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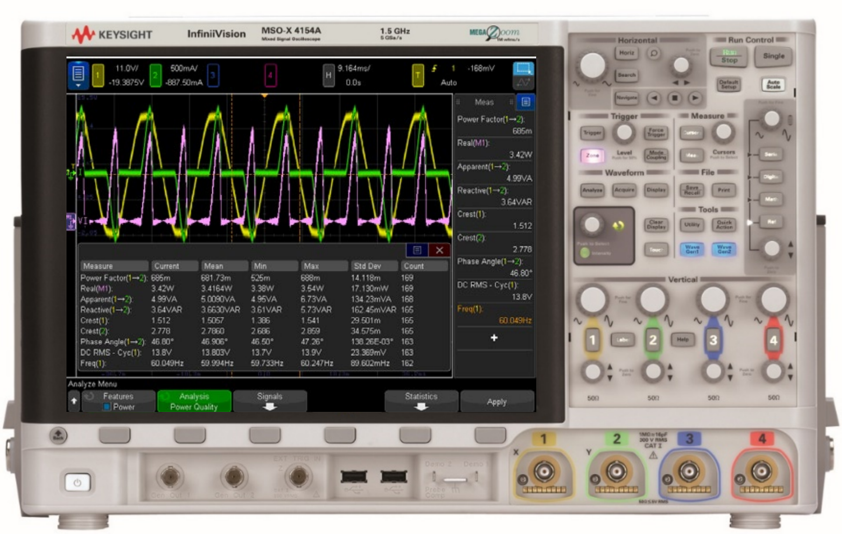
DATA SHEET

Power Software Package

for InfiniiVision X-Series Oscilloscopes

The Power Software Package for Keysight's InfiniiVision oscilloscopes enables a broad range of automated power supply characterization measurements including critical frequency response measurements such as power supply rejection ratio (PSRR) and control loop response. This package also enables hardware-based pass/fail mask testing and USB PD triggering and decode.



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Introduction

The Power Measurements Software Package enables a broad range of automated power supply characterization measurements on Keysight InfiniiVision X-Series oscilloscope including unique frequency response analysis for performing control loop response and power supply rejection ratio (PSRR) measurements. Also included in this package is hardware-based pass/fail mask testing and USB PD trigger and decode capabilities. Table 1 lists the specific measurement capabilities that are enabled on each series with the InfiniiVision Power Software Package.

Table 1. Power Measurements Software Packages for InfiniiVision Oscilloscopes

InfiniiVision Series:			3000A	3000T	4000A	6000A	M9240
Power Package Model Number:			D3000PWRB	D3000PWRB	D4000PWRB	D6000PWRB	M9240PWRB
Power Supply Characterization Measurements	Input Analysis	Real power	✓	✓	✓	✓	✓
		Apparent power	✓	✓	✓	✓	✓
		Reactive power	✓	✓	✓	✓	✓
		Power factor	✓	✓	✓	✓	✓
		Crest factor (V&I)	✓	✓	✓	✓	✓
		Phase angle	✓	✓	✓	✓	✓
		Current harmonics	✓	✓	✓	✓	✓
		Inrush current	✓	✓	✓	✓	✓
	Switching Device Analysis	Switching loss	✓	✓	✓	✓	✓
		$R_{DS(ON)}$	✓	✓	✓	✓	✓
		$V_{CE(SAT)}$	✓	✓	✓	✓	✓
		Slew rate (V&I)	✓	✓	✓	✓	✓
		Modulation analysis	✓	✓	✓	✓	✓
		Auto probe deskew	✓	✓	✓	✓	✓
	Output Analysis	Output ripple	✓	✓	✓	✓	✓
		Turn on/off time	✓	✓	✓	✓	✓
		Efficiency	✓	✓	✓	✓	✓
		Transient response	✓	✓	✓	✓	✓

InfiniiVision Series:			3000A	3000T	4000A	6000A	M9240
Power Package Model Number:			D3000PWRB	D3000PWRB	D4000PWRB	D6000PWRB	M9240PWRB
	Frequency Response Analysis	PSRR		✓	✓	✓	✓
		Control loop response		✓	✓	✓	✓
Other Advanced Analysis Capabilities		Frequency Response Analysis (Bode plots)		✓	✓	✓	✓
		USB PD (Power Delivery) Trigger & Decode		✓	✓	✓	✓
		Mask Limit Test	✓	✓	✓	✓	✓
		Measurement Limit Test	✓	✓	✓	✓	✓
		Advanced Math	✓	Std	Std	Std	Std

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 and crest factor Also, input analysis includes the inrush current measurement (not shown) that provides the absolute peak inrush current (positive or negative) when the power supply is first turned on.

Figure 1. Input AC 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 40th harmonic, and also report total harmonic distortion (THD).

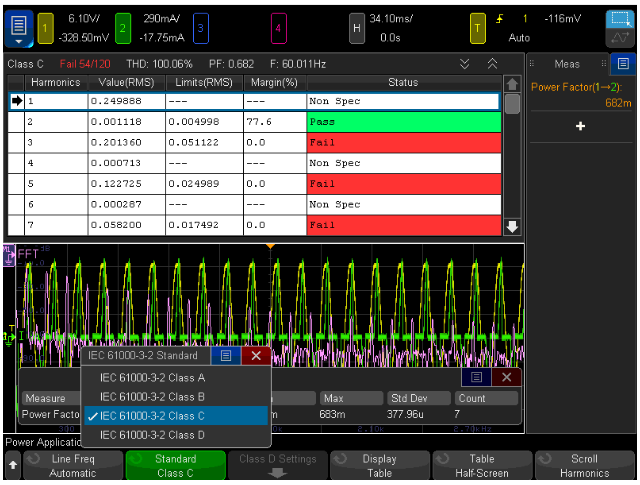

Figure 2. Current harmonics measurement based on IEC 61000-3-2 standards.

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 3. Power and energy loss measurements.

$R_{DS(ON)}$ and $V_{CE(SAT)}$ Analysis

$R_{DS(ON)}$ is the effective drain-to-source resistance of MOSFET type switching transistors when fully turned on during the conduction phase. $V_{CE(SAT)}$ 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 $I^2R_{DS(ON)}$ or I x $V_{CE(SAT)}$ calculations.

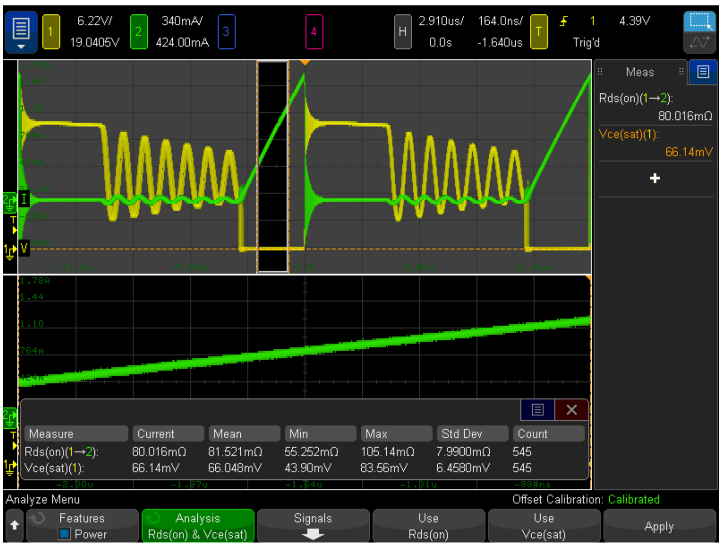

Figure 4. $R_{DS(ON)}$ and $V_{CE(SAT)}$ measurements.

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

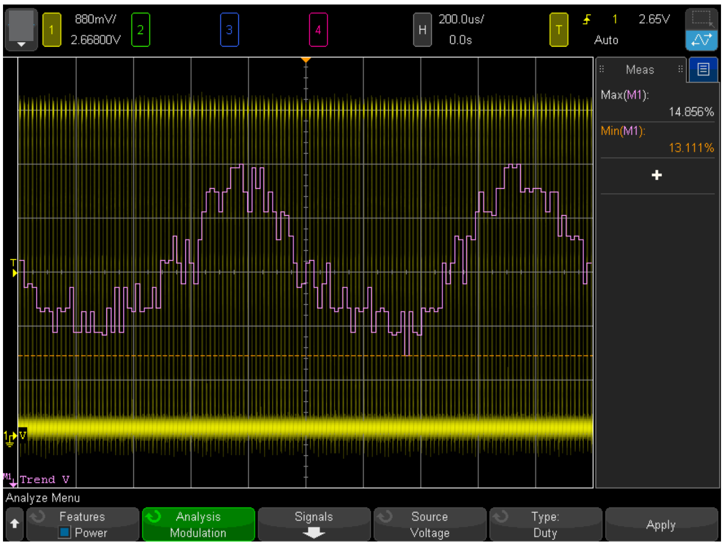

Figure 5. PWM duty cycle versus time.

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.

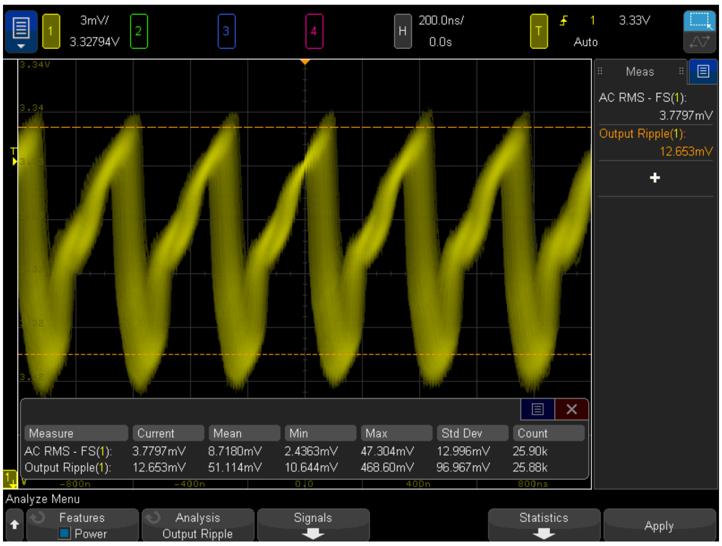

Figure 6. DC-to-DC converter output ripple measurement.

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).

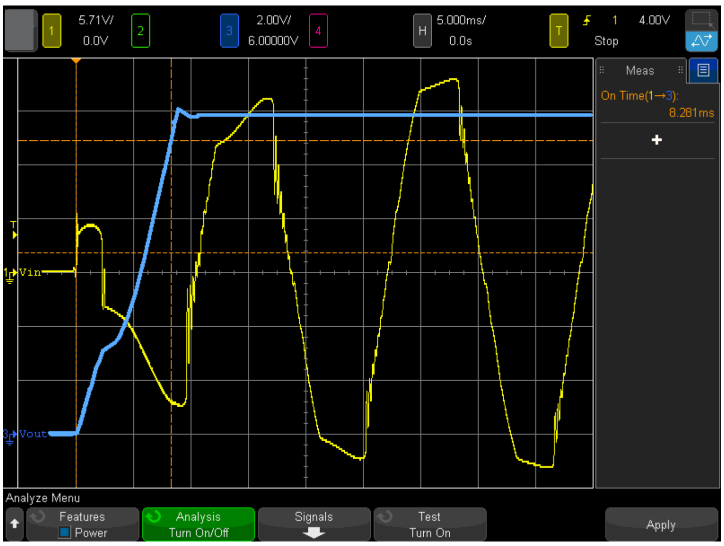

Figure 7. AC-to-DC turn-on time measurement.

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 during a load change.

Figure 8. 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 InfiniiVision 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 power supply rejection ratio is: $PSRR = 20Log(V_{IN}/V_{OUT})$

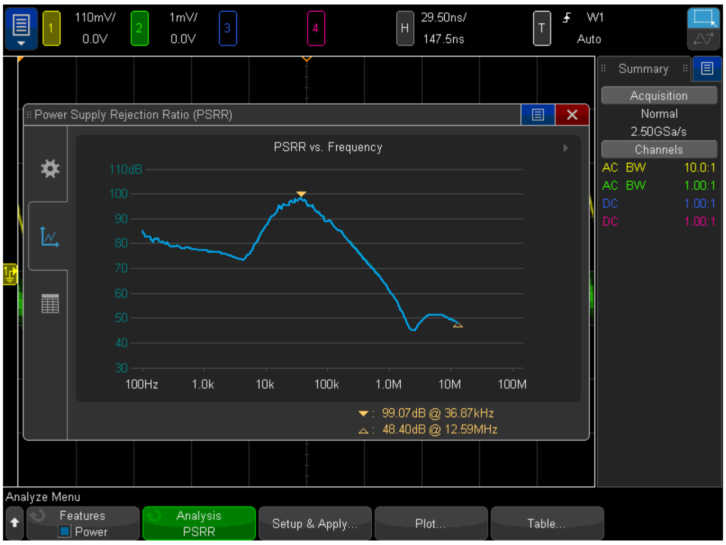

Figure 9. Transient response settling time measurement.

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 InfiniiVision oscilloscope licensed with the Power Software Package. In addition to plotting the gain and phase across the range of tested frequencies, frequency-domain analysis performed by the InfiniiVision oscilloscope with the built-in WaveGen also includes automatic measurements of the feedback network's phase margin (PM) and gain margin (GM).

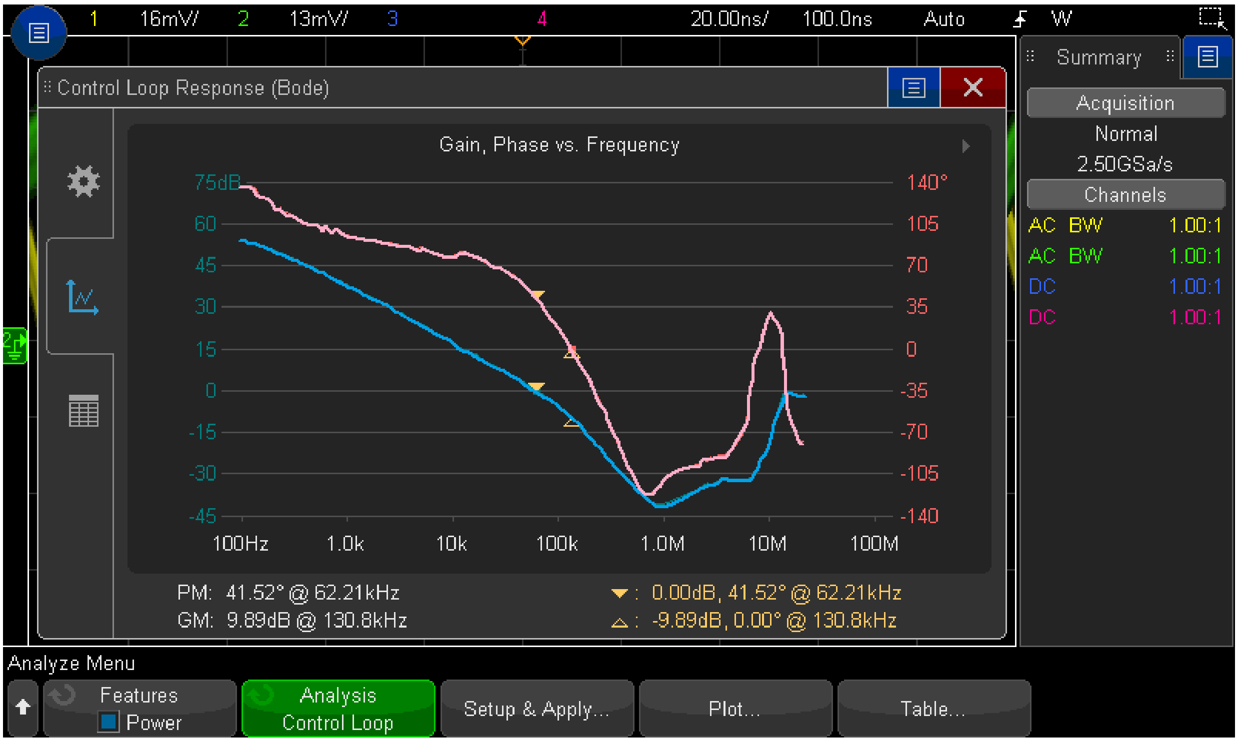

Figure 10. Control loop response gain & phase measurement.

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.

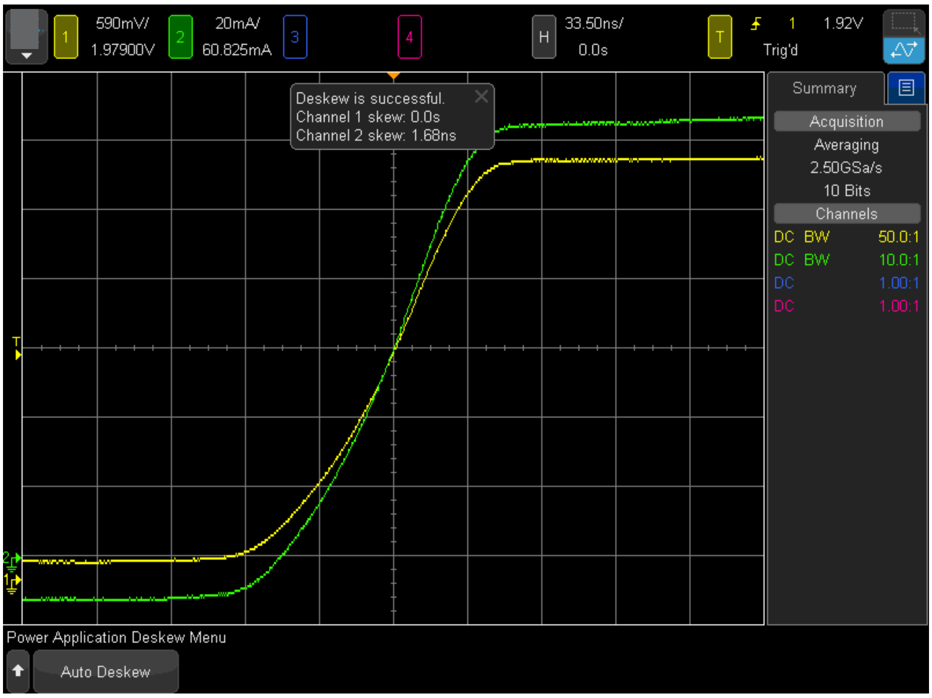

Figure 11. Accurate power measurements require that the time delay between voltage and current be nulled-out (deskewed).

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 one of the power measurements setup, deskewing is automatically performed and the deskew factors are saved in the power measurement application, so the next time when you launch the power measurement application, you can use the saved deskew values or perform the deskewing again.

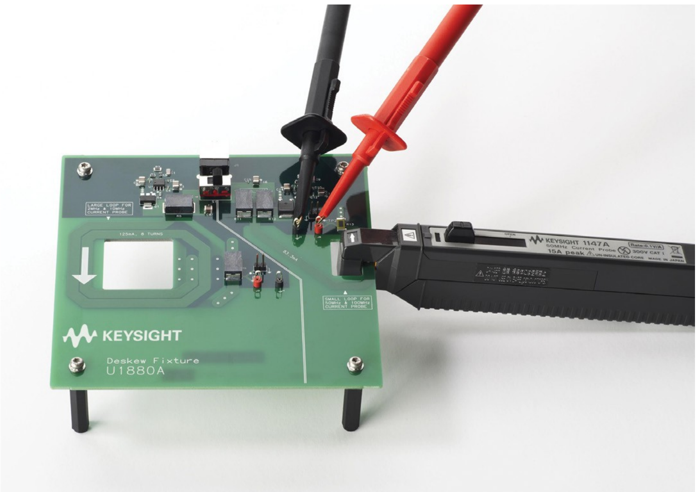

Figure 12. The Keysight U1880A deskew fixture allows you to quickly deskew your voltage and current probes, enabling accurate and precise power measurements.

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 InfiniiVision 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 ($20LogV_{OUT}/V_{IN}$) logarithmically and phase linearly.

- Dynamic range: > 80 dB (typical)
- Frequency range: 10 Hz to 20 MHz
- Sweep or single frequency test modes
- Fixed test amplitude or custom Amplitude Profile
- 60 to 1000 points across Start/Stop sweep range
- Two pair 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

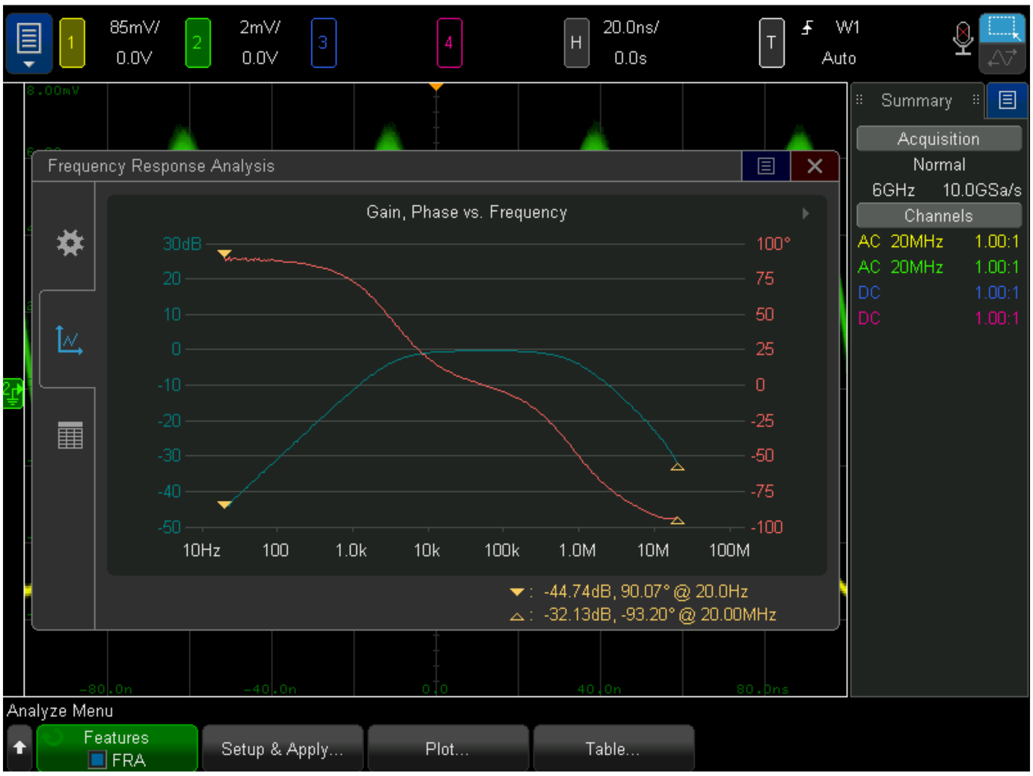

Figure 13. Frequency response analysis (gain & phase) on a bandpass filter.

Table 2. Frequency Response Analysis Performance Characteristics

<table>
<tr><th colspan="3">Frequency Response Analysis</th></tr>
<tr><td>Frequency mode</td><td colspan="2">Sweep or single</td></tr>
<tr><td>Frequency range</td><td colspan="2">10 Hz to 20 MHz</td></tr>
<tr><td>Test amplitude modes</td><td colspan="2">Fixed or amplitude profile</td></tr>
<tr><td rowspan="4">Test amplitude range</td><td rowspan="2">3000T:</td><td>10 mVpp to 2.5 Vpp into 50-Ω load</td></tr>
<tr><td>20 mVpp to 5.0 Vpp into high impedance load</td></tr>
<tr><td rowspan="2">4000A/6000A:</td><td>10 mVpp to 5 Vpp in 50-Ω load</td></tr>
<tr><td>20 mVpp to 10.0 Vpp into high impedance load</td></tr>
<tr><td>Input and output sources</td><td colspan="2">Channel 1, 2, 3, and 4</td></tr>
<tr><td>Number of test points</td><td colspan="2">1 to 1000 points across Start/Stop sweep range</td></tr>
<tr><td>Test results</td><td colspan="2">Overlaid gain and phase plot and tabular view</td></tr>
<tr><td>Dynamic range</td><td colspan="2">> 80 dB (typical) based on 0 dBm (630 mVpp) input into 50-Ω load</td></tr>
<tr><td>Measurements</td><td colspan="2">Dual pair of tracking gain and phase markers
Automatic phase margin (PM) and gain margin (GM) within the power suite</td></tr>
<tr><td>Plot scaling</td><td colspan="2">Auto-scaled during test and manual setting after test</td></tr>
</table>

USB PD (Power Delivery) Serial Bus Trigger and Decode

- Supports decoding and triggering on the USB PD protocol.
- Hardware-based decoding to capture random and infrequent errors quickly
- Supports dual-bus analysis with time-interleave lister display
- Trigger on Preamble, EOP, and Ordered sets (SOP, SOP', SOP", etc.)
- Trigger on Header content hexadecimally, or on symbolic messages including control message types, data message types, or extended message types

Table 3. USB PD Performance Characteristics

Performance Characteristics	
USB Type-C CC wire input source	Analog channels 1, 2, 3, or 4
Baud rate	300 kbps ± 10%
Triggering	Preamble start
	EOP
	Ordered sets:
	• SOP, SOP', SOP", SOP' debug, SOP" debug, hard reset, cable reset
	Errors:
	• CRC error, Preamble error
	Header content (qualified on SOP, SOP', SOP", or none):
	• Control message (GoodCRC, Accept, Reject, Get_Source_Cap, etc. [1])
	• Data message (Source_Cap, Request, BIST, etc. [1])
	• Extended message (Source_Cap_Extended, Status, Battery_Cap, etc. [1])
	• Value (Hex – 4 nibbles)
Hardware-based decode (Time-correlated decode trace below waveform and protocol lister table above waveform)	Preamble (PRE in blue)
	Ordered set (symbolic name in blue)
	Header (Hex digits in yellow)
	Data (32-bit Hex objects in white)
	CRC (Hex in green)
	End of packet (EOP in blue)
	Symbolic:
	• Control messages
	• Data messages
	• Extended messages
	• Source capabilities (in Volts/Amps)
	• Sink capabilities (in Volts/Amps)
	• Structured vendor defined message commands
Multi-bus analysis	USB PD plus one other serial bus

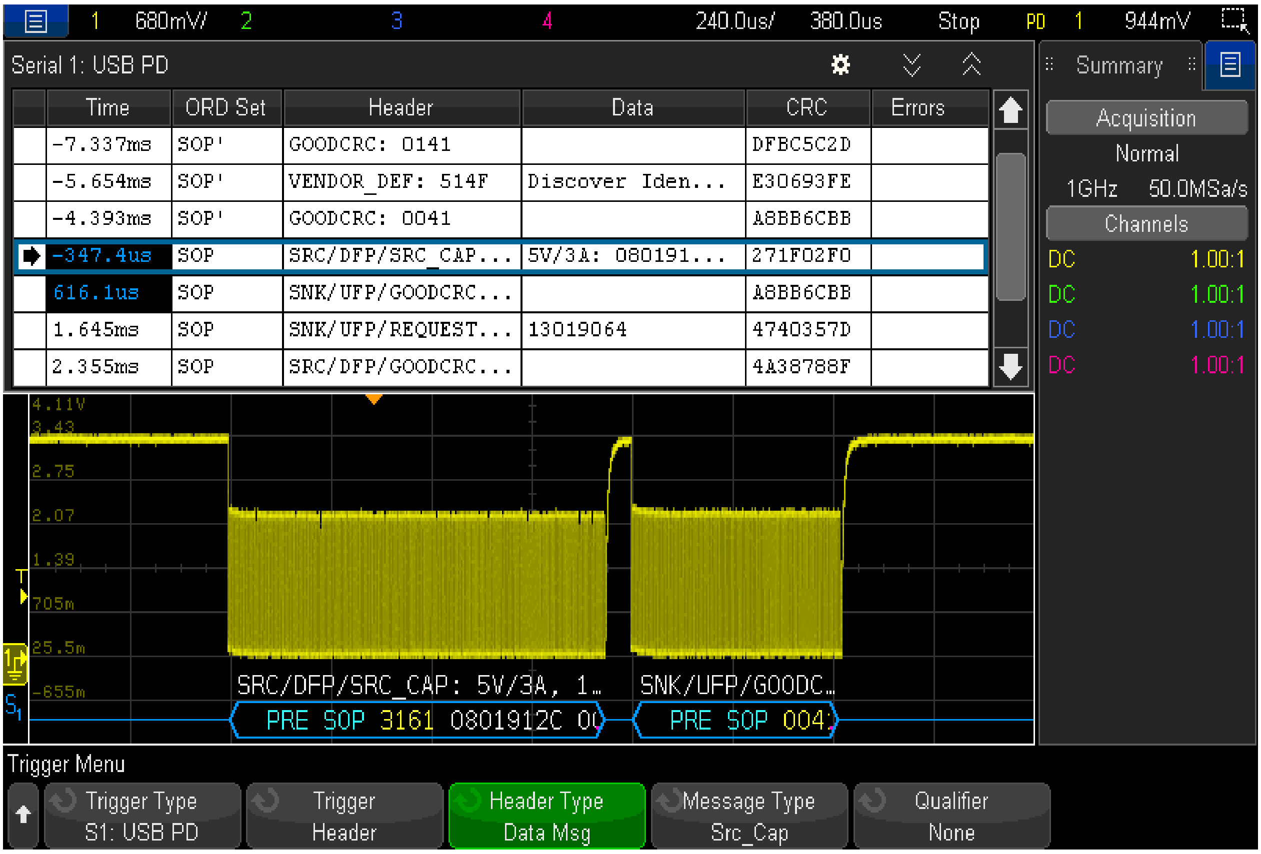

Figure 14. USB PD decode on an InfiniiVision X-Series

Mask Test

If you need to validate the quality and stability of your electronic components and systems, the InfiniiVision oscilloscope’s mask/waveform limit testing capability, which is enabled with the Power Software Package, 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.

The InfiniiVision scope’s mask testing is based on hardware-based technology, meaning that they can perform up to 270,000 real-time waveform pass/fail tests per second. This makes your testing throughput orders of magnitude faster than you can achieve on other oscilloscope mask test solutions.

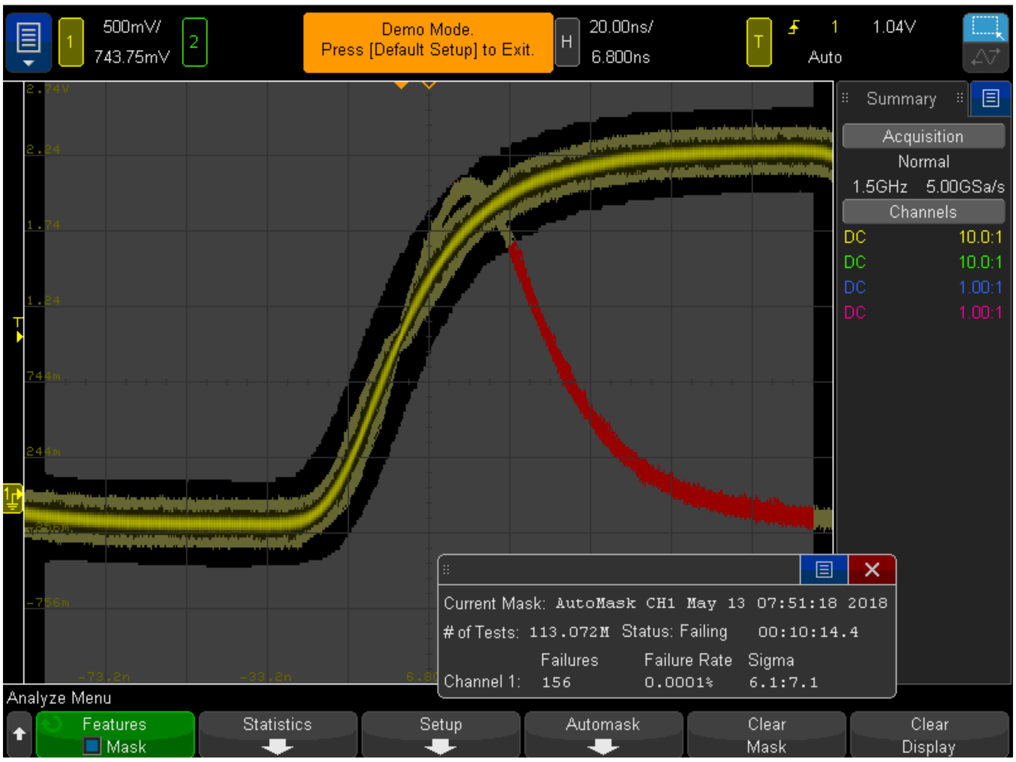

Figure 15. Frequency response of a bandpass filter.

Features

- Test up to 270,000 waveforms per second with the industry’s fastest hardware-accelerated 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

Table 4. Mask Test Performance Characteristics

Performance Characteristics	
Mask test source	Analog channels 1, 2, 3, or 4
Maximum test rate	2000 X-Series: Up to 50,000 waveforms tested per second
	3000 and 4000 X-Series: Up to 270,000 waveforms tested per second
	6000 X-Series: Up to 130,000 waveforms tested per second
Acquisition modes	Real-time sampling–non-averaged, Real-time sampling–averaged
Mask creation	
• Automask-divisions	± X divisions, ± Y divisions
• Automask-absolute	± X seconds, ± Y volts
• Mask file import	Up to 8 failure regions (created in text editor)
Mask scaling	Source lock on (mask automatically re-scales with scope settings)
	Source lock off (mask scaling fixed relative to display when loaded or created)
Test criteria	Run until forever, Minimum number of tests, Minimum time, Minimum sigma
Action on error	Stop acquisitions, save image, print, perform measurements
Trigger output	On failure
Statistics display	Number of tests, Number of failures (for each channel tested), Failure rate (for each channel tested), Test time (hours – minutes – seconds), Sigma (actual versus maximum without failures)
Display formats	Mask – translucent gray, Failing waveform segments – red, Passing waveform segments – channel color
Save/recall	4 non-volatile internal registers (.msk format), USB memory stick (.msk format)

Advanced Waveform Math (3000A X-Series only)

Advanced waveform math functions come standard on all models of the InfiniiVision X-Series oscilloscopes except for the 3000A Series. Refer to the appropriate InfiniiVision X-Series oscilloscope data sheet to see a complete list of standard waveform math functions on each model. When licensed with Power Software Package, advanced waveform math functions are also enabled on the InfiniiVision 3000A Series oscilloscope.

The Keysight 3000A X-Series oscilloscopes come standard with the following waveform math functions:

- Add
- Subtract
- Multiply
- Divide
- Integrate
- Differentiate
- Square Root
- FFT

The Power Software Package adds the following waveform math functions on the Keysight 3000A X-Series:

- Ax + B
- Square
- Absolute
- Common Logarithm
- Natural Logarithm
- Exponential
- Base 10 Exponential
- Low-pass Filter
- High-pass Filter
- Measurement Trend
- Magnify
- Chart Logic Bus Timing
- Chart Logic Bus State

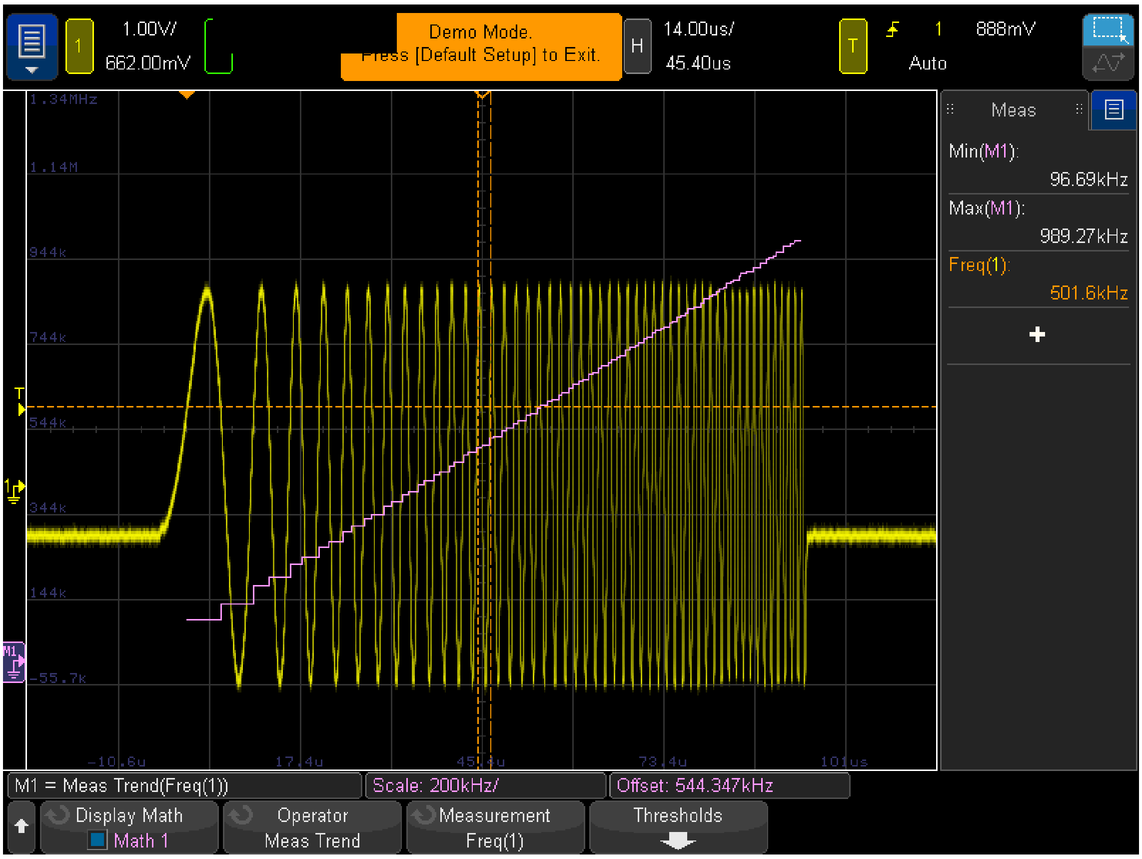

Figure 16. Measurement trend math function used to plot frequency versus time of a FM burst.

Related Literature

Table 5. Related literature

Publication title	Publication number
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
InfiniiVision 3000T X-Series Oscilloscopes, Data Sheet	5992-0140EN
InfiniiVision 4000 X-Series Oscilloscopes, Data Sheet	5991-1103EN
InfiniiVision 6000 X-Series Oscilloscopes, Data Sheet	5991-4087EN
M924XA InfiniiVision PXIe Modular Oscilloscopes, Data Sheet	5992-2003EN
P924XA InfiniiVision USB Oscilloscopes, Data Sheet	5992-2897EN
InfiniiVision Oscilloscope Probes and Accessories, Selection Guide	5968-8153EN

Ordering Information

Table 6. Power Software Package model numbers

InfiniiVision Series	Power Software Package
3000 X-Series	D3000PWRB
4000 X-Series	D4000PWRB
6000 X-Series	D6000PWRB
M9240 Series	M9240PWRB

Table 7. 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
N2893B	100 MHz, 15 A AC/DC current probe with AutoProbe interface
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	
N2790A	100 MHz, ± 1.4 kV differential probe (USB powered, N2779A not required)
N2791A	25 MHz, ± 700 V differential probe with AutoProbe interface
N2804A	300 MHz, ± 300 V differential probe with AutoProbe interface
N2805A	200 MHz, ± 100 V differential probe with AutoProbe interface
N2891A	70 MHz, ± 7 kV 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 ±24V offset capability with AutoProbe interface