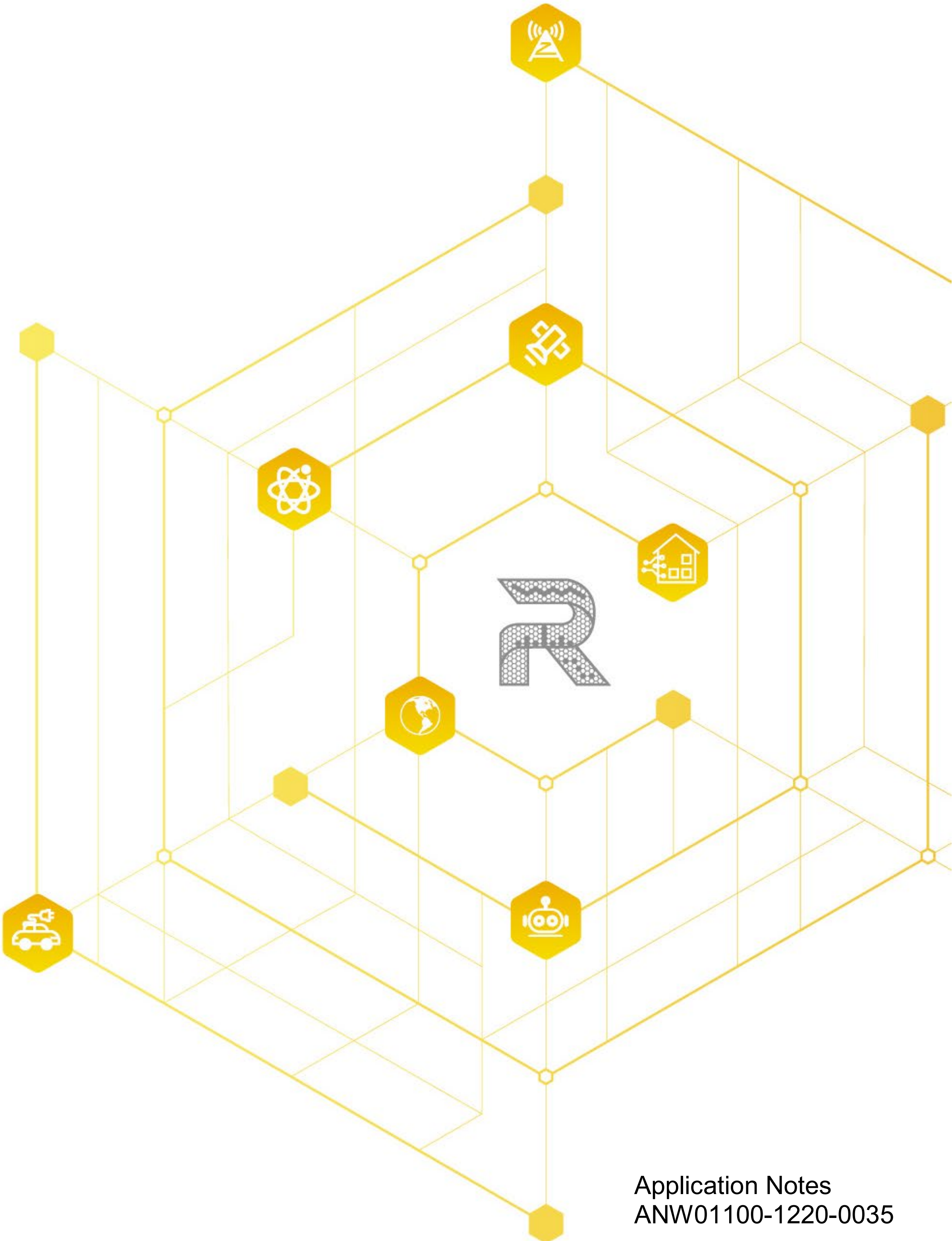
Power Analysis Application Note



Application Notes
ANW01100-1220-0035

1. Document Description

This guide will introduce the power analysis from the following parts:

- Introduction to safety precautions.
- Concepts of power quality, power conversion efficiency, power supply output voltage ripple, etc.
- Test methods for power quality, power conversion efficiency, power supply output voltage ripple, etc.
- Requirements for completing tests.

2. Safety Requirements

Power testing, especially at the AC mains input, involves high voltages and poses an extremely high risk. To ensure safe measurement, you must carefully read and understand the following safety precautions before proceeding:

1. Use a high-voltage differential probe when measuring non-isolated AC mains.
2. Never use a single-ended probe for mains measurements. Connecting its ground lead can create a short circuit, leading to severe equipment damage, and risk of electric shock or personal injury.
3. Ensure all equipment is properly grounded before operation.
4. Wear appropriate Personal Protective Equipment (PPE), such as insulated gloves.

Please read the specific safety precautions for using oscilloscopes and probes below.

2.1 Safety Precautions for Probe

Read the following safety precautions before using probes to avoid personal injury and to prevent damage to this product or any equipment connected to this product. To prevent possible hazards, be sure to use this product in accordance with the regulations.

- Connect or Disconnect the Equipment Properly.

Connect the probe output terminal to the measuring instrument before the probe is connected to the circuit under test. Disconnect the probe input terminal from the circuit under test before disconnecting the probe from the instrument.

- Observe All Terminal Ratings.

To avoid fire or electric shock, please observe all ratings and markings on the product. Before making any connections to the product, consult the User Guide of the product for more details about ratings.

- Use the Product only in Specified Measurement Category.

The probe only applies to circuits not directly connected to the mains (CAT I). It is not applicable to CAT II, CAT III, or CAT IV measurement.

- Check the Equipment Status Periodically.

Check the physical status of the probe and its accessories, including the cables, interfaces, or any visible damage or wear. Do not use the probe with damaged, cracked, or defective cable. Stop using it with suspected failures.

- Do Not Operate with Suspected Failures.

If you suspect that there is damage to the product, have it inspected by RIGOL authorized personnel before further operations. Any maintenance, adjustment or replacement especially to circuits or accessories must be performed by RIGOL authorized personnel.

- Avoid Exposed Circuitry.

Do not touch exposed circuits and components after the power is connected.

- ESD Protection.

Electrostatic Discharge (ESD) may cause damage to the instrument. Therefore, perform tests in an ESD Protected Area (EPA) whenever possible. Before connecting a cable to the instrument, briefly ground its inner and outer conductors to release static electricity.

- Do Not Operate in Wet Conditions.

For indoor use only. To avoid short circuit inside the instrument or electric shock, never use the product in a humid environment.

- Do Not Operate in an Explosive Atmosphere.

To avoid personal injuries or damage to the instrument, never operate the instrument in an explosive atmosphere.

- Keep Product Surfaces Dry and Clean.

2.2 Safety Precautions for Oscilloscope

Please review the following safety precautions carefully before putting the instrument into operation so as to avoid any personal injury or damage to the instrument and any product connected to it. To prevent potential hazards, please follow the instructions specified in this manual to use the instrument properly.

- Use Proper Power Cord.

Only the exclusive power cord designed for the instrument and authorized for use within the local country could be used.

- Ground the Instrument.

The instrument is grounded through the Protective Earth lead of the power cord. To avoid electric shock, it is essential to connect the earth terminal of the power cord to the Protective Earth terminal before connecting any inputs or outputs.

- Connect the Probe Correctly.

If a probe is used, the probe ground lead must be connected to earth ground. Do not connect the ground lead to high voltage. Improper way of connection could result in dangerous voltages being present on the connectors, controls or other surfaces of the oscilloscope and probes, which will cause potential hazards for operators.

- Observe All Terminal Ratings.

To avoid fire or shock hazard, observe all ratings and markers on the instrument and check your manual for more information about ratings before connecting the instrument.

- Use Proper Overvoltage Protection.

Ensure that no overvoltage (such as that caused by a bolt of lightning) can reach the product. Otherwise, the operator might be exposed to the danger of an electric shock.

- Do Not Operate Without Covers.

Do not operate the instrument with covers or panels removed.

- Do Not Insert Objects into the Air Outlet.

Do not insert anything into the holes of the fan to avoid damaging the instrument.

- Use Proper Fuse.

Please use the specified fuses.

- Avoid Circuit or Wire Exposure.

Do not touch exposed junctions and components when the unit is powered on.

- Do Not Operate with Suspected Failures.

If you suspect damage occurs to the instrument, have it inspected by RIGOL authorized personnel before further operations. Any maintenance, adjustment or replacement especially to circuits or accessories must be performed by RIGOL authorized personnel.

- Provide Adequate Ventilation.

Inadequate ventilation may cause an increase of temperature in the instrument, which would cause damage to the instrument. So please keep the instrument well ventilated and inspect the air outlet and the fan regularly.

- Do Not Operate in Wet Conditions.

To avoid short circuit inside the instrument or electric shock, never operate the instrument in a humid environment.

- Do Not Operate in an Explosive Atmosphere.

To avoid personal injuries or damage to the instrument, never operate the instrument in an explosive atmosphere.

- Keep Instrument Surfaces Clean and Dry.

To avoid dust or moisture from affecting the performance of the instrument, keep the surfaces of the instrument clean and dry.

- Prevent Electrostatic Impact.

Operate the instrument in an electrostatic discharge protective environment to avoid damage induced by static discharges. Always ground both the internal and external conductors of cables to release static before making connections.

- Use the Battery Properly.

Do not expose the battery (if available) to high temperature or fire. Keep it out of the reach of children. Improper change of a battery (lithium battery) may cause an explosion. Use the RIGOL specified battery only.

- Handle with Caution.

Please handle with care during transportation to avoid damage to keys, knobs, interfaces, and other parts on the panels.

WARNING

Equipment meeting Class A requirements may not offer adequate protection to broadcast services within residential environment.

3. Introduction to Power Analysis

With the growing demand for efficient, safe, and stable power supplies in electronic products, testing power supply performance has become crucial. The power analysis function of an oscilloscope helps engineers quickly measure and analyze power-related parameters (such as switching loss, efficiency, ripple, etc.), thereby improving test efficiency and optimizing power supply design. This guide will introduce how to use an oscilloscope to complete the power analysis test.

The power analysis test of the oscilloscope can achieve the following goals:

- Evaluate power quality, including the stability and ripple level of the output voltage/current.
- Check harmonics, modulation, and dynamic transient response to analyze the power supply's performance under various operating conditions.
- Measure switching loss, slew rate, and power efficiency to optimize energy efficiency and thermal management.
- Verify the Safe Operating Area (SOA) of switching devices and monitor turn-on/turn-off and inrush current to enhance the system safety and reliability.
- Perform deskew calibration to ensure all measurement data is accurate and reliable.

4. Introduction to the Power Analysis Software Function

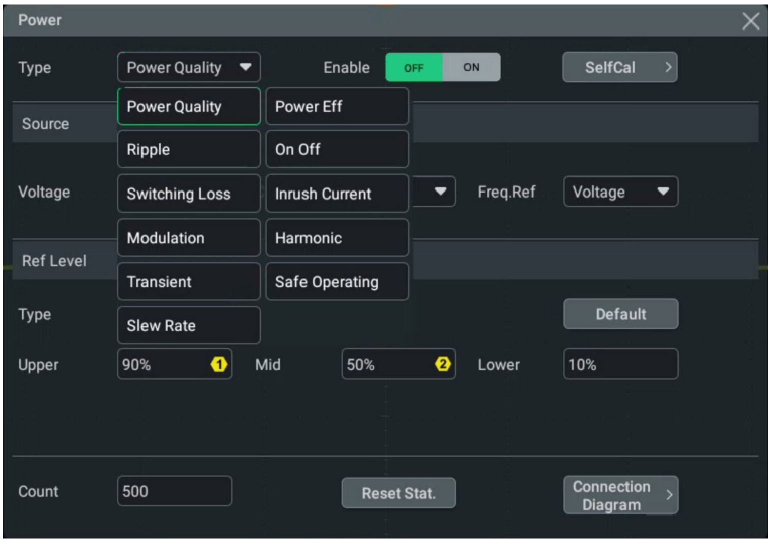
RIGOL MHO/DHO5000 series oscilloscope provides the optional power analysis function, which enables users to efficiently analyze key indicators of switching power supplies, such as efficiency and reliability. The power analysis function supports various measurement and analysis items, such as power quality, ripple, switching loss, modulation analysis, transient response, slew rate, power efficiency, turn-on/off, inrush current, harmonic analysis, and Safe Operating Area (SOA) test.

To ensure the smooth test of the above items, the oscilloscope provides connection diagrams for each test and displays complete measurement results, helping users perform power analysis tests quickly and correctly.

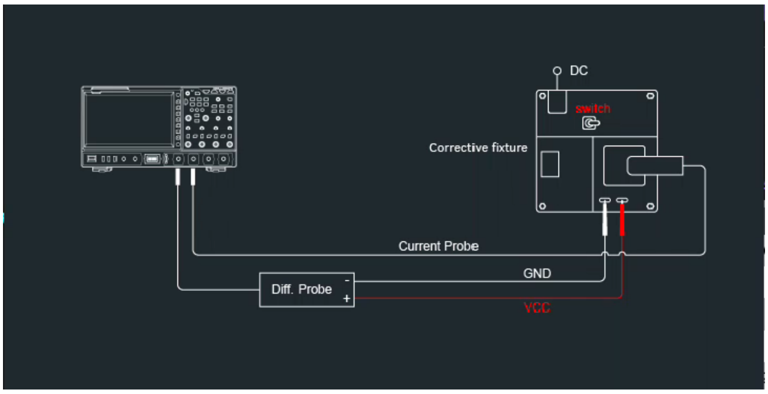
4.1 Introduction to Working Principle

The power analysis function automatically performs delay deskew and offset calibration by synchronously acquiring voltage and current signals at key points. With the built-in algorithms, the oscilloscope analyzes these signals and automatically calculates key metrics such as ripple, harmonics, loss, efficiency, and more. These measurement results are then displayed intuitively through graphs or numerical values, helping users quickly identify and locate issues in the power supply design.

4.2 Function Configuration



4.3 Test Connection Diagram



4.4 Test Results

5. Pre-test Preparation

5.1 Probe Selection

The high-voltage differential probe is required as the voltage probe for power quality testing. Single-ended probes must not be used for this measurement. As the AC neutral conductor forms the current loop with the load and the line conductor, and the oscilloscope probe's ground lead is hard-wired to earth ground, using a single-ended probe on the mains effectively shorts the neutral to earth. This raises common-mode interference and can create a direct short circuit, potentially damaging the equipment.

5.2 Probe Degauss and Zero

Current probes need to be degaussed and zeroed to avoid the influence of initial value errors on the actual current measurement results.
Operation Steps:

1. Warm up the probe

   Turn on the oscilloscope and the current probe, and warm up the probe for 15 minutes.
2. Connect the probe

   Connect the current probe to the oscilloscope and keep the probe jaw open (not clamped the conductor).
3. Degauss

   Press the "DEGAUSS" or "DEMAG" button on the probe and wait for the indicator light or degaussing progress to finish.
4. Zero

   Press the "ZERO" button to verify that the reading on the oscilloscope is approximately zero.
5. Start Measurement

   Clamp the probe around the conductor under test to begin the current measurement.

5.3 Probe Deskew

Perform deskew calibration on the current probe and voltage probe before the measurement to eliminate propagation errors between them. Due to different internal transmission paths in voltage and current probes, nanosecond-level timing differences can occur. In power measurements, this small delay causes significant errors in instantaneous power (V×I) calculations, particularly when analyzing switching losses. Therefore, precise calibration is essential.
Operation Steps:

1. Prepare probes

   Connect the current probe and voltage probe to the designated oscilloscope channels respectively, and complete the following preparation procedures for each:

For the current probe:

• Degauss: Press the “Degauss” button on the probe to erase any residual magnetism in the core caused by Earth magnetic field or previous measurements. Degauss is essential for accurate DC and low-frequency AC measurements.
• Zero: After the probe has been fully warmed up for 15–20 minutes as recommended and with no conductor clamped, press the “Zero” button to compensate for DC offset in the probe's internal circuitry, ensuring zero reading when no current is present.
• Set Units and Ratio: In the oscilloscope’s corresponding channel menu, set the probe units to amperes (A) and select the correct conversion ratio (e.g., 100 mV/A or 10 mV/A).

For the voltage probe:

• Probe Compensation: Connect the probe to the compensation signal output terminal on the front-panel of the oscilloscope and view the waveform on the display. Adjust the low-frequency compensation capacitor on the probe until the top of the displayed square wave is perfectly flat, with no overshoot (spikes) or rolloff (rounding). This step is critical to ensuring a consistent frequency response across the probe's full bandwidth.
• Set Attenuation Ratio: In the corresponding oscilloscope channel menu, set the voltage attenuation ratio to match the probe’s selected range (e.g., 10:1 or 1:1).

2. Connect to calibration source

   Connect both the current and voltage probes to the same standard calibration signal source (such as the deskew signal output port provided with the oscilloscope, or by measuring the same square wave signal through a short wire with both probes).
3. Observe waveforms

   Observe the current and voltage waveforms on the oscilloscope. Adjust the time base to ensure the edges of both waveforms (e.g., the rising edges) are aligned.
4. Adjust delay

   Enter the oscilloscope's probe setup menu, click or tap the "Deskew" or "Delay Calibration" to fine-tune the delay for the current probe (or voltage probe) channel until the corresponding edges of the two waveforms overlap.
5. Complete calibration

   Save the settings and the deskew calibration is complete. Now you can proceed with high-precision measurements such as power and switching loss.

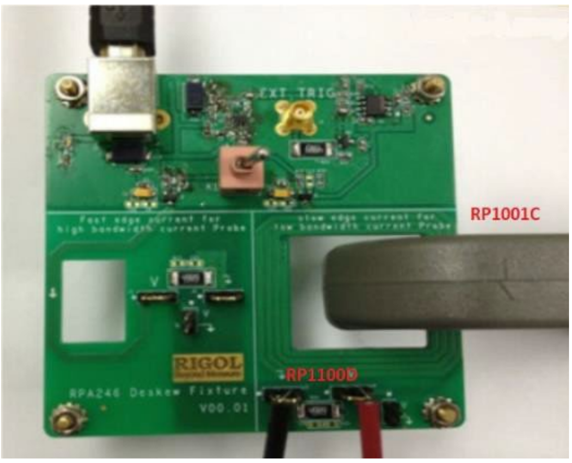
5.4 Set the Probe Attenuation Ratio

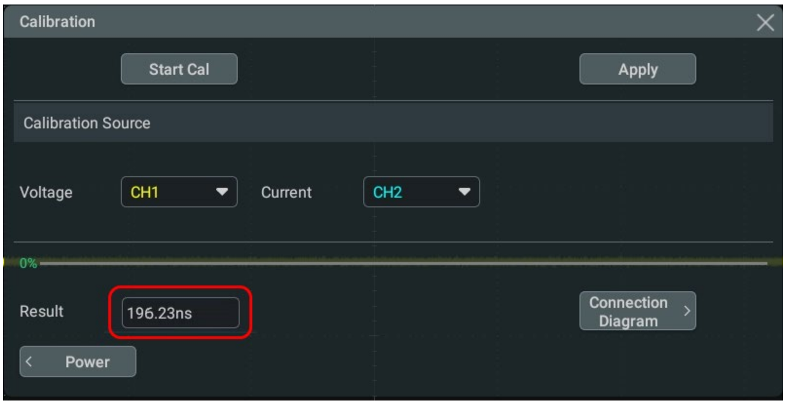
The RIGOL PHA2150 voltage probe provides two probe attenuation ratios: 50X and 500X. You can press the probe switch to select the probe ratio either the 50:1 or 500:1. The detailed choice depends on the oscilloscope's maximum input voltage and the input voltage being measured.
When using the probe, configure the oscilloscope channel's probe ratio to match the physical attenuation setting (50X or 500X) on the probe, ensuring the displayed voltage is the actual voltage.

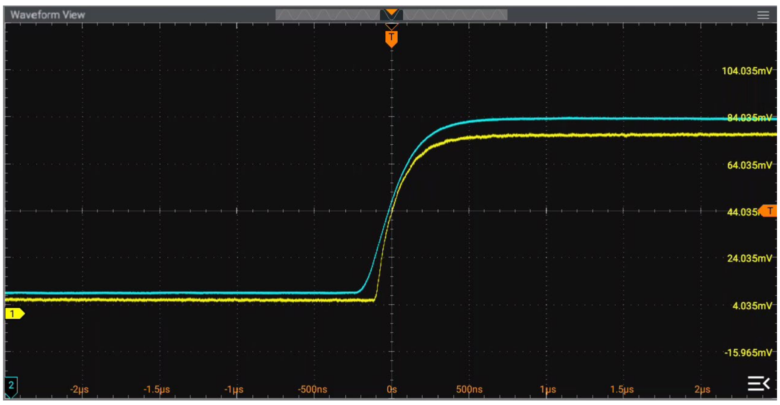
5.5 Channel Deskew

Perform channel deskew before testing the voltage and current of a power supply.
Operation Steps:

1. Press the front-panel Acquire key to enter the Acquisition menu, set the acquisition mode to Average, and set the number of averages to 16.
2. Press the front-panel Auto key to display the waveform on the screen.
3. Click or tap the function navigation icon at the lower-left screen and select UPA to enter the power menu. Click or tap the SelfCal button.
4. In the displayed calibration source menu, select the corresponding voltage and current channels.
5. Click or tap the Start Cal button.
6. Wait for the progress bar to complete to acquire the calibration result.
7. If the result is normal, click or tap the Apply button to apply the correction result. Otherwise, return to Step 3.







Channel Deskew

6. Typical Application Tests

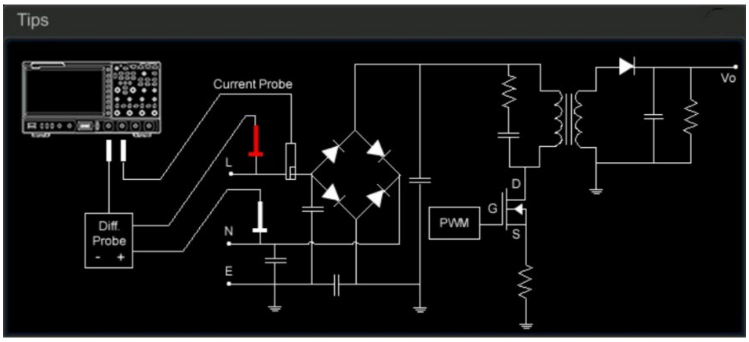
This section introduces 11 tests scenarios including power quality, ripple, switching loss, modulation, transient, slew rate, power efficiency, turn-on/turn-off time, inrush current, harmonic, and safe operating area. Each part introduces the test scenario setup and operation steps and displays the test results. The required test tools are as follows:

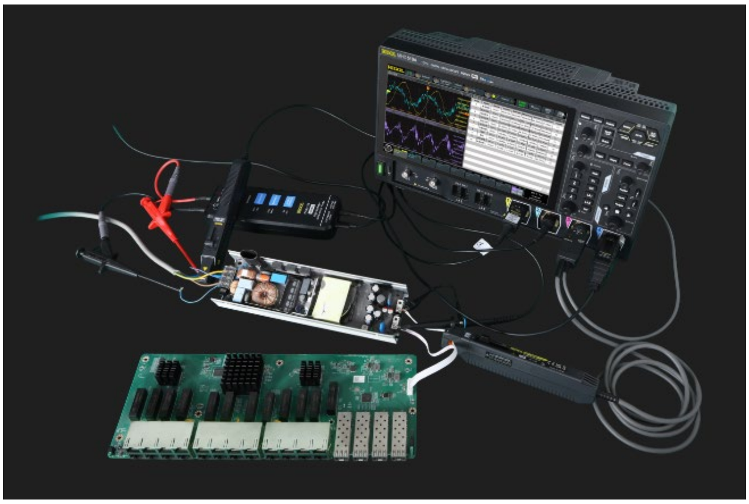
Test Equipment	Description
Oscilloscope	Supports the power analysis function Recommended: MHO/DHO5000 Series
Probe	High-Voltage Differential Active Probe: PHA2150 Current Probe: P1000C or PCA1030B Passive High-Impedance Probe: RP3500A
Calibration Fixture	Channel Delay Calibration Fixture: RPA246

6.1 Power Quality Analysis

Power quality analysis allows for testing the quality of the AC input line. By calculating parameters such as power, phase angle, impedance, and crest factor at the power supply's input, you can understand the voltage and current conditions at the input as well as the energy consumption status.

6.1.1 Test Connection Diagram





Power Quality Test Connection Diagram

6.1.2 Test Steps

1. Click or tap the function navigation icon at the lower-left screen and select UPA to enter the power menu. Click or tap the drop-down button of Type to select Power Quality, and then click or tap the Connection Diagram.
2. Connect the probe to the device under test (DUT) and the oscilloscope as shown in the connection diagram.
   - Connect the D+ lead of the voltage probe to the Live (L) line of the AC input.
   - Connect the D- lead of the voltage probe to the Neutral (N) line of the AC input.
   - Select the appropriate attenuation ratio on the voltage probe.
   - Connect the current probe to the Live (L) line of the AC input, with the arrow pointing in the direction of the current flow.
   - Connect the voltage and current probes to the oscilloscope's input channels.
3. Select the appropriate voltage and current channels and activate the electronic load.
4. Click or tap the Auto button to automatically set the time base and scale of the voltage channel for a complete waveform display.
5. Click or tap the ON/OFF tab for Enable to enable the power quality analysis and view the displayed results.

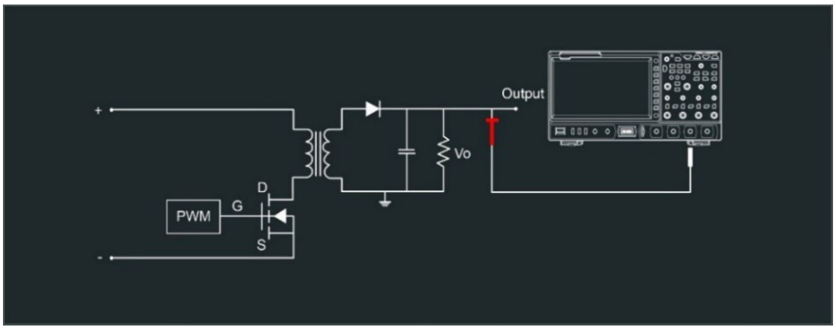
6.1.3 Power Quality Test Results

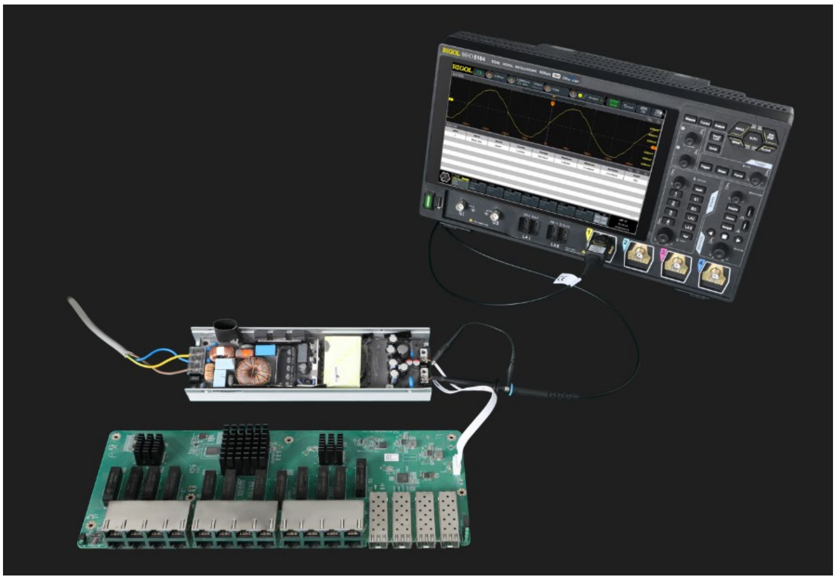
Power Quality Analysis Results

6.2 Power Ripple Measurement

Power supply ripple is a critical parameter for evaluating DC power supply, which indicates the ripple quantity of the output DC voltage. It mainly refers to the AC components within the DC output, and ripple can be generated at both the circuit frequency and switching frequency. The ripple analysis can measure the current value, average value, minimum value, maximum value, standard deviation value, and count value of the ripple on the power output terminal.

6.2.1 Test Connection Diagram



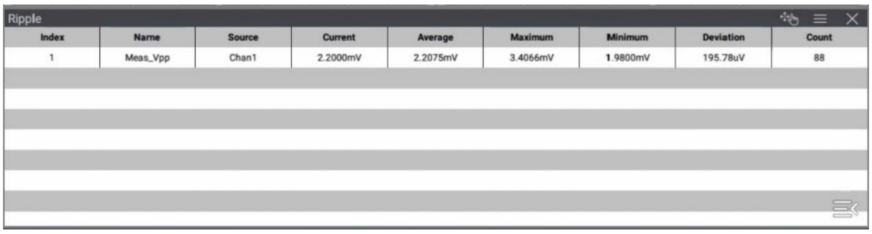


Ripple Analysis Test Connection Diagram

6.2.2 Test Steps

1. Click or tap the function navigation icon at the lower-left screen and select UPA to enter the power menu. Click or tap the drop-down button of Type to select Ripple, and then click or tap the Connection Diagram.
2. Connect the probe to the DUT and the oscilloscope as shown in the connection diagram. Connect a voltage probe (passive or differential) to the DC output of the power supply.
3. Select the proper voltage probe ratio.
4. Click or tap the Auto button to automatically set the time base and scale for a complete waveform display.
5. Click or tap the ON/OFF tab for Enable to enable the ripple analysis and view the displayed results.

6.2.3 Ripple Test Results



Ripple

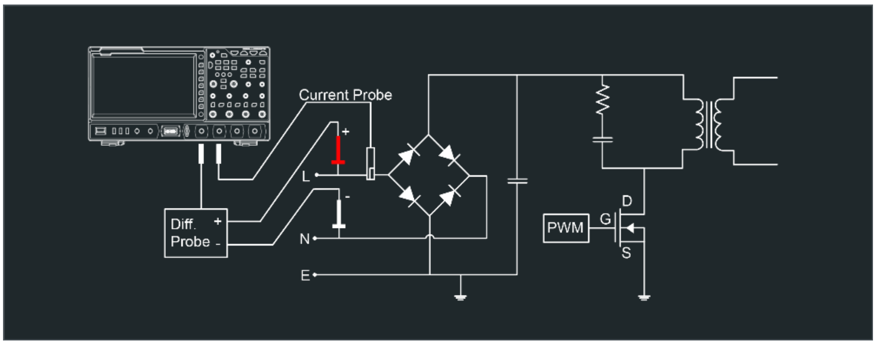
Index	Name	Source	Current	Average	Maximum	Minimum	Deviation	Count
1	Meas_Vpp	Chan1	2.2000mV	2.2075mV	3.4066mV	1.9800mV	195.78uV	88

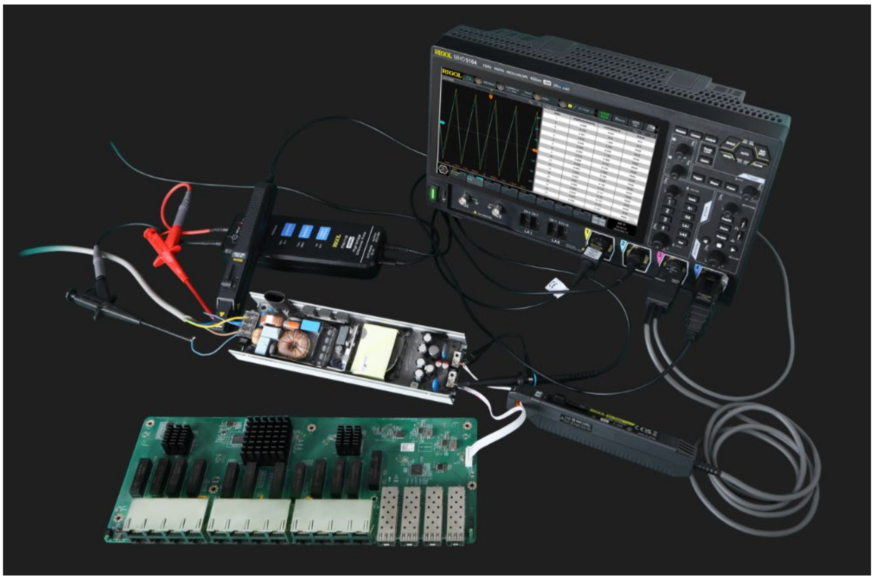
Ripple Analysis Test Results

6.3 Harmonic Analysis

Power harmonics increase harmonic losses in power systems, reduce power utilization efficiency, cause power-side loads and other equipment to operate under overload conditions, shorten the service life, and may trigger resonance phenomena that damage components due to excessive current or voltage. Therefore, testing and analyzing harmonic parameters is crucial.

6.3.1 Test Connection Diagram



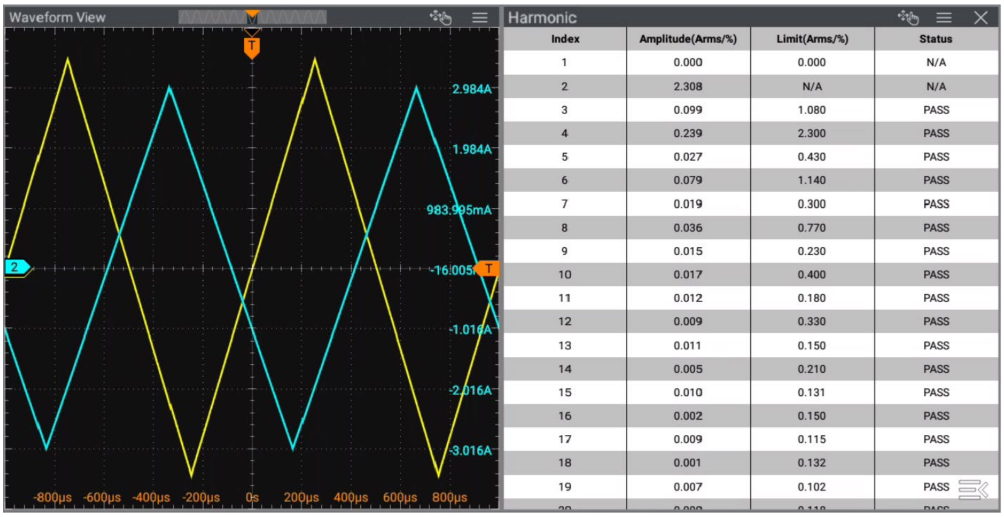


Harmonic Analysis Test Connection Diagram

6.3.2 Test Steps

1. Click or tap the function navigation icon at the lower-left screen and select UPA to enter the power menu. Click or tap the drop-down button of Type to select Harmonic, and then click or tap the Connection Diagram.
2. Connect the probe to the DUT and the oscilloscope as shown in the connection diagram.
   - Connect the D+ lead of the voltage probe to the Live (L) line of the AC input.
   - Connect the D- lead of the voltage probe to the Neutral (N) line of the AC input.
   - Select the appropriate attenuation ratio on the voltage probe.
   - Connect the current probe to the Live (L) line of the AC input, with the arrow pointing in the direction of the current flow.
   - Connect the voltage probe and current probe to the oscilloscope's input channels.
3. Select the proper voltage and current channels.
4. Click or tap the Auto button to automatically set the time base and scale for a complete waveform display.
5. Click or tap the ON/OFF tab for Enable to enable the harmonic analysis and view the displayed results.

6.3.3 Harmonic Test Results



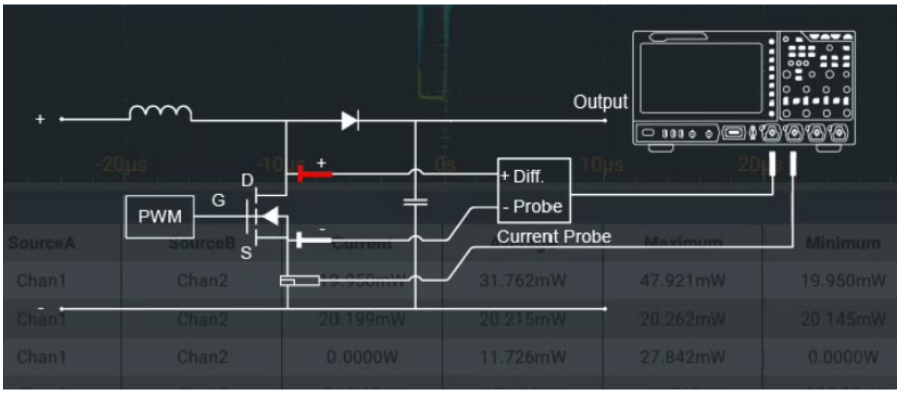
Index	Amplitude(Arms/%)	Limit(Arms/%)	Status
1	0.000	0.000	N/A
2	2.308	N/A	N/A
3	0.099	1.080	PASS
4	0.239	2.300	PASS
5	0.027	0.430	PASS
6	0.079	1.140	PASS
7	0.019	0.300	PASS
8	0.036	0.770	PASS
9	0.015	0.230	PASS
10	0.017	0.400	PASS
11	0.012	0.180	PASS
12	0.009	0.330	PASS
13	0.011	0.150	PASS
14	0.005	0.210	PASS
15	0.010	0.131	PASS
16	0.002	0.150	PASS
17	0.009	0.115	PASS
18	0.001	0.132	PASS
19	0.007	0.102	PASS

Harmonic Analysis Test Results

6.4 Switching Loss

The core power devices in switching power supplies, such as MOSFET and IGBT, are fundamental to high-frequency energy conversion due to their nanosecond-level switching speeds and transient voltage withstand capabilities. However, the dynamic losses generated during the switching process—including turn-on loss (Eon), turn-off loss (Eoff), and conduction loss (Econd)—directly impact both system efficiency and device lifetime. Therefore, it is essential to measure these switching losses.

6.4.1 Test Connection Diagram



Switching Loss Test Connection Diagram

6.4.2 Test Steps

1. Click or tap the function navigation icon at the lower-left screen and select UPA to enter the power menu. Click or tap the drop-down button of Type to select Switching Loss, and then click or tap the Connection Diagram.
2. Connect the probe to the DUT and the oscilloscope as shown in the connection diagram.
   - Connect the D+ lead of the voltage probe to the Drain (D) of the MOSFET.
   - Connect the D- lead of the voltage probe to the Source (S) of the MOSFET.
   - Select the appropriate attenuation ratio on the voltage probe.
   - Connect the current probe to the Source (S) of the MOSFET, with the arrow pointing in the direction of the current flow.
   - Connect the voltage and current probes to the oscilloscope's input channels.
3. Select the proper voltage and current channels.
4. If the offset correction is needed, click or tap the SelfCal button to perform channel deskew.
5. Click or tap the Auto button to automatically set the time base and scale for a complete waveform display.
6. Click or tap the ON/OFF tab for Enable to enable the switching loss analysis and view the displayed results.

6.4.3 Switching Loss Test Results

Switching Loss

Index	Name	SourceA	SourceB	Current	Average	Maximum	Minimum	Deviation	Count
1	Powerloss	Chan1	Chan2	240.94nW	62.494nW	787.46nW	-217.14nW	360.97nW	59
2	Powerlosson	Chan1	Chan2	427.58nW	168.61nW	588.80nW	0.0000W	222.66nW	59
3	Powerlossoff	Chan1	Chan2	0.0000W	86.959nW	473.37nW	0.0000W	172.57nW	59
4	Powerlosscon	Chan1	Chan2	-186.63nW	-193.07nW	-174.32nW	-217.14nW	8.8658nW	59
5	Energyloss	Chan1	Chan2	481.86fW*s	124.98fW*s	1.5749pW*s	-434.28fW*s	721.95fW*s	59
6	Energylosson	Chan1	Chan2	855.16fW*s	337.22fW*s	1.1776pW*s	0.0000W*s	445.89fW*s	59
7	Energylossoff	Chan1	Chan2	0.0000W*s	173.91fW*s	946.74fW*s	0.0000W*s	347.34fW*s	59
8	Energylosscon	Chan1	Chan2	-373.22fW*s	-386.13fW*s	-348.64fW*s	-434.28fW*s	17.302fW*s	58

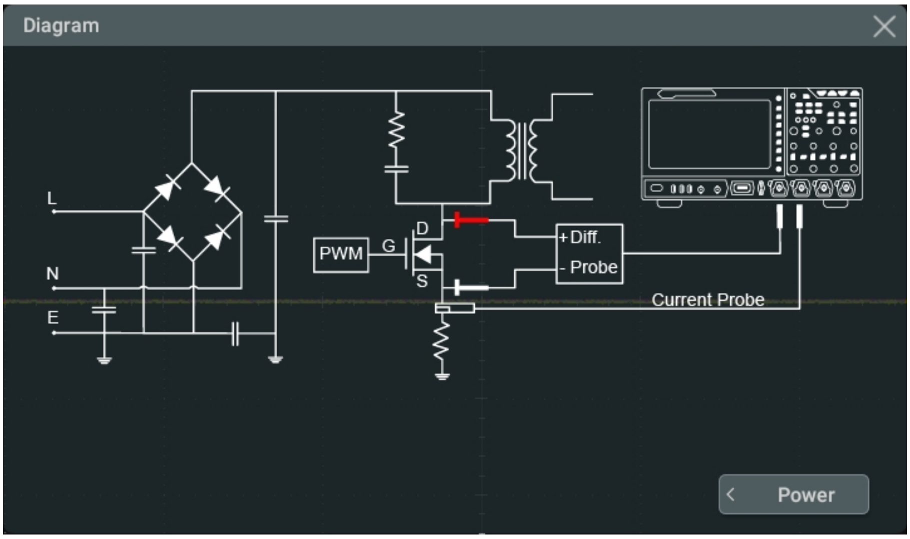
Switching Loss Test Results

6.5 Safe Operating Area (SOA)

The Safe Operating Area (SOA) is the voltage-current combination region where a power switching device (like a MOSFET or IGBT) can operate safely under specific conditions, used

to prevent the device failure caused by excessive instantaneous power. The SOA provides the reference for electrical stress boundaries, ensuring the switching device is operating within the thermal and electrical tolerance limits.
Therefore, measuring whether the power switching device operates within its SOA and evaluating its reliability in hard-switching and soft-switching scenarios is a critical verification step in power supply and motor drive design.

6.5.1 Test Connection Diagram



Safe Operating Area Test Connection Diagram

6.5.2 Test Steps

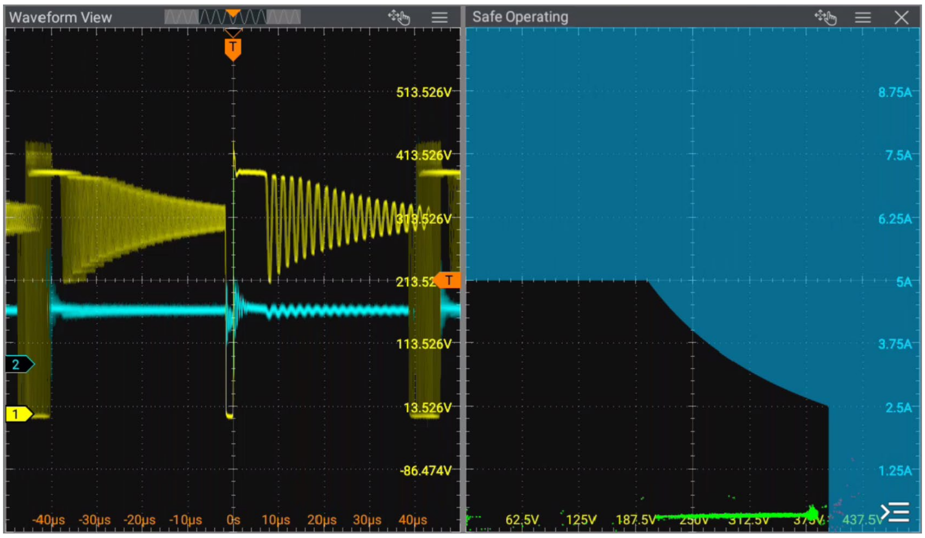
1. Configure the parameters as shown in the figure below.

2. As shown in the connection diagram:
   - Voltage: Connect the positive lead of the voltage probe to the Drain (D) and the negative lead to the Source (S).

- Current: Connect the current probe to the current output of the Source (S).

3. Connect the voltage probe to Channel 1 and current probe to Channel 2 respectively, set the appropriate probe ratios, and click or tap the ON/OFF tab for Enable to start the test.

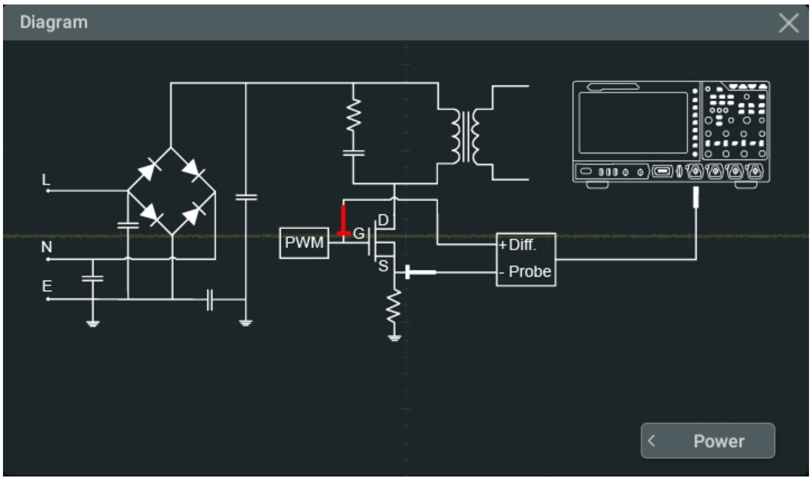
6.5.3 SOA Test Results



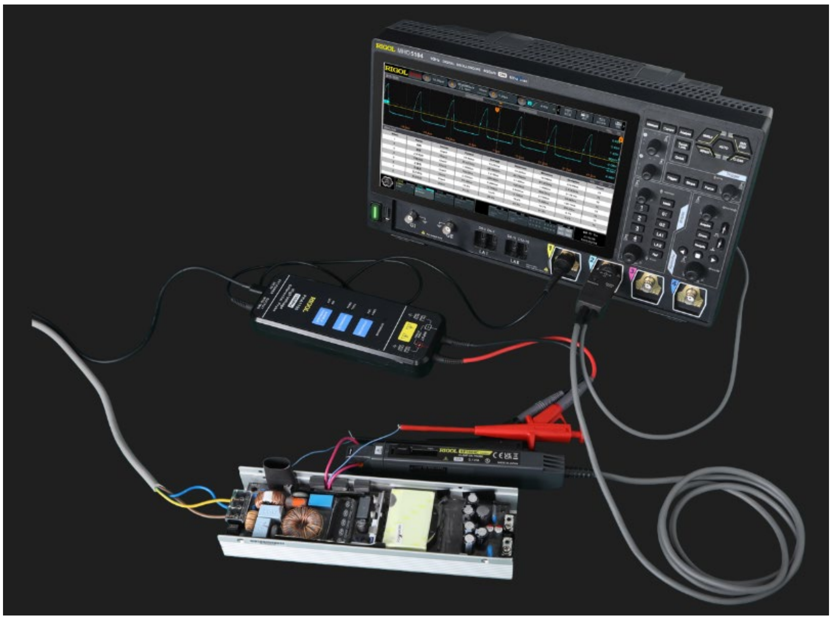
6.6 Modulation Analysis

The modulation test measures the PWM control signal used in the power-supply control loop. In practice, modulation analysis evaluates the key parameters of the MOSFET gate-drive signal in a switching power supply, providing data for closed-loop control studies. The modulation analysis mainly includes pulse analysis, duty cycle, period, frequency, rise time, and fall time.

6.6.1 Test Connection Diagram



Modulation Analysis Test Connection Diagram



Modulation Analysis Test Environment Connection Diagram

6.6.2 Test Steps

1. As shown in the connection diagram, connect the positive lead of the voltage probe to the Gate (G) and the negative lead to the Source (S).
2. Connect the probe to Channel 1, set the appropriate probe ratio, and click or tap the ON/OFF tab for Enable to start the test.

6.6.3 Modulation Analysis Test Results

- 12V, 10A

Index	Name	Source	Current	Average	Maximum	Minimum	Deviation	Count
1	Period	Chan2	14.360us	15.292us	16.220us	14.340us	573.99ns	73
2	Freq	Chan2	69.637kHz	65.482kHz	69.735kHz	61.652kHz	2.4763kHz	73
3	RiseTime	Chan2	1.9000us	2.0150us	2.1400us	1.9000us	51.261ns	73
4	FallTime	Chan2	700.00ns	638.90ns	700.00ns	580.00ns	34.065ns	73
5	+Width	Chan2	2.2200us	2.3846us	2.8000us	2.1200us	138.14ns	73
6	-Width	Chan2	12.140us	12.908us	13.760us	12.080us	490.39ns	73
7	+Duty	Chan2	15.5%	15.6%	18.2%	14.7%	0.7%	73
8	-Duty	Chan2	84.5%	84.4%	85.3%	81.8%	0.7%	73

- 12V, 5A

Index	Name	Source	Current	Average	Maximum	Minimum	Deviation	Count
1	Period	Chan2	21.900us	20.442us	22.060us	19.580us	752.99ns	41
2	Freq	Chan2	45.662kHz	48.979kHz	51.072kHz	45.330kHz	1.7147kHz	41
3	RiseTime	Chan2	1.8400us	1.8146us	1.8600us	1.7000us	36.963ns	41
4	FallTime	Chan2	680.00ns	650.73ns	700.00ns	580.00ns	31.883ns	41
5	+Width	Chan2	2.3000us	2.2185us	2.3400us	1.9200us	143.50ns	41
6	-Width	Chan2	19.600us	18.224us	20.120us	17.660us	767.42ns	41
7	+Duty	Chan2	10.5%	10.9%	11.6%	8.8%	0.8%	41
8	-Duty	Chan2	89.5%	89.1%	91.2%	88.4%	0.8%	41

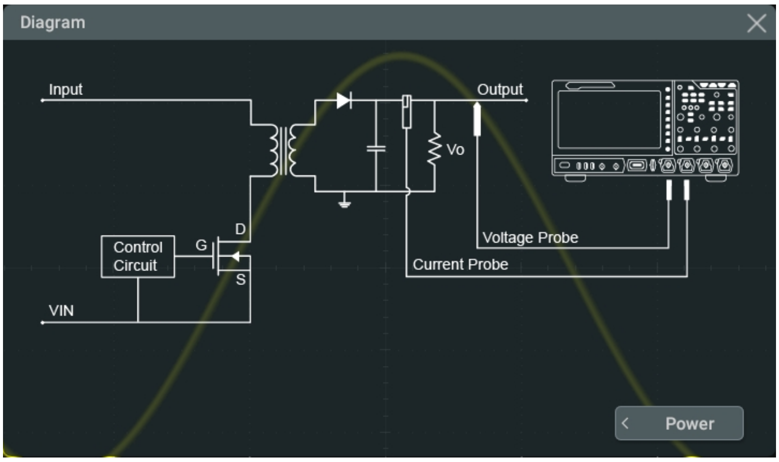
- 12V, 1A

Index	Name	Source	Current	Average	Maximum	Minimum	Deviation	Count
1	Period	Chan2	38.880us	26.245us	119.54us	18.140us	14.532us	59
2	Freq	Chan2	25.720kHz	43.171kHz	55.126kHz	8.3654kHz	10.897kHz	59
3	RiseTime	Chan2	1.5000us	1.9853us	20.420us	280.00ns	2.4191us	60
4	FallTime	Chan2	680.00ns	1.1680us	18.420us	540.00ns	2.7789us	60
5	+Width	Chan2	1.6600us	2.4083us	20.440us	1.2800us	2.3922us	60
6	-Width	Chan2	37.220us	23.818us	118.24us	40.000ns	15.084us	59
7	+Duty	Chan2	4.3%	11.0%	99.8%	1.1%	12.2%	59
8	-Duty	Chan2	95.7%	89.0%	98.9%	0.2%	12.2%	59

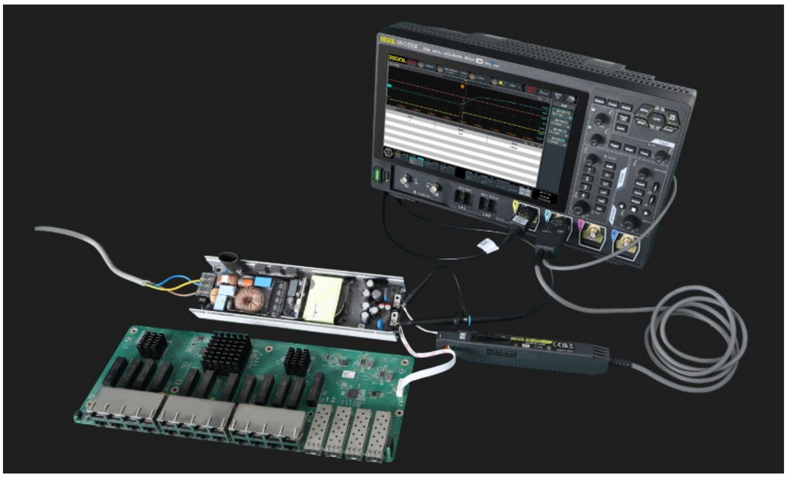
6.7 Transient Response Analysis

Transient response analysis is primarily used to measure how quickly the output DC voltage /current returns to a steady state following a sudden change in load. Specifically, it refers to the transition time required for the voltage or current to settle back to its initial steady-state value from a state of fluctuation when the output load is applied (current increases) or shed (current decreases).

6.7.1 Test Connection Diagram

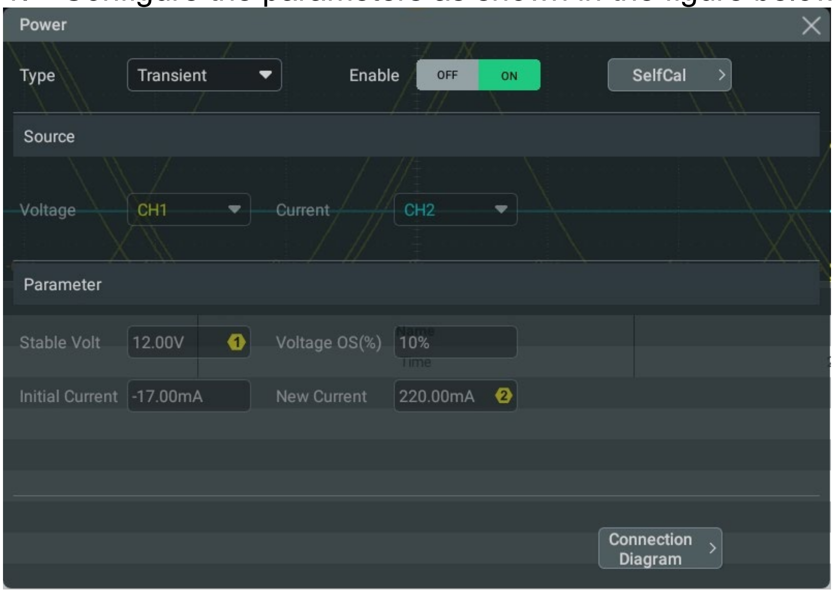


Transient Response Analysis Test Connection Diagram


Transient Response Test Environment Wiring Diagram

6.7.2 Test Steps

1. Configure the parameters as shown in the figure below.



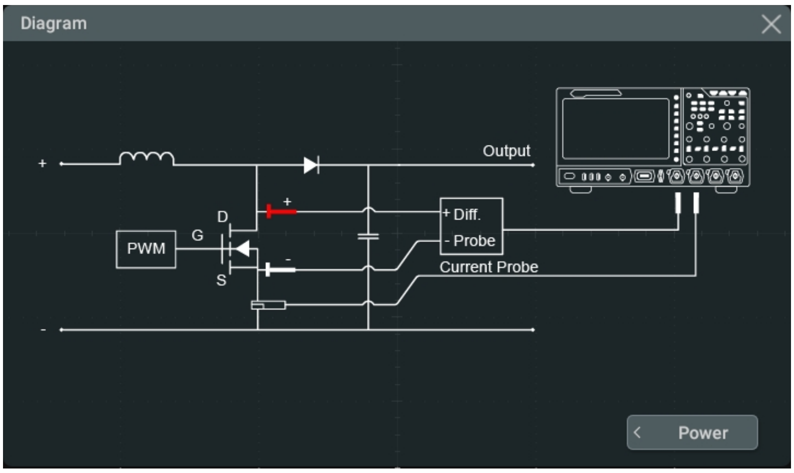
2. Connect the voltage probe to Channel 1 and the current probe to Channel 2, and set the appropriate probe ratios.
3. Power off the device under test. Then on the oscilloscope interface, enter the power menu, select Transient from the drop-down button of Type, and click or tap the ON/OFF tab to enable the function. Then enter the Trigger menu, and set the trigger mode to "Single". After completing these configurations, power on the device under test to start the test.

6.7.3 Transient Test Results

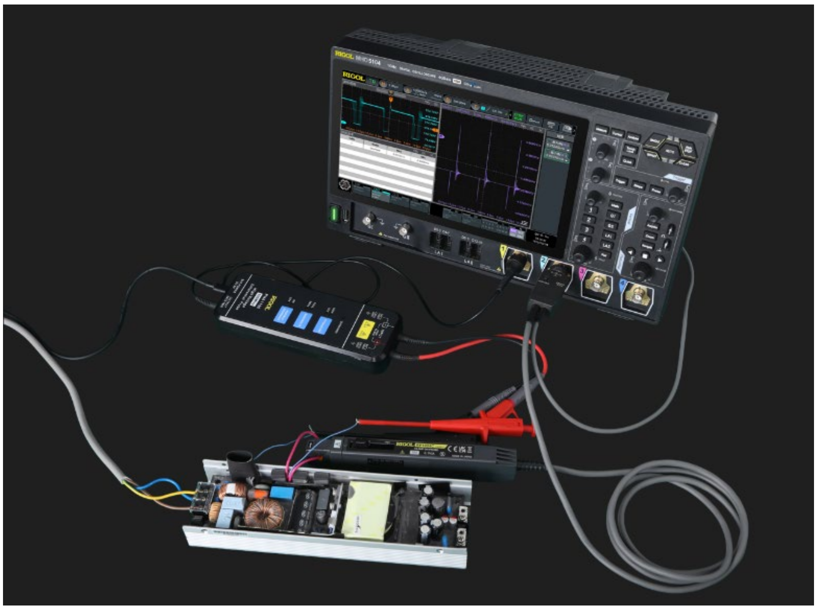
6.8 Slew Rate

Slew Rate is used to quantify the transient change capability of voltage/current during the switching process of a MOSFET. The core test method involves applying a PWM drive signal to the device's gate and using an oscilloscope to capture the drain-source voltage (Vds) and drain current (Id) waveforms, then calculating the maximum rate of change over time.

6.8.1 Test Connection Diagram



Slew Rate Test Connection Diagram



Slew Rate Test Environment Wiring Diagram

6.8.2 Test Steps

Complete the connections according to the diagram before the test:

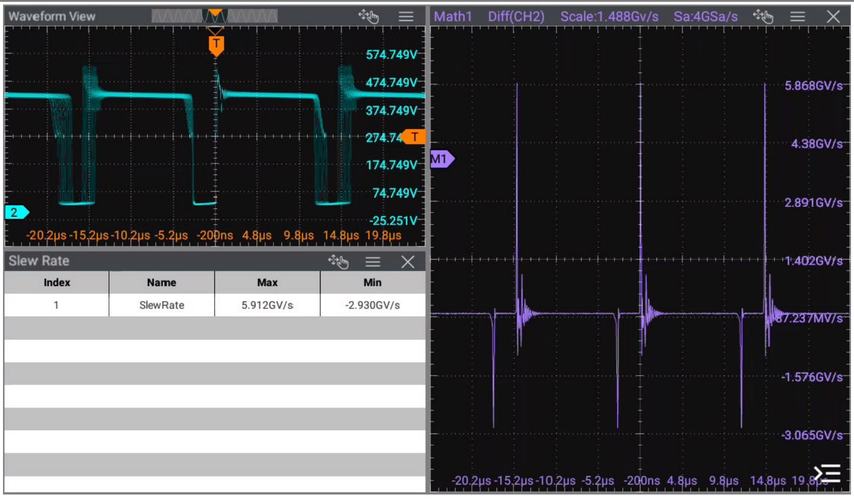
1. Select a proper range for the voltage probe (e.g., DC 0-100 V). Connect the red positive probe tip precisely to the MOSFET's drain (D) metal contact, and the black negative probe tip securely to the source (S) ground reference.
2. Select a matching range for the current probe (e.g., DC 0-50 A). Clamp the closed jaws around the DUT's Source (S) pin, ensuring a secure and stable connection.
3. After wiring, double-check the diagram to confirm that the signal terminal of the voltage and current probes correspond to the DUT pins, avoiding reversed polarity or short circuits.

Configure channels and start the test:

1. Power on the test equipment and enter the signal acquisition interface.
2. Connect the voltage probe to the Channel 1 and the connect current probe to the Channel 2.
3. Set the attenuation ratios based on the probe specifications (e.g., 100X for the voltage probe, 1000X for the current probe), and set the corresponding ratio on the oscilloscope and save the settings.
4. View the waveform on the oscilloscope. After confirming that the voltage and current waveforms are free of abnormal jumps or distortions, click or tap the AUTO button to start data acquisition.

6.8.3 Slew Rate Test Results

Voltage:



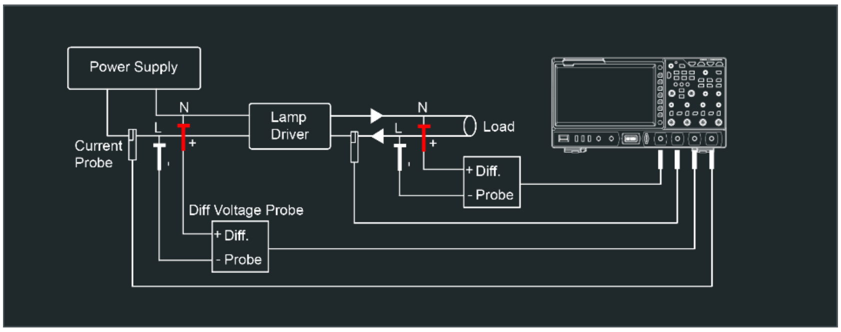
Current:

6.9 Power Efficiency

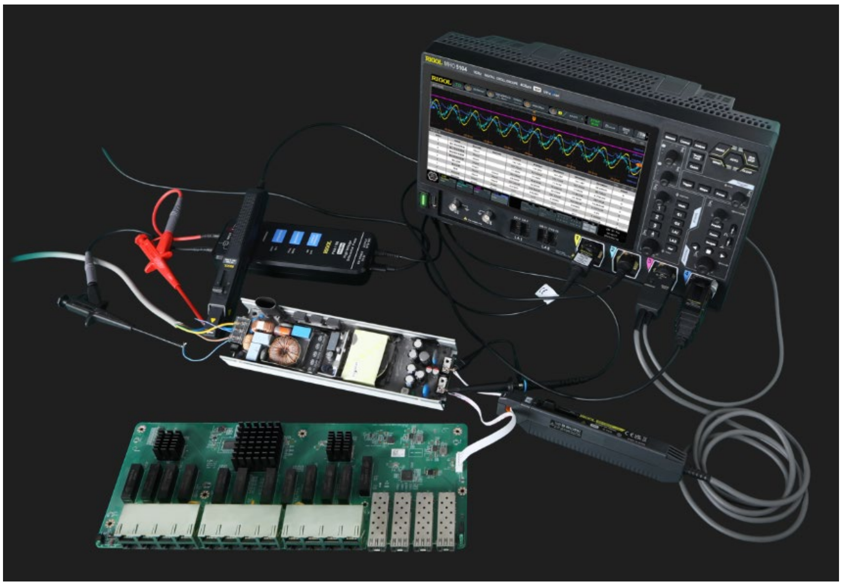
Power efficiency testing is a technique to evaluate the energy utilization and performance stability of the power supply (DUT) by measuring its input and output power. Acquire the measurement results for active power (real power), reactive power (magnetic/electric-field energy exchange), and apparent power (the product of the voltage and current) while simultaneously sampling voltage, current, phase angle, and other parameters.

Then calculate the efficiency value with the formula: $\eta = \left(\frac{P_{\text{out}}}{P_{\text{in}}}\right) \times 100\%$

6.9.1 Test Connection Diagram



Power Efficiency Connection Diagram



Power Efficiency Test Environment Wiring Diagram

6.9.2 Test Steps

1. Channel Configuration

- Input: Connect the voltage probe in parallel with the power supply input and the current probe in series with the input circuit (arrow pointing towards the power supply).
- Output: Connect the voltage probe in parallel with the load and the current probe in series with the load circuit (arrow pointing towards the load).

2. Type Setting

Click or tap the drop-down button for Type to select AC or DC for the input type, and ensure the output type matches the load.

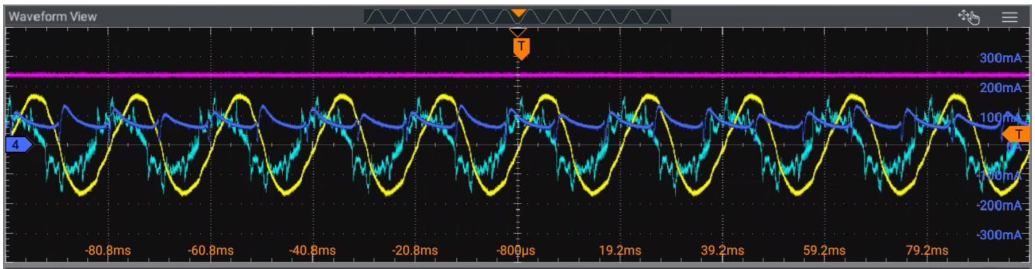
3. Start Measurement

Power on the power switch (DUT) and gradually increase the load until the target power level is reached.

Note:

- For AC tests, you need to monitor the frequency and harmonics. For DC tests, pay attention to ripple.
- **Reversed polarity connection will lead to incorrect power sign calculations (especially in DC test**). Probes must be strictly calibrated.
- If the output contains inductive or capacitive loads (e.g., motors, capacitive filter circuits), it is recommended to connect a **voltage snubber circuit** in parallel across the load side to prevent probe damage from back EMF.

6.9.3 Power Efficiency Test Results



Power Eff

Index	Name	SourceA	SourceB	Current	Average	Maximum	Minimum	Deviation	Count
1	inVrms	Chan1		147.14V	147.20V	147.25V	147.14V	48.249mV	5
2	inIrms	Chan2		157.70mA	157.62mA	157.71mA	157.47mA	90.730uA	5
3	outVrms	Chan3		11.894V	11.900V	11.919V	11.893V	9.7281mV	5
4	outIrms	Chan4		78.298mA	78.444mA	79.040mA	77.862mA	487.99uA	5
5	inP	Chan1	Chan2	23.205W	23.202W	23.224W	23.182W	15.864mW	5
6	outP	Chan3	Chan4	931.35mW	933.54mW	941.57mW	926.04mW	6.2573mW	5
7	Efficiency	Chan3	Chan4	4.0134%	4.0233%	4.0559%	3.9945%	2.4%	5
8	RealP	Chan3	Chan4	*****	*****	*****	*****	0.0000W	0
9	ApparentP	Chan3	Chan4	*****	*****	*****	*****	0.0000VA	0

6.10 Turn-On / Turn-Off Time Test

Turn-On Time Test

Turn-On Time is defined as the time from the initial moment the input voltage reaches 10% of its rated value until the output voltage stabilizes at 90% of its rated value. It reflects the transient response capability of the power module during startup. Use the oscilloscope to synchronously monitor the input voltage and output voltage waveforms. Set the trigger conditions for two channels on the oscilloscope.

- For the input channel, enter the Trigger menu and select Rising in the Slope item, with the threshold set to 10% of the rated input voltage.
- For the output channel, enter the Trigger menu and select Rising in the Slope item, with the threshold set to 90% of the rated output voltage.

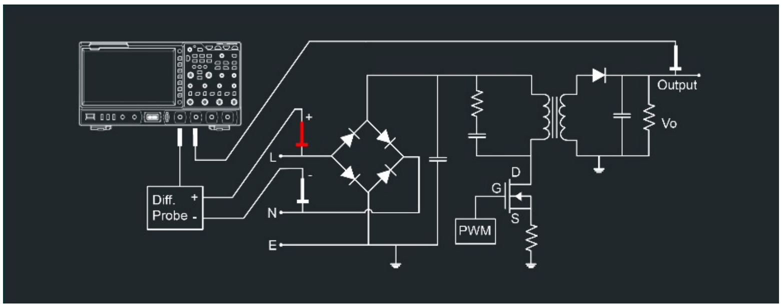
During the test, ensure the load is constant (a constant power mode of an electronic load or a real resistor is recommended) and record the time difference at the waveform inflection points with millisecond-level precision.

Turn-Off Time Test

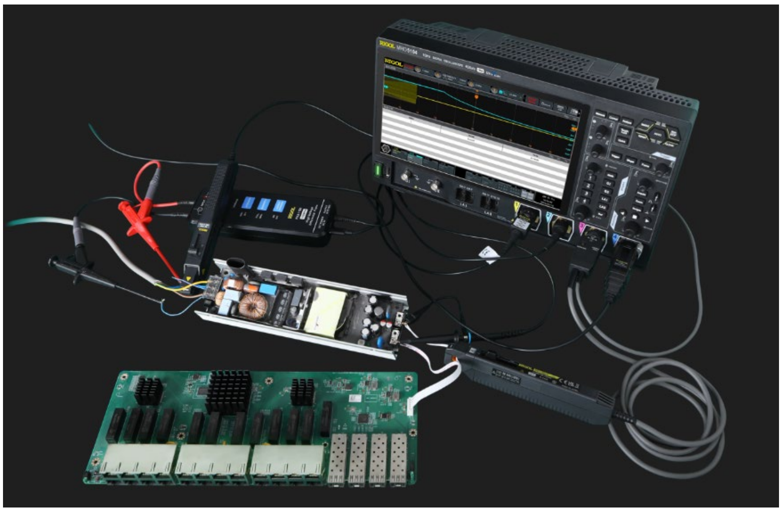
Turn-Off Time is the time from the moment the input voltage drops to 20% of its rated value until the output voltage drops to 10% of its rated value. The test should focus on the shutdown characteristics of the power module.

- For the input channel, enter the Trigger menu and select Falling in the Slope item, with the threshold set to 10% of the rated input voltage.
- For the output channel, enter the Trigger menu and select Falling in the Slope item, with the threshold set to 10% of the rated output voltage.

6.10.1 Test Connection Diagram



Turn-On / Turn-Off Connection Diagram

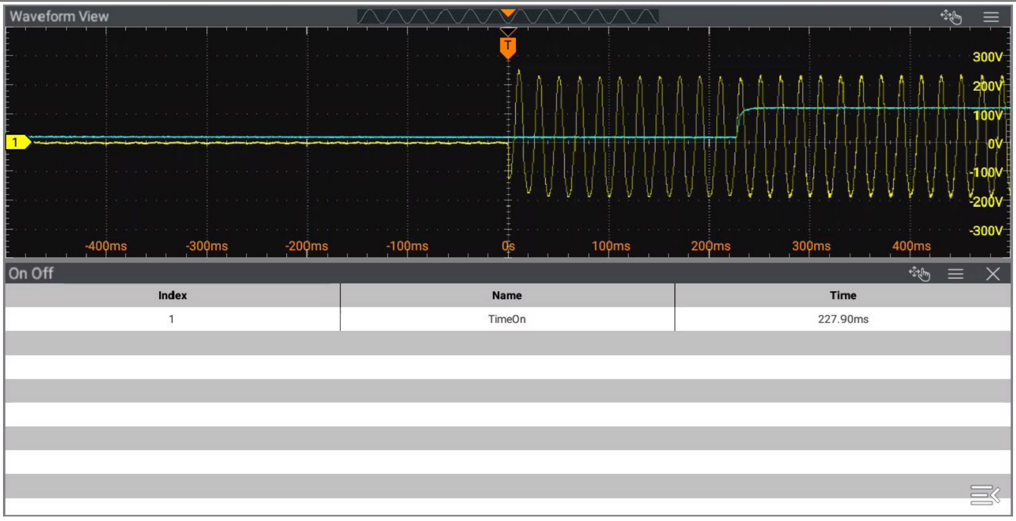

Turn-On / Turn-Off Test Environment Wiring Diagram

6.10.2 Test Steps

1. Select the Edge trigger for the input voltage channel (use the default settings).
2. Enter the power menu, and select the input voltage and output voltage channels.
3. In the parameter configuration column, click or tap the On/Off drop-down button to select "On" or "Off".
4. Set the maximum input voltage and the stable output voltage.
5. When On, the input threshold is 10% and the output threshold is 90%. When Off, both the input threshold and the output threshold are 10%.
6. Rotate the knob to set an appropriate time base, with millisecond scale for turn-on (e.g., 100-200 ms), and second scale for turn-off (e.g., 1-2 s, with slow capacitor discharge).
7. Click or tap the ON/OFF tab for Enable to enable the measurement.
8. Enter the Trigger menu and select “Single”.
9. For turn-on time measurement, power on the DUT. For turn-off time measurement, power off the DUT.

6.10.3 Turn-On/ Turn-Off Time Test Results

Turn-On (After capturing the waveform, you can adjust the channel knobs for better observation).

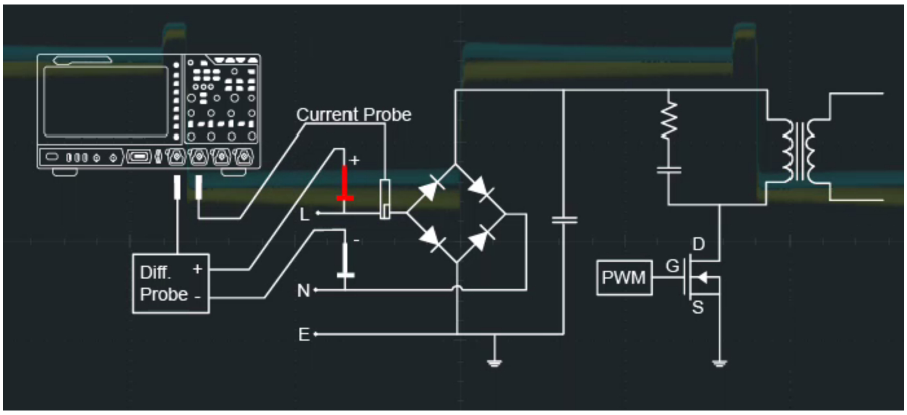


Turn-Off (After capturing the waveform, you can adjust the channel knobs for better observation).

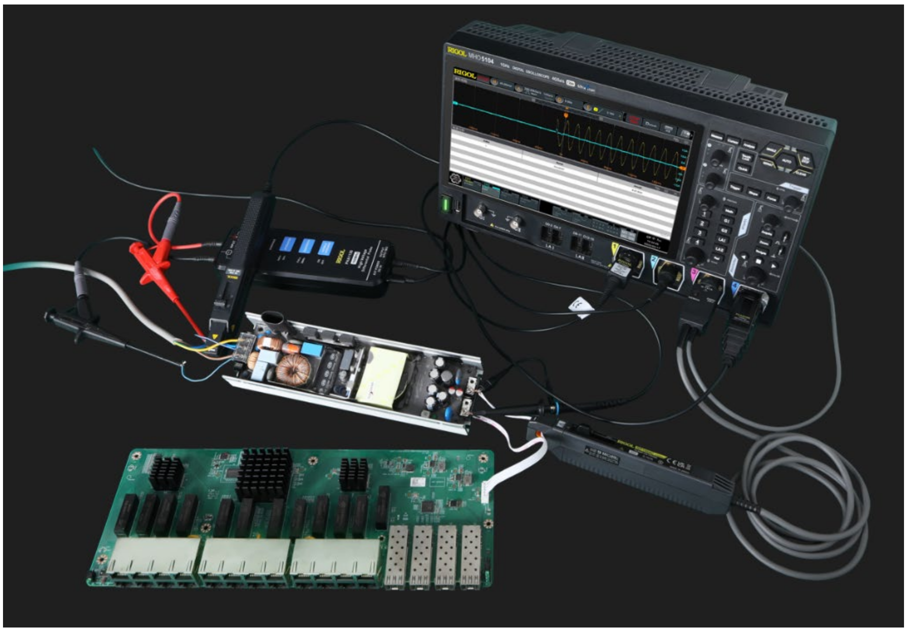
6. 11 Inrush Current

When a power module is energized under no-load conditions, a transient current spike, significantly larger than the steady-state current, can occur at the moment of turn-on. This current is known as the inrush current. The inrush current analysis function measures the peak inrush current when the power supply is first turned on.

6.11.1 Test Connection Diagram



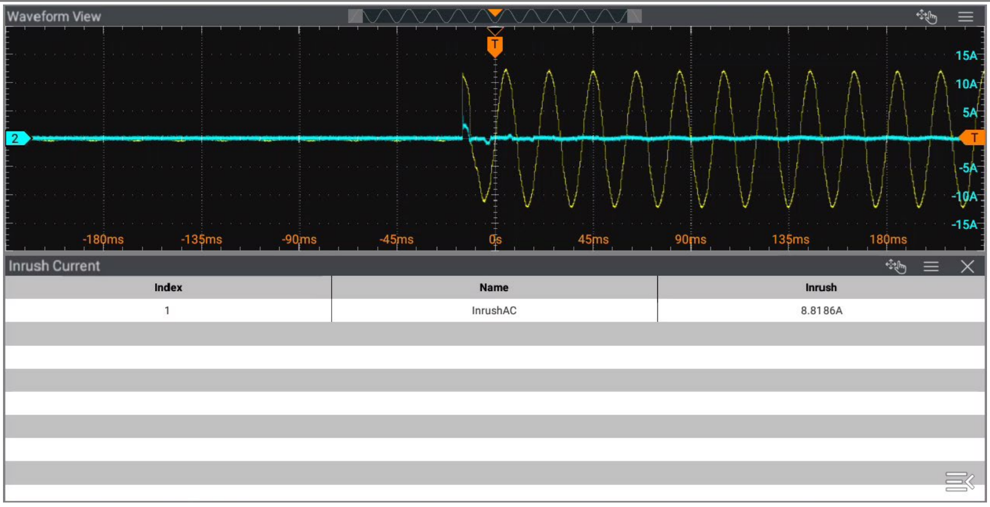
Inrush Current Connection Diagram


Inrush Current Test Environment Wiring Diagram

6.11.2 Test Steps

1. Enter the power menu, and select the voltage channel and current channel.
2. Click or tap the input-field of Max Volt to set the maximum input voltage with the pop-up numeric keypad.
3. Click or tap the input-field of Expected Curr to set the expected current with the pop-up numeric keypad.
4. Rotate the time base knob to set the appropriate time base.
5. Click or tap the ON/OFF tab for Enable to enable the measurement.
6. Enter the Trigger menu and select “Single”.
7. Power on the DUT.

6.11.3 Inrush Current Test Results



7. Conclusion

RIGOL MHO/DHO5000 series digital oscilloscopes provide a full suite of power analysis functions, including power quality analysis, conversion efficiency, output ripple measurements, and so on. With the oscilloscope and a DC electronic load, engineers can perform comprehensive power supply quality tests quickly. It replaces the traditional test methods that uses the power analyzer and complex software, reducing the test costs significantly. For detailed information about the MHO/DHO5000 series digital oscilloscope, go to the official website (https://www.rigol.com) to acquire.

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