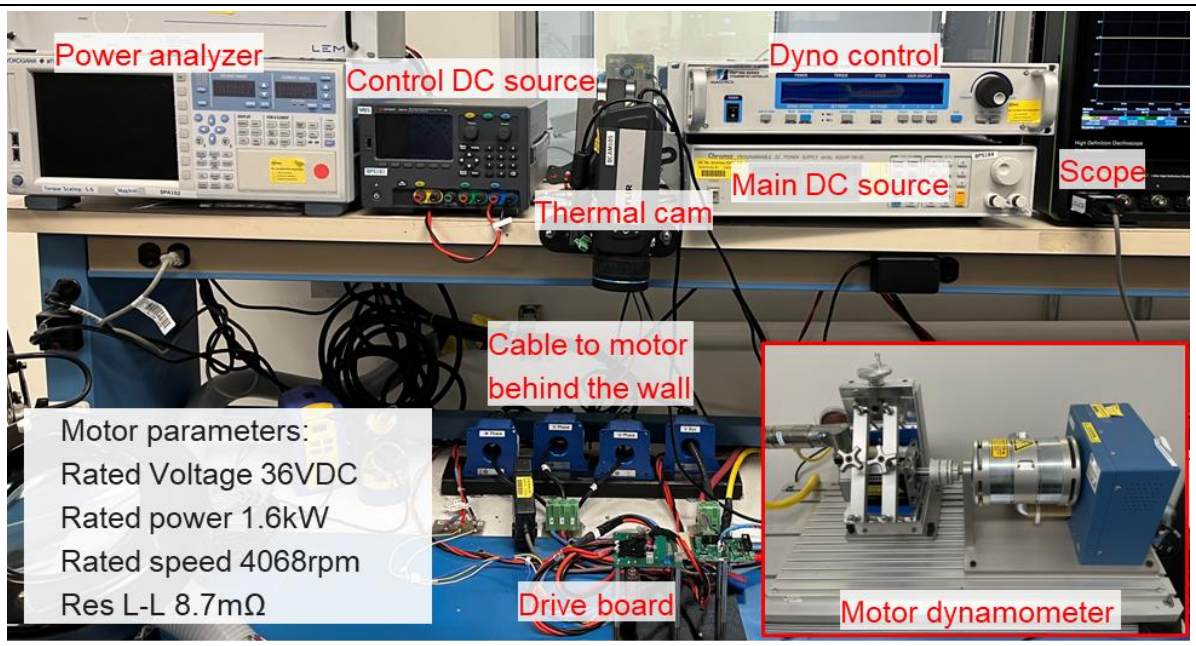

Figure 10 Motor drive test setup

3.2 Motor drive tests: OptiMOS™ 7 motor-drive-optimized MOSFET vs. OptiMOS™ 6

To evaluate the performance improvement of OptiMOS™ 7 motor-drive-optimized MOSFET over OptiMOS™ 6 MOSFET, the best-in-class MOSFETs from each family are selected as the representatives (ISCH54N04NM7V and ISC007N04NM6), respectively.

The test conditions and setup are described in Section 3.1. The specifications of the selected devices are outlined in the following table.

Table 4 Key parameters of the devices under test

Parameter	Symbol	Unit	ISC007N04NM6	ISCH54N04NM7V
Drain-source on-state resistance	$R_{DS(on)-max}$	mΩ	0.7	0.54
Drain-source voltage	$V_{(BR)DSS}$	V	40	40
Gate threshold voltage	$V_{GS\ (th)}$	V	2.3	2.75
Output charge	Q_{OSS}	nC	103	147
Reverse recovery charge	Q_{rr}	nC	182	82
Total gate charge	$Q_{G\ (10V)}$	nC	94	117
Transconductance	g_{fs}	S	310	120

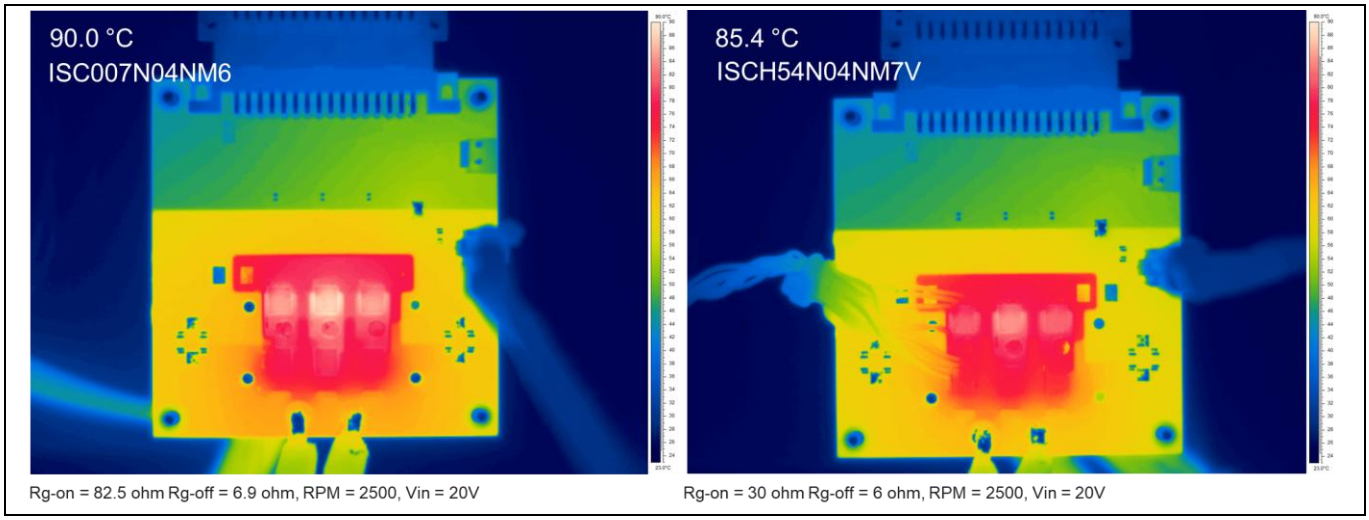

Figure 11 Thermal images of ISC007N04NM6 and ISCH54N04NM7V

The gate resistors are optimized to achieve the fastest switching speed with the V_{DS} overshoot lower than 32 V (80% of the breakdown voltage).

The $R_{g\text{-}on}$ (turn-on gate resistor) for ISCH54N04NM7V is 30 ohm and $R_{g\text{-}off}$ (turn-off gate resistor) is 6 ohm. The $R_{g\text{-}on}$ of ISC007N04NM6 is 82.5 ohm and its $R_{g\text{-}off}$ is 6.9 ohm.

The input power is 600 W. The control method is block commutation.

After 12 minutes of operation, the thermal images are captured and shown in Figure 11. The highest case temperature of ISCH54N04NM7V devices is 85.4°C and is 4.6°C lower compared to ISC007N04NM6.

As a conclusion, OptiMOS™ 7 motor-drive-optimized MOSFETs can achieve lower case temperature compared to OptiMOS™ 6 MOSFETs with similar parameters.

3.3 Motor drive tests: Infineon vs. other vendors

In this section, ISC011N04NM7V is selected as the representative of OptiMOS™ 7 motor-drive-optimized MOSFET to compare with devices from other three vendors. The devices from other vendors have the same market position and similar $R_{DS(on)}$.

The key parameters (in datasheets) of the DUTs are listed in Table 2. The test conditions and setup are described in Section 3.1. For each device, the gate resistors are optimized to achieve the fastest switching speed with the V_{DS} overshoot lower than 32 V (80% of the breakdown voltage). The case temperatures are recorded after operating for 12 minutes.

Figure 12 shows the case temperature vs. input power of DUTs. The results of Infineon's ISC011N04NM7V are shown as green bars. It has the lowest case temperature within all the input power ranges.

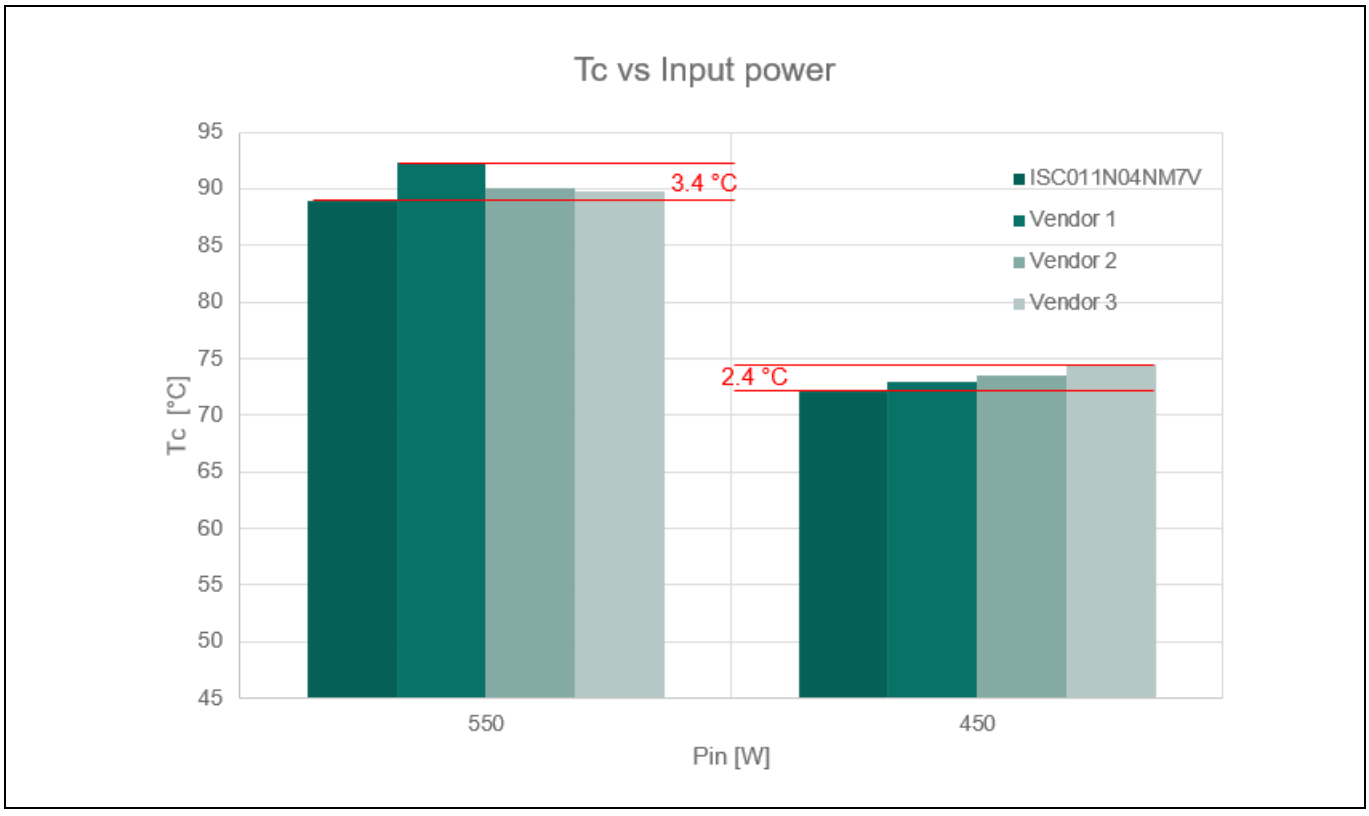

Figure 12 Test results: case temperature (Tc) vs. input power

Performance of OptiMOS™ 7 motor-drive-optimized MOSFET in motor drive applications

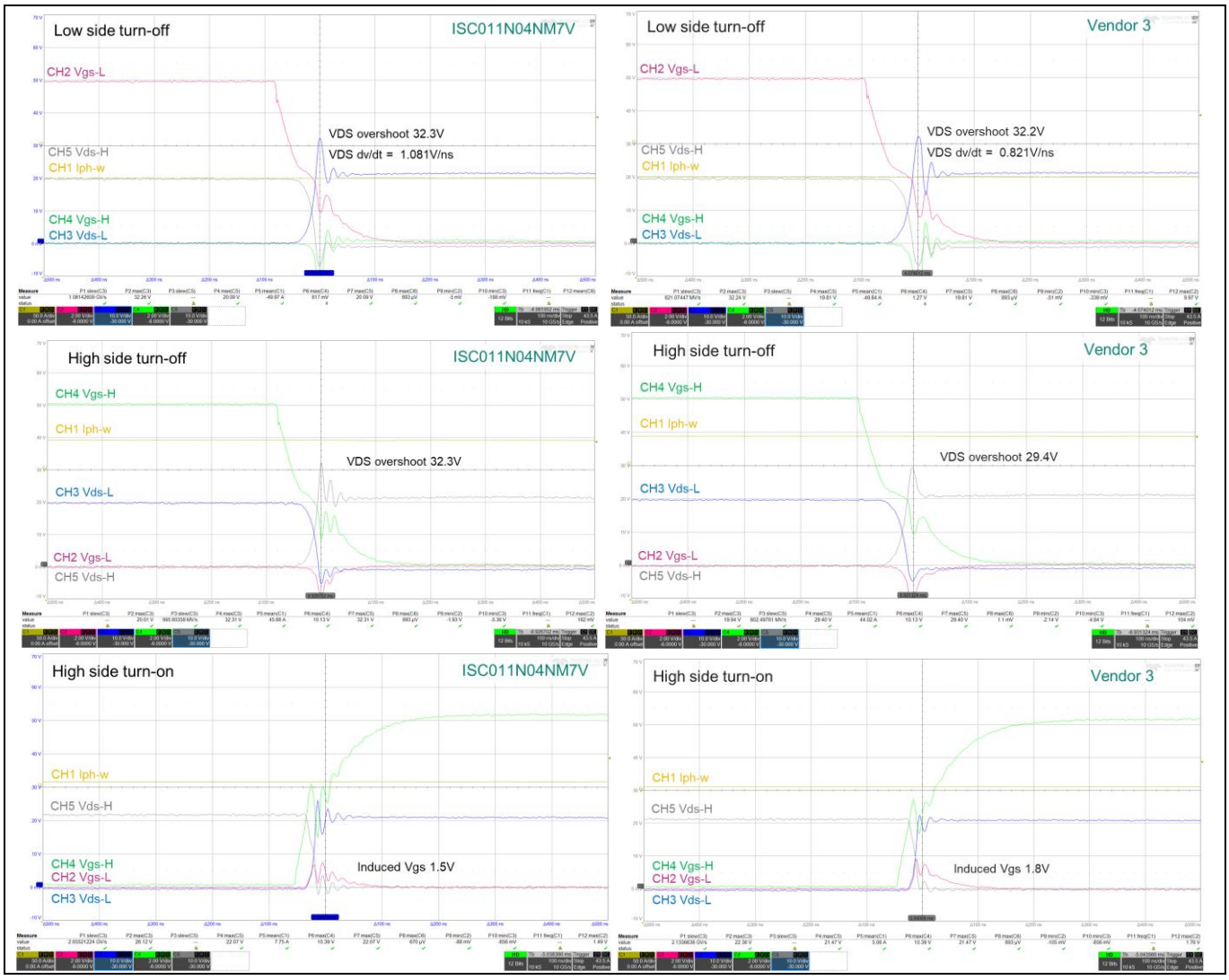

Figure 13 Waveforms – ISC011N04NM7V vs. vendor 3

The switching transient waveforms of ISC011N04NM7V and vendor 3's device are in Figure 13.

Durning the low-side turn-off transient, the V_{DS} slew rate of ISC011N04NM7V is 1.081 V/ns and is 0.260 V/ns faster compared to the vendor 3 device. The V_{DS} overshoots of ISC011N04NM7V and the vendor 3 device are 32.3 V and 32.2 V, respectively.

In conclusion: compared to MOSFETs from other vendors, ISC011N04NM7V has the fastest switching speed with tuned gate resistors, and consequently, its case temperature is the lowest.

4 Conclusion

Infineon's OptiMOS™ 7 motor-drive-optimized MOSFETs are ideally suited for the power and gardening tool applications. The major enhancements of the family are:

- Superior $R_{DS(on)}$
- Improved immunity
- 3x wider safe-operating-area
- Lower switching losses
- Choice of dual-side cooled (DSC) package for lower R_{th} with upcoming DSC portfolio extension

In double-pulse tests, with optimized gate resistance, the OptiMOS™ 7 motor-drive-optimized MOSFET achieves the lowest switching losses compared to the OptiMOS™ 6 MOSFET and three MOSFETs from other vendors.

The performances of OptiMOS™ 7 motor-drive-optimized MOSFETs are the best to that of the OptiMOS™ 6 MOSFET and the three MOSFETs from other vendors in 3-phase motor drive systems.

5 Related resources

Product family: OptiMOS™ 7 40 V motor-drives optimized power MOSFETs

Product datasheet:

- Infineon Technologies AG: *ISCH54N04NM7V datasheet*; Available online
- Infineon Technologies AG: *ISCH69N04NM7V datasheet*; Available online
- Infineon Technologies AG: *ISCH99N04NM7V datasheet*; Available online
- Infineon Technologies AG: *ISC011N04NM7V datasheet*; Available online
- Infineon Technologies AG: *ISC012N04NM7V datasheet*; Available online
- Infineon Technologies AG: *ISC016N04NM7V datasheet*; Available online
- Infineon Technologies AG: *ISZ015N04NM7V datasheet*; Available online

Developer Community: MOSFET (Si/SiC)

References

[1] Infineon Technologies AG: *OptiMOS™ 7* motor-*drives optimized N-channel MOSFET 40 V*; Available online

Revision history

Document revision	Date	Description of changes
V 1.0	2025-06-10	Initial release
V 1.1	2025-11-13	Portfolio update, picture update, and test data update

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Edition 2025-11-13

Published by

Infineon Technologies AG

81726 Munich, Germany

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AN215719

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