Testing of Power Electronic Devices

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SIGLENT® 鼎阳

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1 Overview

Power electronics testing covers a broad range of applications, from small power converters used in personal computers to large-scale generation/transmission systems. Because power electronic devices are essential to these functions, it is important to have power-electronic circuitry that is both robust and reliable. Key electronic and electrical components include resistors, inductors, semiconductor devices (such as diodes, thyristors, MOSFETs, IGBTs, etc.), capacitors, and various other elements. These find corresponding applications in R&D design, production, fault diagnosis and maintenance, education, and training. This article will introduce how to use oscilloscopes to test power-electronics educational projects.

2Significance

In power electronics testing and design, certain issues often arise at the circuit test points. To improve the operational efficiency of components, engineers employ various methods for testing and verification. Using oscilloscopes for power electronics testing is of great significance, mainly reflected in the following aspects:

Accurate Capture of Dynamic Processes: Oscilloscopes can capture transient changes in signals such as voltage and current in power electronic circuits in real time, providing engineers with detailed dynamic-process information. This helps deepen the understanding of circuit operating principles and performance characteristics.

Efficient Fault Diagnosis: By comparing normal and abnormal waveforms, oscilloscopes assist engineers in quickly locating fault points in power electronic systems, improving the accuracy and efficiency of fault diagnosis.

Optimized Design and Debugging: The data support provided by oscilloscopes enables engineers to optimize the design and debugging processes of power electronic systems, enhancing overall system performance and stability.

Support for Teaching and Research: Oscilloscopes also play an important role in power electronics education and research. They help students and researchers intuitively understand power-electronic phenomena, promoting knowledge dissemination and innovation.

3 Solution

1.1 Testing of Simple Power Electronic Devices

In power electronics education experiments, components such as Unijunction Transistors (UJTs), switching DC-DC converters, and AC voltage regulators require testing with an oscilloscope. Observing the voltage and current waveform shapes, phase differences, amplitudes, and other parameters under different test conditions, and analyzing the waveforms, helps students understand the working principles of power electronic equipment.

When using an oscilloscope, a 2-channel oscilloscope can simultaneously display the signal waveforms from two test points. By connecting probes to the synchronization voltage and the test point voltage, and enabling measurement items, specific numerical values of the items under test can be quickly read.

Figure 1: Testing Two Signals with an Oscilloscope

Additionally, Siglent oscilloscopes feature a Save to Memory Waveform function. This allows storing the waveform information from the current test into memory. After adjusting parameters of other components and inputting the new waveform information into a channel, the previous waveform can be recalled, enabling a detailed comparison between the two.

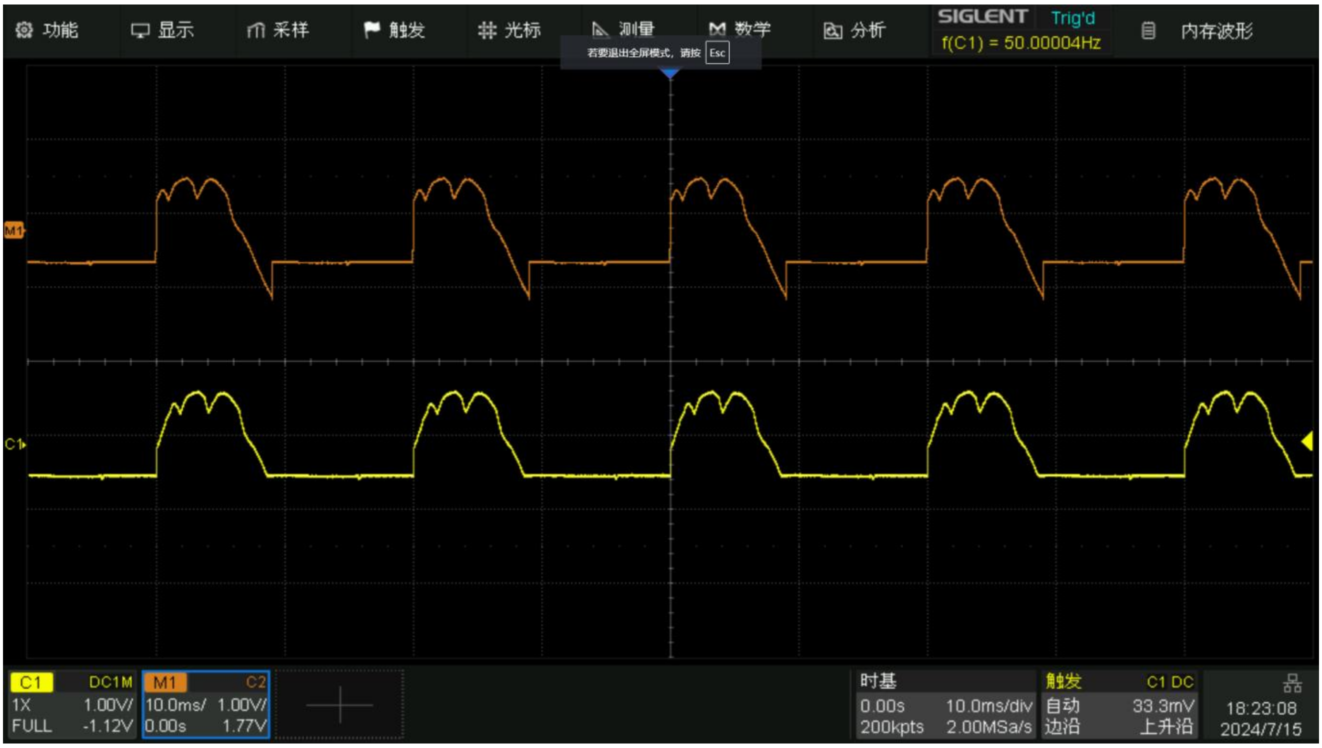

Figure 2: Using the Memory Function to Compare Test Point Waveforms at Different Phases

Furthermore, SIGLENT oscilloscopes offer an X-Y display mode for component testing, such as plotting the I-V characteristic curve of a diode. It can also be used to draw Lissajous figures for clear observation of phase difference and frequency ratio between two signals, or to directly measure the voltage transfer characteristic of an integrated operational amplifier. The multiple functions and operations of the oscilloscope can meet the needs of your power electronics education and testing experiments.

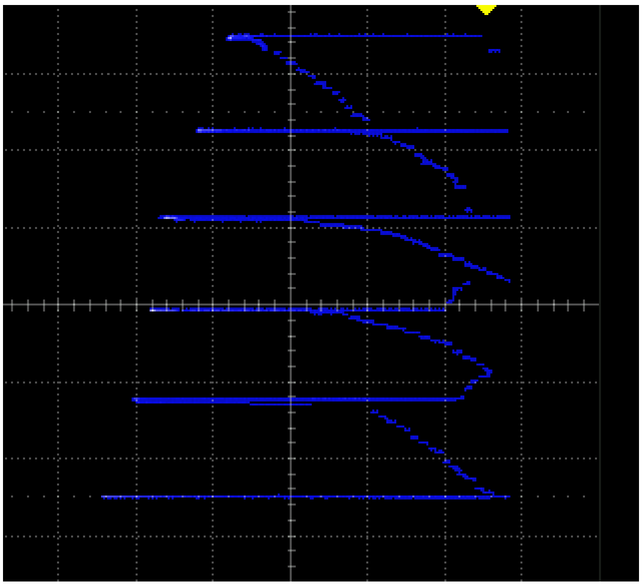

Figure 3: Testing the Voltage Transfer Characteristic of a Transistor in X-Y Mode

1.2 Simulation of PWM Signals

In power electronics technology, Pulse Width Modulation (PWM) control utilizes switching devices that are periodically turned on and off to control the average voltage or current in a circuit. This control method is commonly used to regulate AC power to DC loads or DC power to AC loads. PWM control varies the conduction time (pulse width) of the switching devices to control their average on-time, thereby regulating the output voltage or current. PWM control is characterized by high efficiency and precision. By adjusting the pulse density, i.e., the duty cycle (the ratio of high-level time to the period), the conduction time of the switching devices can be changed, consequently controlling the magnitude of the output voltage or current. PWM control is widely applied in power electronics fields such as variable-frequency speed control, power converters, inverters, and power supply management, offering flexibility and high efficiency for circuit design.

Using an Arbitrary Waveform Generator (AWG) to simulate the generation of PWM waveforms allows for a more intuitive observation of PWM modulation characteristics. The modulation function within an AWG can output user-defined PWM signals. Selecting a sine wave as the modulation signal causes the pulse width to vary in the form of a sine wave. Setting the duty cycle deviation controls the maximum extent of variation in pulse width.

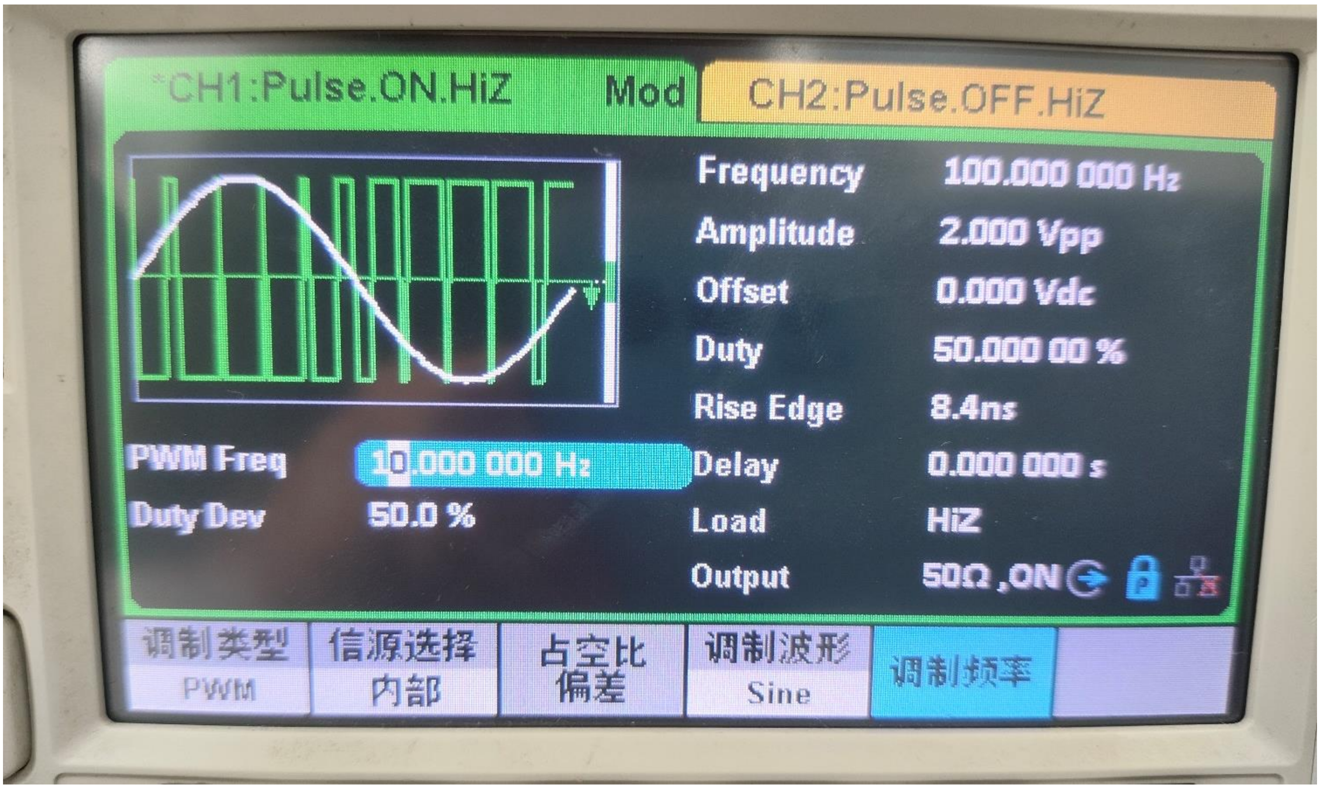

Figure 4: Setting PWM Modulation Signal with SDG2082X

Inputting the PWM signal from the signal source into the oscilloscope displays the shape of the modulated waveform.

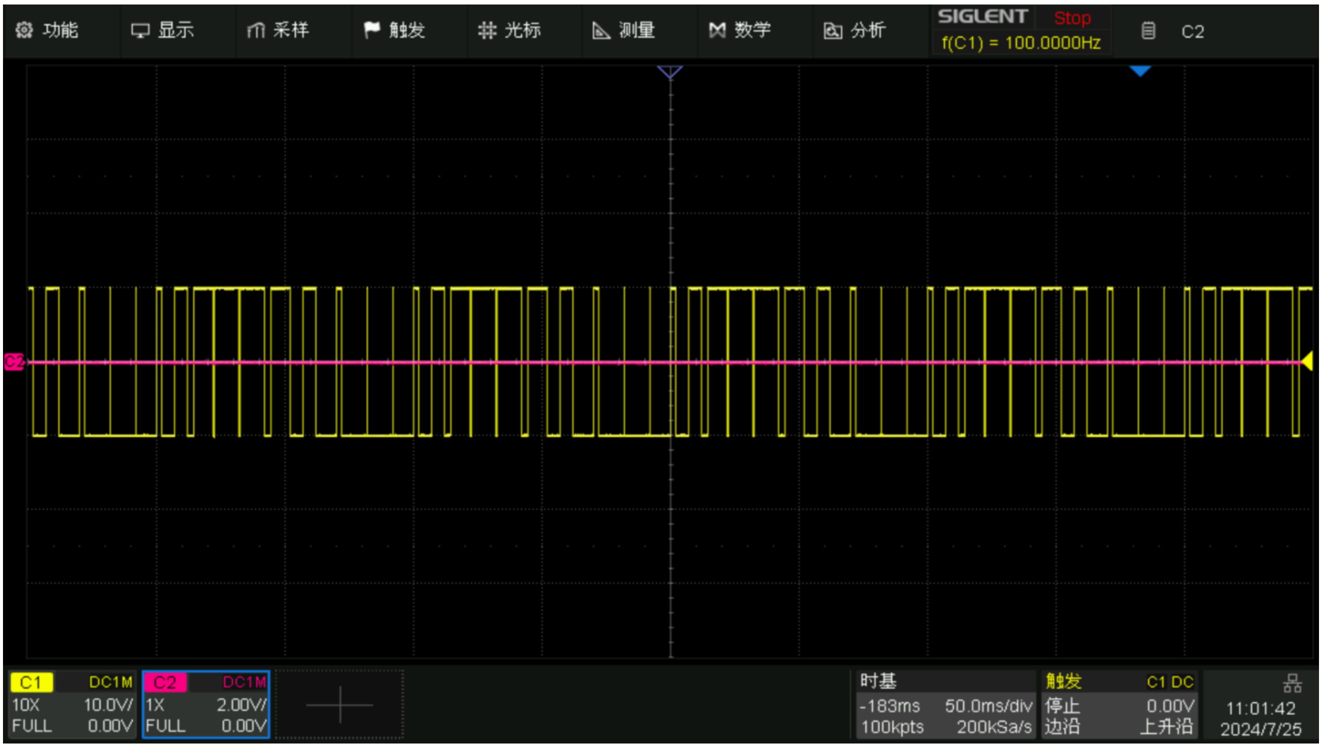

图 5：用示波器观察 PWM 调制信号

1.3 Bode Plot Testing

The Bode plot function of an oscilloscope can be used to test the frequency response and transmission characteristics of power electronic devices. By observing the device's response at different frequencies, its operating range, frequency distortion, filtering effectiveness, and other performance aspects (e.g., for inverters, converters, inductors, and capacitors) can be evaluated. In an oscilloscope, the Bode plot function measures the amplitude and phase of input and output signals, plotting the frequency response curve of the circuit or system across different frequencies. This helps engineers understand the gain, phase, and other characteristics of the circuit or system at various frequencies, aiding in analysis and design.

To use the Bode plot function on an oscilloscope, it needs to be paired with a signal source such as the SAG1021I or an SDG series generator. The following example demonstrates using an oscilloscope to test the frequency response of a 22 MHz low-pass filter. A 2V voltage signal is input into the 22 MHz low-pass filter. The two output signals from the low-pass filter are connected to two channels of the oscilloscope, and the Bode plot test is initiated. The test shows that the frequency at which the gain is -3 dB relative to the highest gain point (UF) is 22 MHz, visualizing the frequency response curve of the low-pass filter.

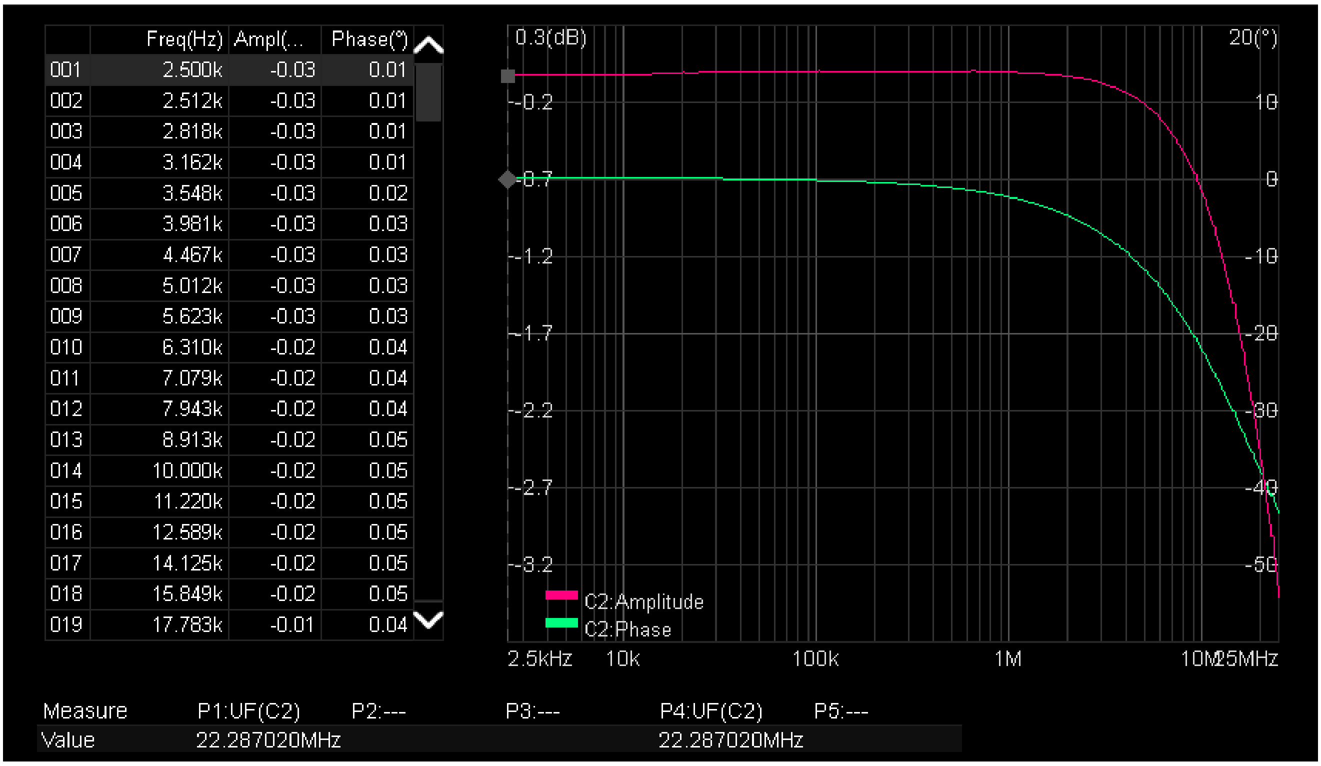

Figure 6: Testing the Frequency Response of a Low-Pass Filter Using the Oscilloscope's Bode Plot Function

1.4 Switching Loss Testing

Power electronics testing faces challenges such as improving efficiency and performance requirements, while also meeting reliability standards, achieving higher power density, and reducing costs. Increasing the switching speed of power switching components can lead to higher switching losses and potentially reduce the output power of converters. To optimize circuit efficiency and performance, oscilloscopes are often chosen for analysis during the research and verification testing phases. The following introduces using the oscilloscope's power analysis option for switching loss testing.

Before performing switching loss tests on an oscilloscope, time delay calibration is required. After configuring the parameters for each channel and connecting the test points according to the connection guide, the test can be initiated. The oscilloscope automatically analyzes and displays test items such as power loss and energy loss.

4 Summary

Siglent provides corresponding solutions for power electronics education testing. Using a basic oscilloscope model like the SDS800X HD, input waveforms can be debugged, and basic electronic components can be verified and tested. This enables waveform display and measurement for multiple test points. The SDG2000X signal generator enables the output of various waveforms including PWM. When paired with a signal source, frequency response testing can be achieved. Additionally, pairing with high-voltage and current probes enables power analysis testing.

关于鼎阳

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