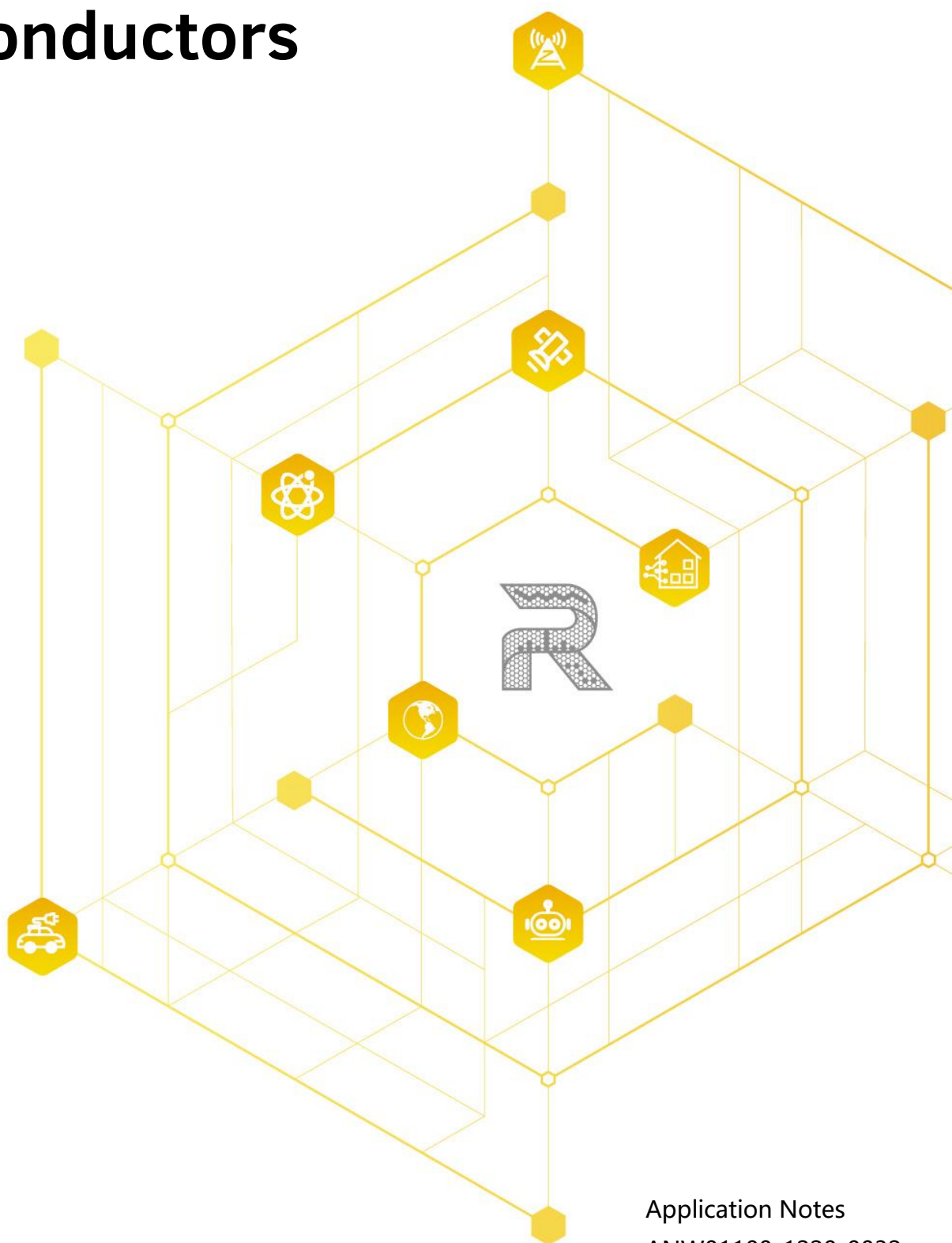




RIGOL

Dynamic Performance Analysis of Power Semiconductors



Introduction

Power converters are important devices for electrical energy utilization, playing a crucial role in production and daily life. The core of power converters is power semiconductor devices, which largely determine the performance of power converters. After decades of development, power semiconductor devices have developed from a few volts to thousands of volts and from a few amperes to thousands of amperes. Common types of power semiconductor devices include MOSFETs, IGBTs, diodes, etc.

Most power devices are based on Si semiconductor materials, whose characteristics have approached the theoretical limit, becoming a bottleneck in the development of power converters. Compared with Si power devices, SiC power devices have higher switching speed and can operate at higher junction temperature, simultaneously achieving the high voltage and the high current. These characteristics can significantly improve the performance of power converters, achieve higher power conversion efficiency, realize higher power density, and reduce system costs. SiC power devices are suitable for applications such as automotive traction inverters, electric vehicle on-board chargers, electric vehicle charging piles, photovoltaics, uninterruptible power supply systems, energy storage, and industrial power supplies. Currently, the SiC industrial chain at home and abroad is gradually maturing. Mainstream power semiconductor device manufacturers have already launched power device products based on SiC with the continuously decreasing costs, and the application of SiC power devices is in explosive growth.

Testing Requirements

Power semiconductor dynamic parameter testing (a complete set of evaluation methods for the switching characteristics of switching tubes, such as double pulse testing, has been developed based on the half-bridge circuit) is a core evaluation tool in the R&D and application of power semiconductors. It not only provides key dynamic parameters but also reveals the latent risks and optimization directions of devices by simulating actual operating conditions. The rapid development and application of third-generation semiconductors represented by SiC and GaN have brought disruptive changes to industries such as new energy vehicles and power supplies, and also pose significant testing challenges to engineers. To ensure that the selected high-speed power devices can operate stably and reliably in their own products, it is necessary to understand the dynamic characteristics of power devices.

2.1 Test Purpose

1. Measure key dynamic parameters. Measure dynamic parameters such as switching losses, switching time, and reverse recovery characteristics to optimize system efficiency, evaluate device response speed, and determine its safety margin during the commutation process.

2. Verify the design of the drive circuit. Evaluate the rationality of the gate drive resistor, optimize the rise/fall slope of the drive signal to reduce switching oscillations, and test the effectiveness of the protection function of the drive chip.
3. Compare the performance of the devices. Perform the test under different voltage, current, and temperature conditions to compare the performance between devices made of different materials (Si IGBT and SiC MOSFET) or from different manufacturers, supporting the device selection decision-making process.
4. Analyze the impact of parasitic parameters.
5. Evaluate the reliability under extreme operating conditions.

2.2 Test Principle

As shown in Figure 1, taking the SiC MOSFET as an example. The double pulse test circuit consists of the bus capacitor C_{Bus} , switch tube Q_L under test, companion diode VD_H , drive circuit, and load inductor L . During the test, sending a double-pulse drive signal to Q_L allows measurement of its switching characteristics under specified voltage and current conditions.

Practical power converters operate in two commutation modes: MOS-diode and MOS-MOS. The pulse test must adopt the same commutation mode and devices as the actual converter. For MOS-MOS mode, replace diode VD_H with SiC MOSFET Q_H and apply the shutdown signal throughout the test.

When testing diode reverse recovery characteristics, the lower switch (Q_L) is the device under test with load inductor L connected in parallel, the upper switch (Q_H) acts as the companion device, performing turn-on and turn-off operations, as shown in Figure 2.

Throughout the test, Q_L undergoes two turn-on and turn-off cycles, forming two pulses. By capturing and retaining its V_{GS} , V_{DS} , and I_{DS} waveforms, dynamic performance during the first turn-off and second turn-on events can be analyzed and evaluated.

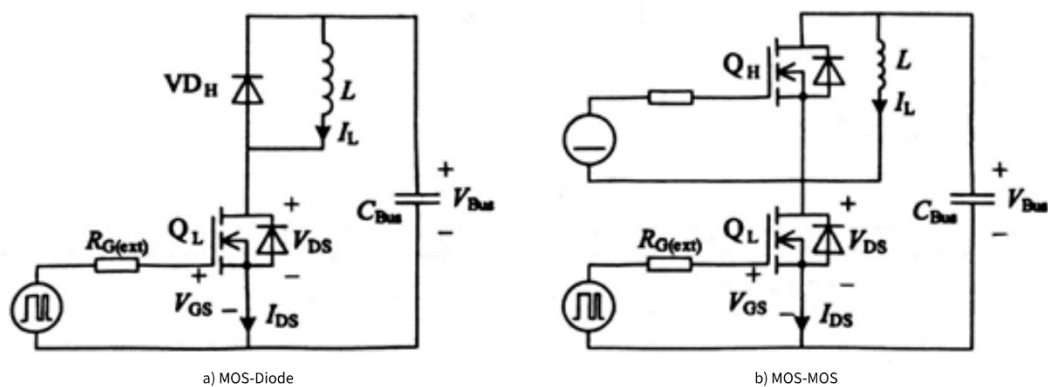


Figure 1 Double-pulse test circuit

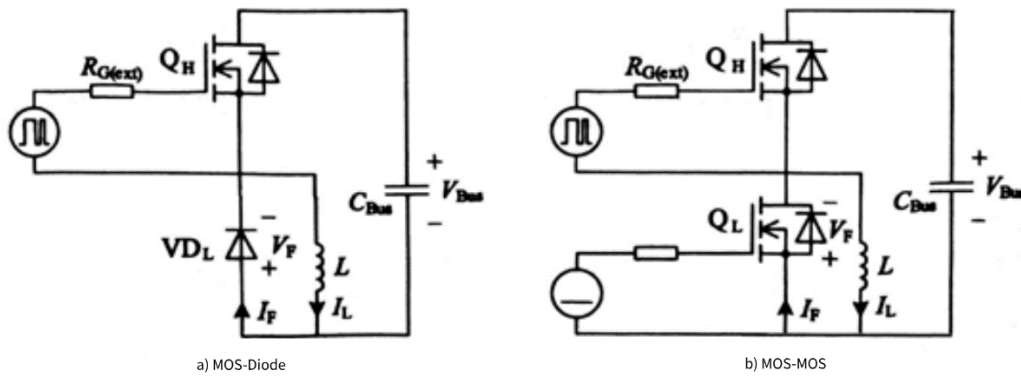


Figure 2 Diode reverse-recovery test circuit

2.3 Typical Application Scenarios

1. Electric Vehicle Drivetrain System: Validate switching losses and thermal stability of IGBT/SiC modules in inverters.
2. Renewable Energy: Test reliability of power devices in PV inverters and Power Conversion System (PCS) under high-frequency switching.
3. Industrial Frequency Converter: Evaluate dynamic response and voltage stress of components in motor drive circuits.
4. Switching Power Supply: Optimize efficiency and EMI characteristics of high-frequency DC-DC converters.

Set up the Test Platform

The test solution for power semiconductors supports single-pulse, double-pulse and multi-pulse measurements, and integrates the oscilloscope, signal generator, low-voltage DC power supply, high-voltage DC power supply, voltage and current probes, and dedicated software. The system can measure turn-off, turn-on and reverse-recovery characteristics, including turn-off delay time, fall time, turn-off time, turn-off energy loss, turn-on delay time, rise time, turn-on time, turn-on energy loss, reverse-recovery time, reverse-recovery current, reverse-recovery charge, reverse-recovery energy, voltage slew rate (dv/dt), current slew rate (di/dt), etc.

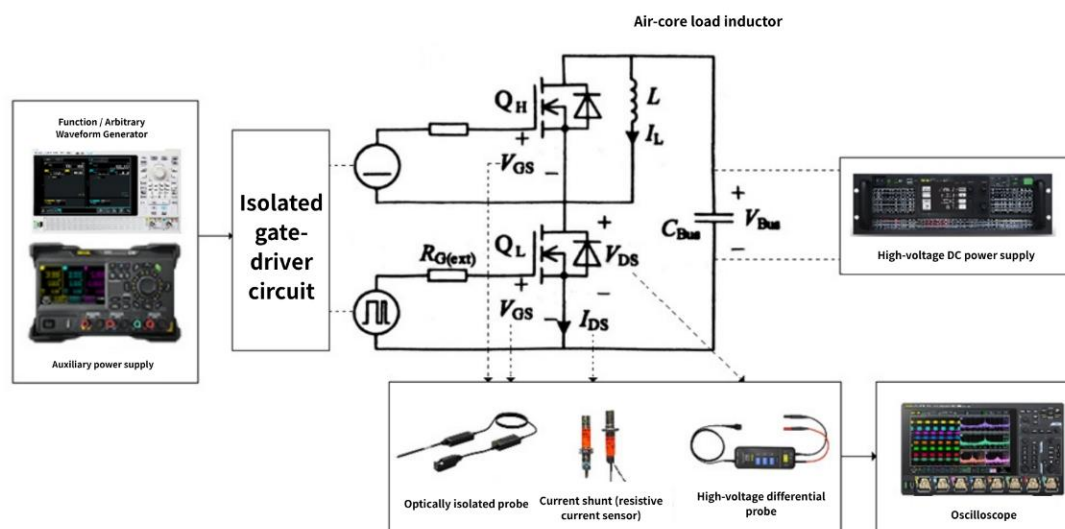


Figure 3 Double-pulse test platform architecture

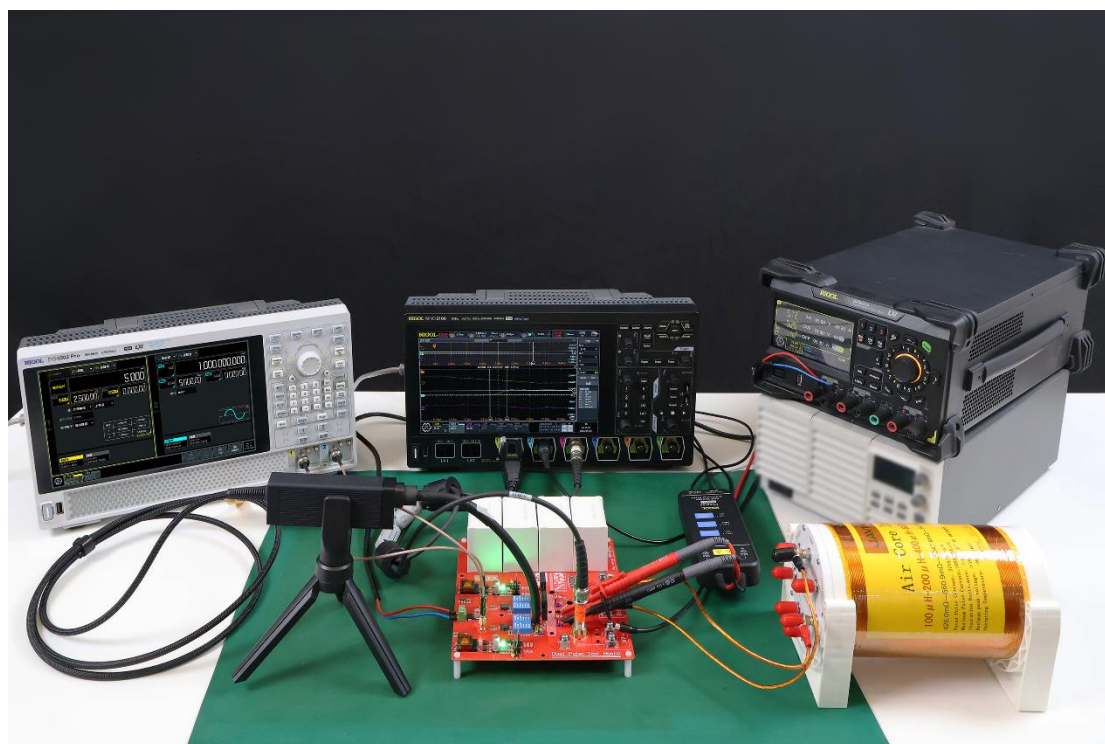


Figure 4 Double-pulse test system

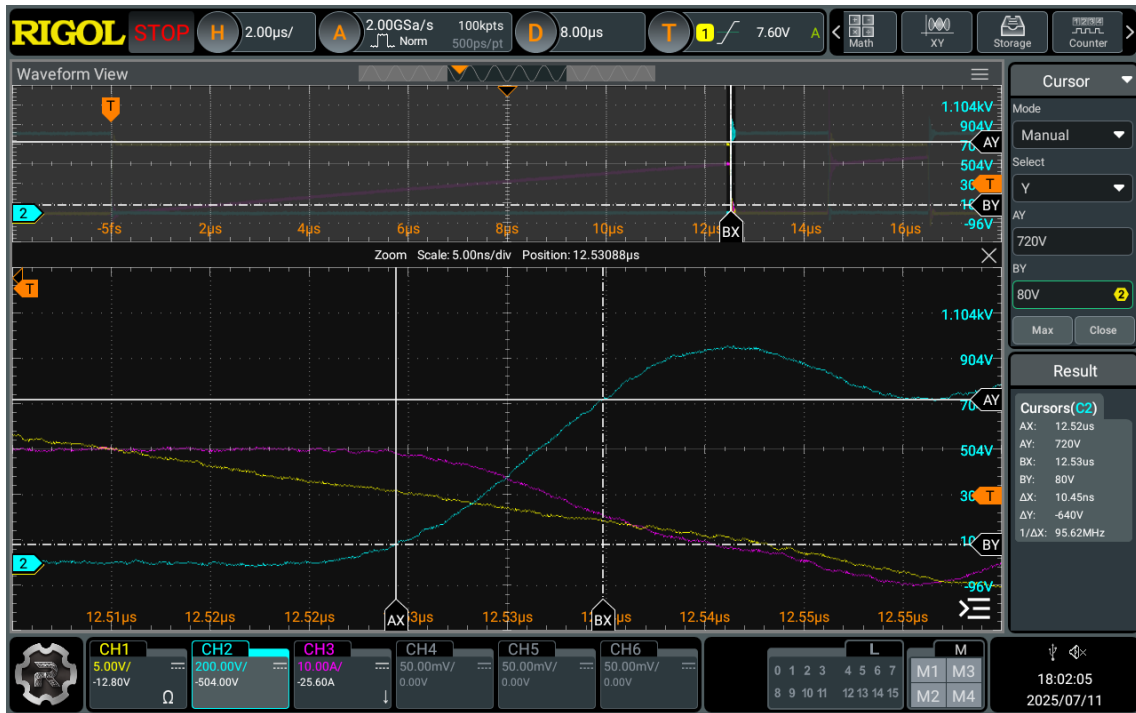


Figure 5 Fall-time test (Toff)



Figure 6 Turn-off energy loss (Eoff)

1. The DG5000 Pro generates the double-pulse drive signal.
2. The optically isolated probe accurately measures the gate voltage (V_{gs}) of the switching device and the gate crosstalk signal on the companion device. It can also be used for gate charge measurement.
3. The MH05106 oscilloscope captures the voltage and current waveforms and performs the required calculations.

Features of the Solution

1. To reliably and repeatedly test the dynamic characteristics of power semiconductors, including IGBT, MOSFET, and third-generation SiC and GaN devices.
2. The measurement parameters include turn-on, turn-off, switching transition, reverse-recovery, gate-drive, switching-loss parameters, etc.
3. Supports customer-defined test fixtures.
4. Paired with RIGOL oscilloscopes and probes, the system precisely compensates probe time delay and applies dedicated switching-loss algorithms to deliver trustworthy results.
5. Features unique optically isolated probes with up to 1 GHz bandwidth and a common-mode rejection ratio of 180 dB, accurately testing the actual situation of the driving signal.

Solution Configuration

Instrument	Key Specifications	Benefits
DHO/MH05000 Oscilloscope	• 6 / 8 channels • 1 GHz bandwidth • 4 GSa/s sample rate • 500 Mpts memory depth	Synchronously captures multiple signals including the switching device's Vgs, Vds, and Id, as well as the companion device's gate crosstalk, Vds, and Id, with support for long-duration waveform recording and high-precision triggering.
PIA1000 Optically-Isolated Probe	• Up to 1 GHz Bandwidth • Up to 180 dB CMRR • Selectable differential-mode voltage ranges, up to ± 2500 V	Removes ground-loop interference and enables accurate floating measurements of small signals such as upper-switch Vgs, upper-switch crosstalk, and gate-drive voltages.
DG5000 Pro Function / Arbitrary Waveform Generator	• Single-channel multi-pulse output with arbitrary pulse width • Dual-channel multi-pulse output with controllable dead-time	Unique, user-friendly UI allows quick generation of multi-pulse signals with any desired pulse width

Boost Smart World and Technology Innovation



5G Cellular-5G/WIFI
UWB/RFID/ ZIGBEE
Digital Bus/Ethernet
Optical Communication

Digital/Analog/RF Chip
Memory and MCU Chip
Third-Generation Semiconductor
Solar Photovoltaic Cells

New Energy Automobile
PV/Inverter
Power Test
Automotive Electronics

*Provide Testing and Measuring Products
and Solutions for Industry Customers*

HEADQUARTER

RIGOL TECHNOLOGIES CO., LTD.
No.8 Keling Road, New District,
Suzhou, JiangSu, P.R.China
Tel: +86-400620002
Email: info-cn@rigol.com

JAPAN

RIGOL JAPAN CO., LTD.
5F, 3-45-6, Minamitsuka, Toshima-Ku,
Tokyo, 170-0005, Japan
Tel: +81-3-6262-8932
Fax: +81-3-6262-8933
Email: info.jp@rigol.com

EUROPE

RIGOL TECHNOLOGIES EU GmbH
Friedrichshafener Str. 5
82205 Gilching
Germany
Tel: +49(0)8105-27292-21
Email: info-europe@rigol.com

KOREA

RIGOL KOREA CO., LTD.
5F, 222, Gonghang-daero,
Gangseo-gu, Seoul, Republic of Korea
Tel: +82-2-6953-4466
Fax: +82-2-6953-4422
Email: info.kr@rigol.com

NORTH AMERICA

RIGOL TECHNOLOGIES, USA INC.
10220 SW Nimbus Ave.
Suite K-7
Portland, OR 97223
Tel: +1-877-4-RIGOL-1
Email: sales@rigol.com

For Assistance in Other Countries

Email: info.int@rigol.com

RIGOL® is the trademark of **RIGOL TECHNOLOGIES CO., LTD.** Product information in this document is subject to update without notice. For the latest information about **RIGOL's** products, applications and services, please contact local **RIGOL** channel partners or access **RIGOL** official website: **www.rigol.com**