

# D9010PWRA Power Supply Test Software for Infiniium Oscilloscopes

Input analysis, switching device analysis, safe operating area, output analysis, frequency response, and more

## Introduction

Power supply analysis is easy with Keysight's Infiniium MXR or EXR-Series oscilloscopes with the optional D9010PWRA software. The broad range of automated power supply characterization measurements includes critical frequency response measurements such as power supply rejection ratio (PSRR) and control loop response (Bode plots). The Infiniium MXR-Series and EXR-Series oscilloscopes also support multi-channel waveform mask testing for detailed analysis of supply system turn-on/turn-off testing of up to 8 power supply lines.



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The Power Measurements Software Package enables a broad range of automated power supply characterization measurements on Keysight Infinium EXR-Series and MXR-Series oscilloscopes including unique frequency response analysis for performing control loop response and power supply rejection ratio (PSRR) measurements. Table 1 lists the specific measurement capabilities that are enabled on each series with the Infinium Power Supply Analysis Package.

While designed to measure the rigorous operating parameters of switched-mode power supplies, the measurements can also be used as a toolkit of measurements for any power converter and/or inverter. These measurements provide an ideal method to document the performance parameters of your power system.



**Figure 1.** Easy to use configuration with Setup Wizards and built-in performance standards

# Power measurements included with the power supply analysis package

## Input Analysis

Real power	The portion of power flow that, averaged over a complete cycle of the AC waveform, results in net transfer of energy in one direction.
Apparent power	The portion of AC line power flow due to stored energy, which returns to the source in each cycle.
Reactive power	The difference between apparent power and real power due to reactance.
Power factor	The ratio of the actual AC line power to the apparent power.
Crest factor (V&I)	The ratio between the instantaneous peak AC line current/voltage required by the load and the RMS current/voltage.
Phase angle	The angle between the apparent power and the real power
Current harmonics	For the first 40 harmonics, Harmonic, Actual Value (RMS), Limit (RMS), Margin, Pass/Fail Status
Inrush current	Peak inrush current of the power supply when the power supply is first turned on.

## Switching Device Analysis

Switching loss	Calculates the power dissipated in the switching cycles across the switching device.
R <sub>DS(ON)</sub>	Measures RDS (ON) characteristics of a switching device
V <sub>CE(SAT)</sub>	Measures VCE(SAT) characteristic of a switching device
Slew rate (V&I)	Rate of voltage or current change during switching
Modulation analysis	Modulation analysis measures the control pulse signal to a switching device (MOSFET) and observes the trending of the pulse width, duty cycle, period, frequency, etc. of the control pulse signal in response to different events.
Safe operating area (SOA)	Plots an I-V curve and compares it against mask limits

## Output Analysis

Output ripple	Ripple noise of the power supply output
Turn on/off time	Determines how fast a turned-on power supply takes to reach 90% of its steady-state output. Determines how fast a turned-off power supply takes to reduce its output voltage to 10% of the maximum.
Efficiency	Overall efficiency of the power supply by measuring the output power over the input power.
Transient response	Determines how fast a power supply's output voltage responds to change at the output load.

## Frequency Response

PSRR (Power Supply Rejection Ratio)	Determine voltage regulator rejection ripple noise over a specified frequency range
Control loop response	Bode analysis performs a gain/phase plot over a specified frequency sweep.
Frequency Response Analysis (Bode plots)	Bode analysis performs a gain/phase plot over a frequency sweep. (Included with the WaveGen option EXR2WAV / MXR2WAV, as well as the Power Supply Test Software D9010PWRA.)

# Power Supply Characterization Measurements

## Input AC power quality

Power supply designers need to characterize the line power for power quality. Some of the implicit measurements are real power, apparent power, reactive power, power factor, and crest factor. Also, input analysis includes the inrush current measurement that provides the absolute peak inrush current (positive or negative) when the power supply is first turned on.



Figure 2. Input power quality measurements

# Current harmonics analysis

Power supply designers need to characterize the line power for harmonics related to conducted emissions under different operating conditions of the power supply. Current harmonics analysis measures the amplitude of harmonic frequency components that can be injected back into the AC grid. Products must meet specific standards of compliance based on IEC specifications. This measurement performs an FFT on the current input, compares amplitudes of odd and even harmonics against a user-selected IEC 61000-3-2 standard (Class A, B, C, or D) with color-coded pass/fail indicators for frequencies up the 40<sup>th</sup> harmonic, and also reports total harmonic distortion (THD).



Figure 3. Current harmonics measurement based on IEC 61000-3-2 standards

## Switching device analysis

The switching loss in a power supply is a major factor in determining a power supply's efficiency. With the switching loss measurement, you can quickly characterize the power and energy loss over an entire switching cycle, as well as determine losses during particular switching phases. To determine the efficiency of the power supply it is very important to measure the power loss during dynamic load changes. By measuring the switching loss and conduction loss, you can characterize the instantaneous power dissipation in your switching power supply. Locating peak switching loss helps you analyze the reliability of the power supply.



Figure 4. Power and energy loss measurements with automatic isolation of switching cycle

## R<sub>DS(ON)</sub> and V<sub>CE(SAT)</sub> analysis

R<sub>DS(ON)</sub> is the effective drain-to-source resistance of MOSFET-type switching transistors when fully turned on during the conduction phase. V<sub>CE(SAT)</sub> is the saturation voltage of bipolar-type transistors when fully turned on during the conduction phase. These parameters can be used by the oscilloscope to more accurately determine conduction losses based on I<sup>2</sup>R<sub>DS(ON)</sub> or I x V<sub>CE(SAT)</sub> calculations.



Figure 5. R<sub>DS(ON)</sub> and V<sub>CE(SAT)</sub> measurements

## Modulation analysis

Modulation analysis allows designers to quickly see the on-time and off-time information of the PWM signal, which is difficult to visualize because the information bandwidth is much lower than the pulse switching frequency. Plotting the embedded variation of on time or off time in the PWM signal over a long period of time can reveal the control loop response of the feedback loop system. This measurement performs data trending on the switching variation of the acquired waveform in the following format.

- Frequency vs time
- Period vs time
- Duty cycle vs time
- Positive pulse width vs time
- Negative pulse width vs time

## Output ripple analysis

Output analysis includes characterization of the ripple component (either power line or switching) in output DC voltage. Ripple is the residual AC component that is superimposed on the DC output of a power supply. Line frequency as well as switching frequency can contribute to ripple. This measurement analyzes the output voltage ripple and presents the peak-to-peak value as well as the frequency response of the captured signal.

## Turn On/Off time analysis

This analysis measures the time taken to reach steady-state output DC voltage conditions of the power supply after the input voltage (AC or DC) is applied (turn-on time) and for the output voltage of the power supply to turn off after the input voltage is removed (turn-off time).

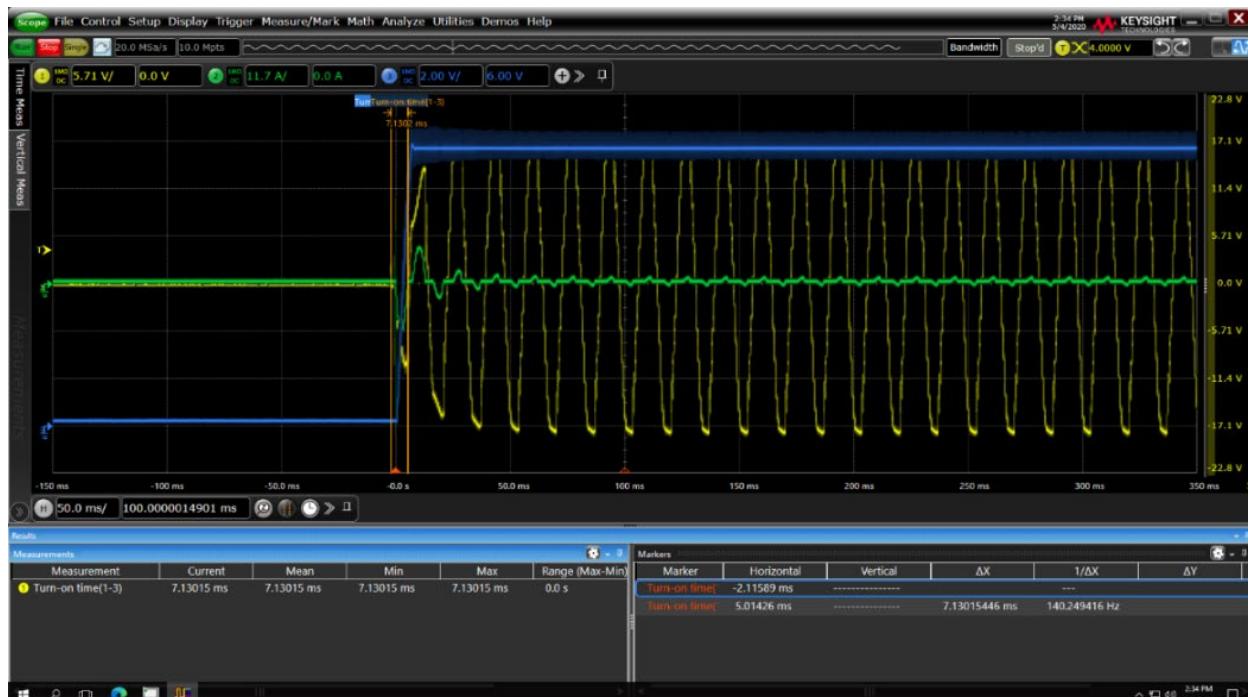


Figure 6. AC-to-DC turn-on time measurement

## Transient response analysis

Power supplies are subject to transient conditions, such as turn-on and turn-off transients, as well as sudden changes in output load and line input voltage. These conditions lead to one of the key specifications of the power supplies; load transient response. This analysis measures the load transient response of the DC output, namely the time taken for the DC output to stabilize after a load change.



Figure 7. Transient response settling time measurement

## PSRR (Power Supply Rejection Ratio)

PSRR is a measure of how well a DC-to-DC converter can reject noise on the input from getting to the output. It is defined as the ratio of the input ripple compared to the output ripple over a wide frequency range and is plotted logarithmically vs. frequency in units of dB. To perform this measurement the Infiniium MXR-Series oscilloscope uses its own built-in WaveGen to sweep the input from a user-defined start frequency to a user-defined stop frequency while measuring  $V_{IN}$  and  $V_{OUT}$  at each step frequency. The basic equation to measure and compute the power supply rejection ratio is:

$$PSRR = 20\log(V_{IN}/V_{OUT})$$

## Control loop response analysis

All power supplies have a negative feedback amplifier that regulates the output voltage. This feedback network should be characterized in the frequency-domain to insure proper power supply stability under a variety of load conditions. A closed-loop response test is a specialized in-circuit test commonly performed by power supply designers using a vector network analyzer (VNA) or frequency response analyzer (FRA). This same test can be performed using a Keysight MXR-Series oscilloscope licensed with the Power Supply Test Software. In addition to plotting the gain and phase across the range of tested frequencies, frequency-domain analysis performed by the Infiniium MXR-Series oscilloscope with the built-in WaveGen also includes automatic measurements of the feedback network's phase margin (PM) and gain margin (GM).

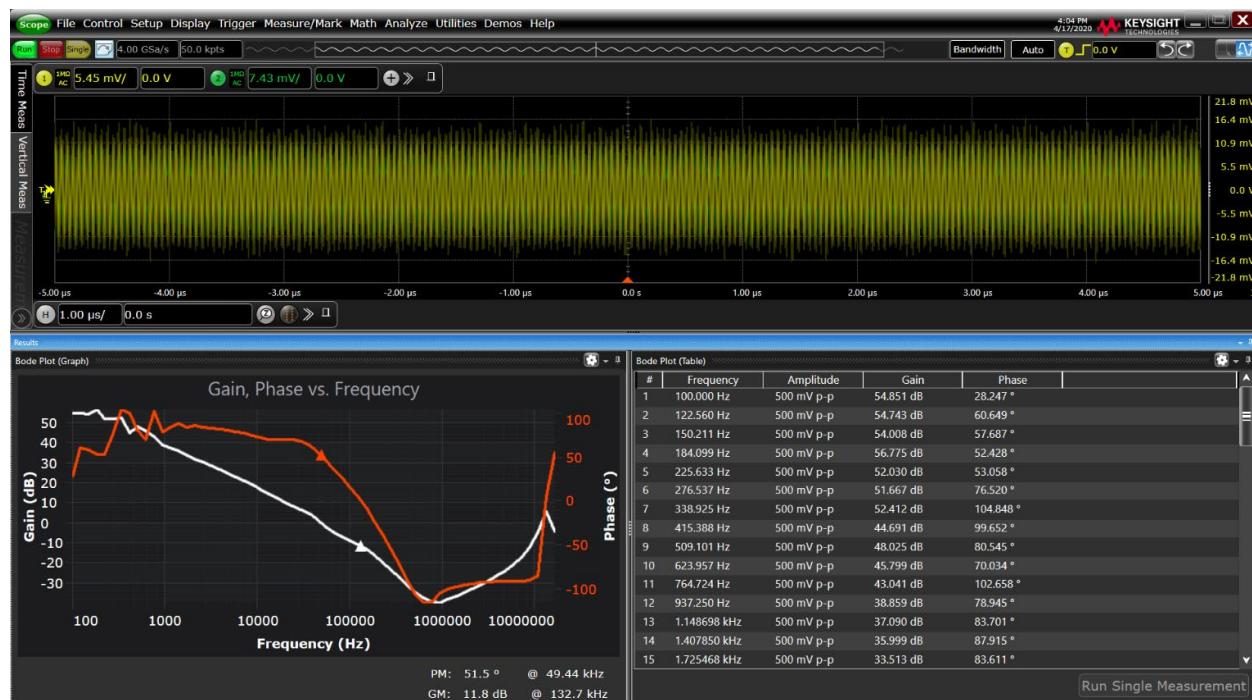


Figure 8. Control loop response measurement with automatic phase margin (PM) and gain margin (GM) measurement

## SOA (Safe Operating Area)

The safe operating area (SOA) is defined as the **voltage** and **current** conditions over which the device can be expected to operate without self-damage. The safe operating area curve is a graphical representation of the power handling capability of the device under various conditions. SOA analysis tests the power device by plotting an I-V curve and comparing it against mask limits that you define (according to the power device's specifications).

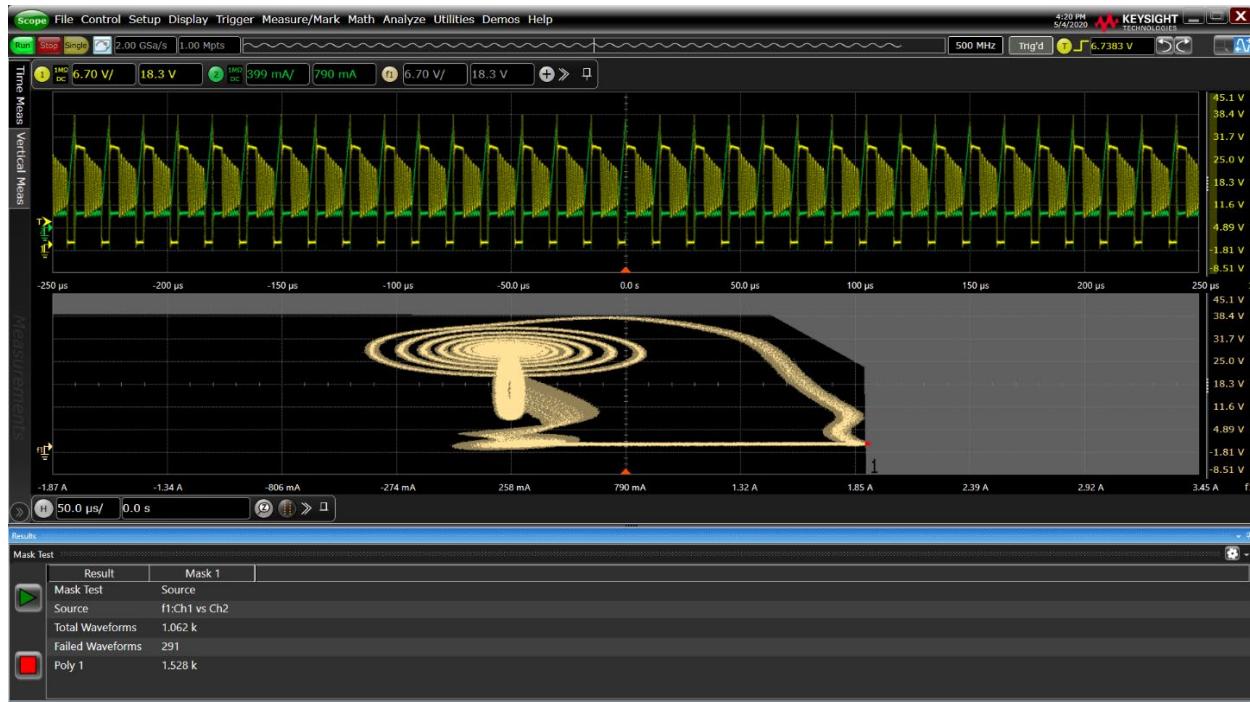
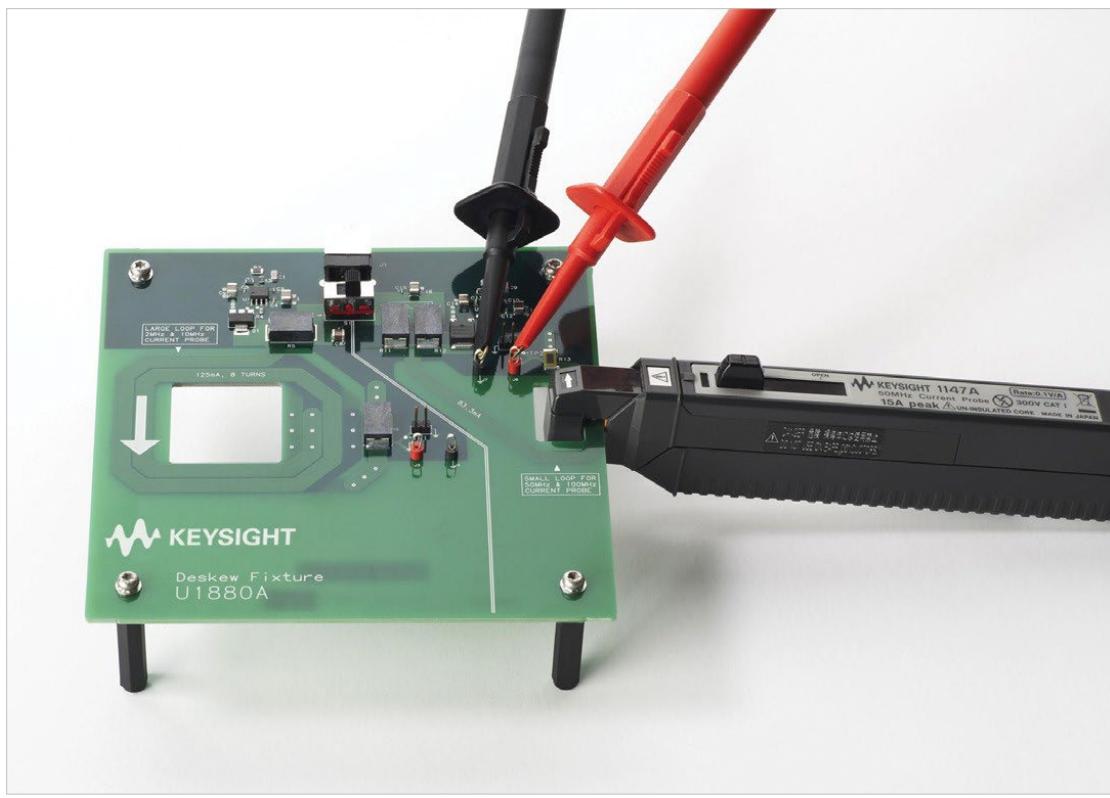


Figure 9. Safe Operating Area measurement

# Probe Deskewing with the U1880 Probe Deskew Fixture

Timing delay errors between voltage and current probes may have a significant impact on power measurements as each specific voltage and current probes have different propagation delays. To make accurate power measurements and calculations, it is extremely important to null out the time delay between the voltage and current probes using a procedure known as “deskewing.” This step is critically important since a small offset in the timing of the voltage and current traces can cause a large error in the instantaneous power reading. By performing probe deskew before making power measurements, you can ensure the most accurate measurement.

The Keysight U1880A deskew fixture allows you to quickly deskew your voltage and current probes, enabling accurate and precise power loss and efficiency measurements. The U1880A deskew fixture generates a built-in voltage and current test signal and allows you to probe the same electrical point with a variety of voltage and current probes. With only a single click in the setup menu, deskewing is automatically performed and the deskew factors are saved in the power measurement application, so the next time you launch the power measurement application, you can use the saved deskew values or perform the deskewing again.



**Figure 10.** The Keysight U1880A deskew fixture allows you to quickly deskew your voltage and current probes, enabling accurate and precise power measurements

# Additional Advanced Analysis Capabilities

## Frequency response analysis (Bode plots)

In addition to the specialized PSRR and Control Loop Response measurements that are part of the power suite of measurements, the Power Software Package also includes a general-purpose frequency response analysis (FRA) that can be used for a broad range of applications, such as for characterizing passive and active filters and amplifiers. This frequency-domain measurement capability is achieved with a swept gain and phase measurement versus frequency (Bode plot). The Infiniium MXR-Series oscilloscope uses the scope's built-in waveform generator (WaveGen) to stimulate the circuit under test at various frequency settings and then captures the input and output signals using two channels of the oscilloscope. At each test frequency, the scope measures, computes, plots gain ( $20\log V_{\text{OUT}}/V_{\text{IN}}$ ) logarithmically and phase linearly.

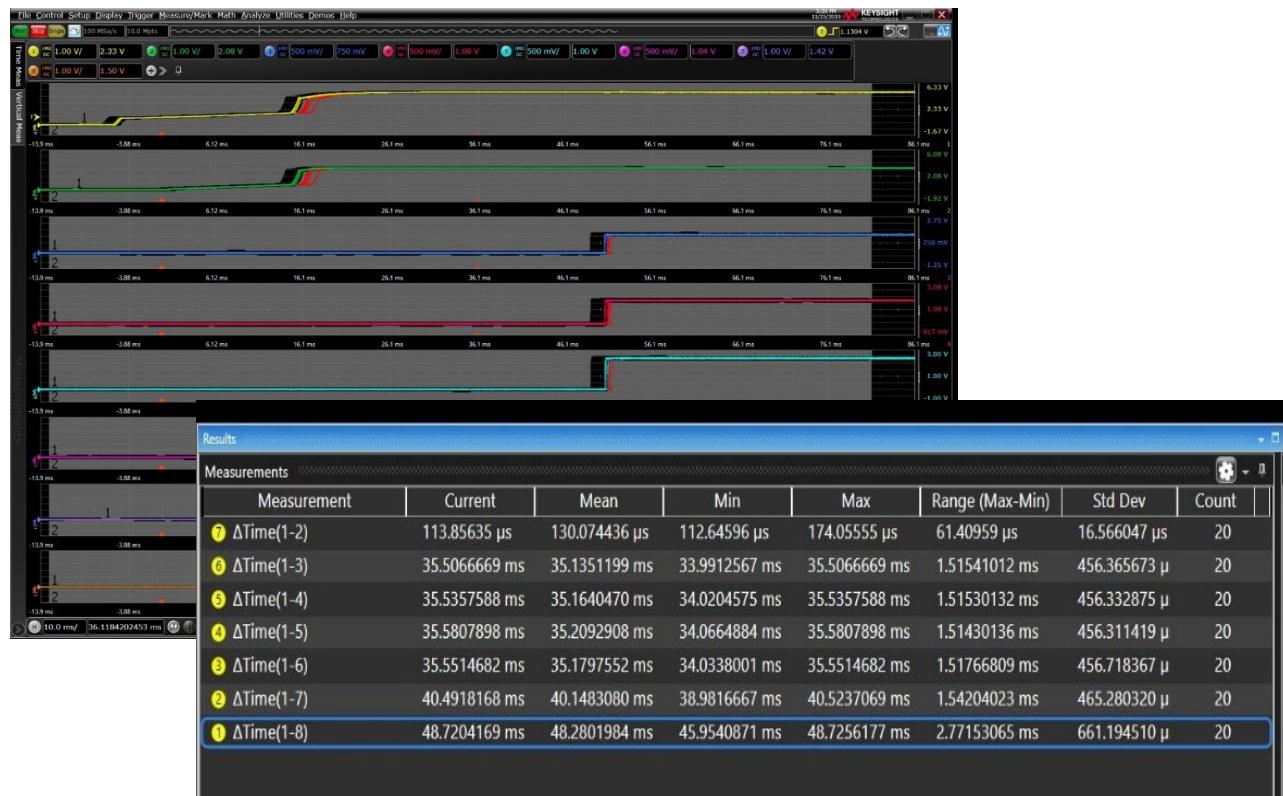
- Dynamic range: > 80 dB (typical)
- Frequency range: 10 Hz to 50 MHz
- Sweep or single-frequency test modes
- Fixed test amplitude or custom Amplitude Profile
- 60 to 1000 points across the Start/Stop sweep range
- Two pairs of tracking gain and phase markers
- Plots gain and phase and tabular view of test results
- Easily export and/or save measurement results in .csv format for offline analysis



**Figure 11.** Frequency Response Analysis is included with the WaveGen (MXR2WAV) option in addition to the Power Supply Analysis software

## Mask test

Take advantage of up to 8 channels of analysis to validate the operation of multiple power rails during turn-on/turn-off sequences. If you need to validate the quality and stability of your electronic components and systems, the Infiniium EXR-Series and MXR-Series oscilloscope's standard mask/waveform limit testing capability can save you time and provide pass/fail statistics almost instantly. Mask testing offers a fast and easy way to test your signals to specified standards, as well as the ability to uncover unexpected signal anomalies, such as glitches. Mask testing on other oscilloscopes is usually based on software-intensive processing technology, which tends to be slow.



## Features

- Test up to 1,000 waveforms per second with the industry's fast mask testing technology
- Automatic mask creation using input standard
- Easily download multi-region masks and setups based on industry standards
- Detailed pass/fail statistics
- Test to high-quality standards based on sigma
- Multiple user-selectable test criteria
- Add custom timing measurements with ease

# Ordering Information

## Required hardware

Model	Compatibility
D9010PWRA	Infinium 9000, S-Series, EXR-Series, MXR-Series

## Recommended Accessories and Probing Solutions

Accessories	
U1880A	Deskew fixture
N2779A	Probe power supply for non-AutoProbe interface active probes
AC/DC current probes	
N7026A	150 MHz, 30 A AC/DC high-sensitivity current probe with AutoProbe interface
N2893B	100 MHz, 15 A AC/DC current probe with AutoProbe interface
1147B	50 MHz, 15 A AC/DC current probe with AutoProbe interface
N2783B	100 MHz, 30 A AC/DC current probe (requires N2779A power supply)
N2780B	2 MHz, 500 A AC/DC current probe (requires N2779A power supply)
N2781B	2 MHz, 150 A AC/DC current probe (requires N2779A power supply)
N2782B	2 MHz, 30 A AC/DC current probe (requires N2779A power supply)
N2783B	2 MHz, 30 A AC/DC current probe (requires N2779A power supply)
High-voltage differential probes	
DP0001A	400 MHz, $\pm$ 1 kV differential probe with AutoProbe interface
DP0030A	100 MHz, $\pm$ 750 V differential probe with BNC + USB interface
DP0031A	200 MHz, $\pm$ 750 V differential probe with AutoProbe interface
DP0032A	200 MHz, $\pm$ 1.5 kV differential probe with AutoProbe interface
DP0033A	200 MHz, $\pm$ 3 kV differential probe with AutoProbe interface
PS0004A	350 MHz, $\pm$ 2.5 kV optically isolated differential probe with AutoProbe interface
PS0006A	700 MHz, $\pm$ 2.5 kV optically isolated differential probe with AutoProbe interface
PS0008A	1 GHz, $\pm$ 2.5 kV optically isolated differential probe with AutoProbe interface
Passive probes (for measuring output noise and frequency response measurements)	
N2870A	1:1 35 MHz passive probe with AutoProbe interface
10070D	1:1 20 MHz passive probe with AutoProbe interface
Active probes (for measuring output noise/ripple)	
N7020A	1:1 2.0 GHz active probe with $\pm$ 24 V offset capability with AutoProbe interface

# Flexible software licenses and KeysightCare Software Support Subscriptions

Keysight offers a variety of flexible licensing options to fit your needs and budget. Choose your license term and license type.

## License terms

**Perpetual** – Perpetual licenses can be used indefinitely.

**Subscription** – Subscription licenses can be used through the term of the license only.

## License types

**Node-locked** – License can be used on one specified instrument/computer.

**Transportable** – License can be used on one instrument/computer at a time but may be transferred to another using Keysight Software Manager (internet connection required).

**USB Portable** – License can be used on one instrument/computer at a time but may be transferred to another using a certified USB dongle (available for additional purchase with Keysight part number SW1000-D10).

**Floating (single site)** – Networked instruments/computers can access a license from a server one at a time. Multiple licenses can be purchased for concurrent usage.

## KeysightCare Software Support Subscriptions

Perpetual licenses are sold with a 12 (default) and up to 60-month software support subscription with a user-selected start and end date. Support subscriptions can be renewed for a fee after that.

Subscription licenses include a software support subscription through the term of the license, from 3 to 36 months, with a user-selected start date.

## Selecting your license

Step 1. Choose your software product (e.g. D9020ASIA)

Step 2. Choose your license term: perpetual or subscription.

Step 3. Choose your license type: node-locked, transportable, USB portable, or floating.

Step 4: Depending on the license term, choose your support subscription duration.

## Example

If you selected:	Your quote will look like this:	
D9020ASIA Node-locked	Part Number D9020ASIA	Description Advanced Signal Integrity Software (EQ, InfiniiSimAdv, Crosstalk)
Perpetual license	SW1000-LIC-01 SW1000-SUP-01	Node-locked perpetual license Node-locked KeysightCare software support subscription with user-selected start and end dates
D9020ASIA Transportable Subscription 6-month license	Part Number D9020ASIA SW1000-SUB-01	Description Advanced Signal Integrity Software (EQ, InfiniiSimAdv, Crosstalk) 6-months, transportable subscription license

To configure your product and request a quote:

<http://www.keysight.com/find/software>

Contact your Keysight representative or authorized partner for more information or to place an order:

[www.keysight.com/find/contactus](http://www.keysight.com/find/contactus)

## Related Literature

Publication Title	Publication number
Infiniium MXR B-Series Oscilloscopes – Data Sheet	3123-1557.EN
Infiniium EXR-Series Oscilloscopes – Data Sheet	3120-1495.EN
Characterizing Switch Mode Power Supplies- Application Note	5991-1117EN
Control Loop Response Measurements - Application Note	5992-0593EN
Power Supply Rejection Ratio (PSRR) Measurements - Application Note	5992-0594EN
Making your Best Power Integrity Measurements - Application Note	5992-0493EN
Considerations in Making Small Signal Measurements - Application Note	5991-3317EN
How to Test USB Power Delivery (PD) Over Type-C - Application Note	5992-1394EN
Oscilloscope Probes and Accessories - Selection Guide	5968-8153EN

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