DATA SHEET

M9602A and M9603A PXIe Precision Source/Measure Units

15 MSa/s, 1 pA/100 fA, 60 V, 3.5 A DC/10.5 A pulse

PXIe precision SMU with a best-in-it-class narrow pulse width as narrow as 10 µs, a fast sampling rate of up to 15 MSa/s and a wide output range enabling dynamic/pulsed measurements for broad emerging applications such as VCSEL optical devices and IC testing.

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Introduction

With the growing importance of dynamic and pulsed measurements in emerging fields such as device characterization and circuit testing, there is new demand for the ability to utilize source/measure unit (SMU) in DC, dynamic, and pulsed measurements. The Keysight M9602A and M9603A are PXIe precision SMUs which offer a best-in-their-class narrow pulse width of 10 μs, a fast sampling rate of up to 15 MSa/s, and a wide output range. They enable dynamic/pulsed measurements for a broad range of emerging applications such as vertical cavity surface emitting laser (VCSEL) optical devices, integrated circuit (IC) testing across a wide output range of up to 60 V/3.5 A DC/10.5 A pulse, and high resolution to a precision of 6 μV/100 fA. In addition, the M9602A and M9603A improve test throughput by providing low-noise performance of as low as 400 fArms at 1 power line cycle (PLC) for low current measurements of less than nA, which enables measurements with shorter aperture times. The seamless current measurement ranging function also eliminates range change time. These capabilities make the M9602A and M9603A ideal for emerging applications that require dynamic/pulsed measurements.

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10 µs Narrow pulse and 15 MSa/s high sampling rate enabling emerging dynamic/pulsed measurements

Dynamic/pulsed measurements are getting more important in emerging applications such as VCSEL optical devices and IC testing. The evaluation of the VCSEL optical devices requires narrow current pulse applications with a duration of tens of microseconds to suppress the self-heating effects during measurement. In addition, the capability of measuring at fast sampling rates is also required to capture such a narrow pulse while ensuring its output. IC testing also requires a sampling rate of more than 10 MSa/s to capture its dynamic behavior. The M9602A and M9603A have the capability to apply narrow pulse at a width as small as 10 µs and enable dynamic/pulsed measurements at a sampling rate of up to 15 MSa/s.

There are a variety of cables available for electrical measurements. However, it is important to select cables with less inductance when applying a narrow current pulse with a width as small as 10 µs, because cable inductance is critical when applying a clean and narrow current pulse. Keysight provides the PX0104A Low Inductance Cable for the M9602A and M9603A, enabling the application of a clean and narrow current pulse. Another issue of cable inductance is the voltage drop on the measurement cable when applying a narrow current pulse. The Remote Transient Voltage Measurement function of the M9602A and M9603A has a dedicated voltmeter with higher bandwidth and reduces the influence of cable inductance and voltage drop on the measurement cable using a 4-wire connection when applying narrow current pulse. Once the function is enabled, the M9602A and M9603A can make transient measurements of voltage at the device terminal with reducing the influence of cable inductance when applying a narrow current pulse.

These capabilities make the M9602A and M9603A suitable for emerging applications such as VCSEL optical devices and IC testing with enabled dynamic/pulsed measurements.

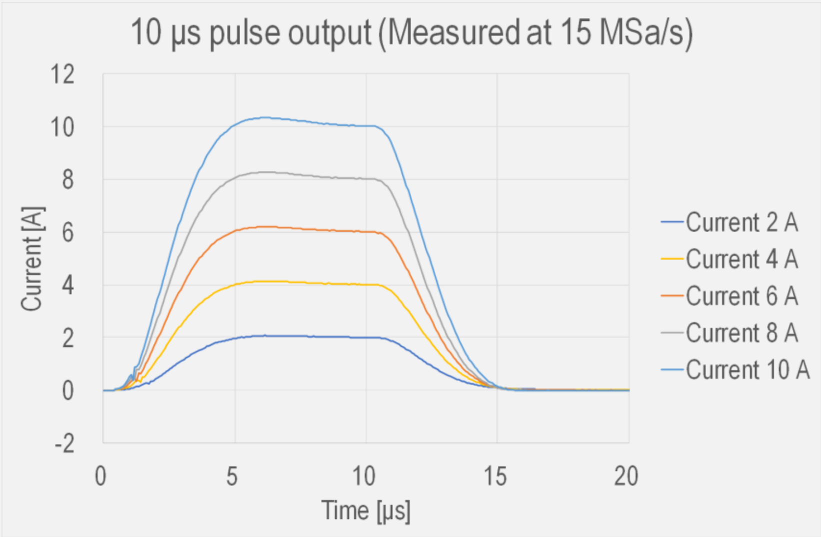

Figure 1. Narrow pulse output with measuring at 15 MSa/s sampling rate

Fast throughput with PXIe advantages, lower measurement noise, and seamless current measurement ranging

Throughput improvement is always a challenge in the manufacturing test for reducing test costs. The M9602A and M9603A fully utilize PXIe advantages such as increased testing speed thanks to the PCIe bus speed and an embedded PC controller, improving test throughput.

The low measurement noise performance is also important for low-level measurement, as is the high measurement resolution capability, which shortens the measurement time. The long aperture time is commonly used to eliminate measurement noise, especially for small current measurement, but this also increases the measurement time. The Keysight M9603A can achieve a 400 fArms noise level with 1 power line cycle (PLC) aperture time (at 50 Hz power line frequency), which is more than two times lower than the conventional PXIe SMU under the same conditions (aperture time) and five times faster than the conventional PXIe SMU module in achieving the same level of noise (please see Figures 2 and 3). This capability enables you to shorten the measurement time significantly for low current measurement less than nA.

Because conventional PXIe SMUs work with fixed measurement range operation, you must continually measure and change ranges to make wide dynamic range measurements and to find the range that provides the most precise results. That process increases testing time. The seamless current measurement ranging function of the M9602A and M9603A enables the SMU channel to make a wide dynamic range measurement without range changing. It automatically detects which current measurement range will return the most precise measurement. As a result, the SMU channels can eliminate the time it takes to change the range, which reduces testing time.

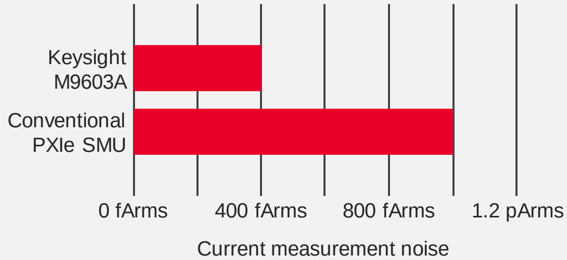

Figure 2. Current measurement noise with 1 PLC (20 ms) aperture time for low current measurement less than nA

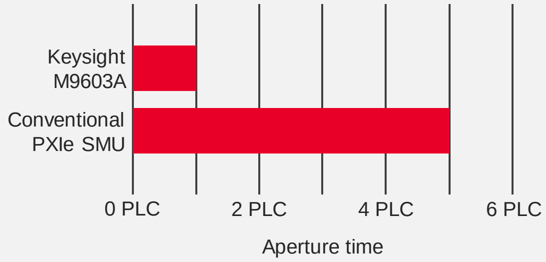

Figure 3. Aperture time required to achieve 400 fArms current measurement noise

Broad coverage from low current to high current via a single module

IC testing needs to cover characteristics more widely between its stand-by, sleep, and active states. While the stand-by current of the circuit is decreasing with the reduction of the circuit power consumption, active currents from devices such as power amplifiers remain. The evaluation of the VCSEL optical devices requires pulse application with a high current pulse peak to suppress self-heating effects during the measurement.

The M9602A and M9603A integrate different source and measurement capabilities into a single PXIe module (please see Figure 4). They enable flexible I/V measurements from DC to pulsed measurements with the capability of a wide output range of up to 60 V/3.5 A DC/10.5 A pulse with a resolution as low as 6 µV/100 fA. Low current measurements (< 1 nA) require guarding to prevent leakage through the measurement cable. The triaxial output of the M9602A and M9603A with the triaxial cable ensures stable low current measurement with a 100 fA minimum resolution using the guarding technique. These capabilities enable the M9602A and M9603A to achieve broad coverage from low current to high current via a single module for a variety of the applications.

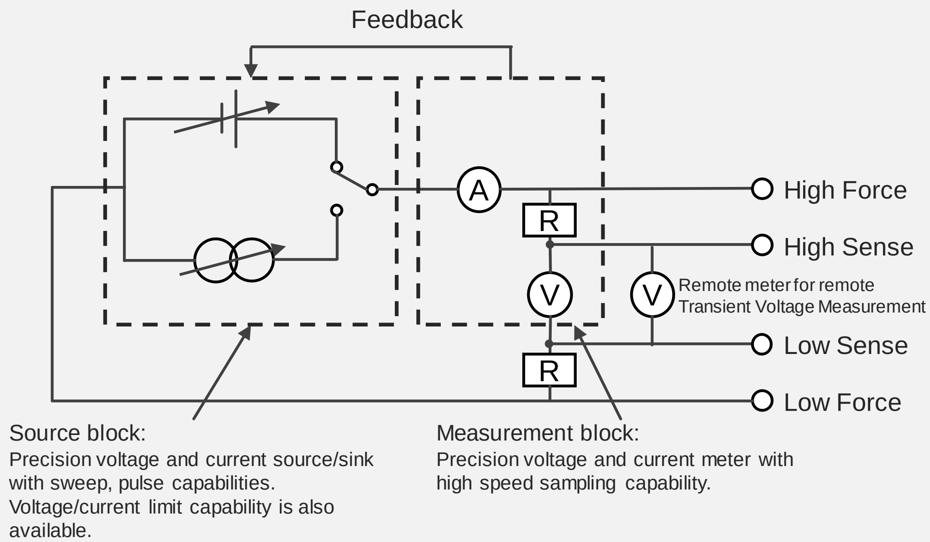

Figure 4. Simplified block diagram of the SMU channel in the M9602A and M9603A

Drivers and Soft Front Panel

The M9602A and M9603A come with IVI-C, IVI.NET, and LabVIEW software drivers for Microsoft Windows 7 Professional SP1 or later (32-bit and 64-bit), Windows 8.1 Professional or later (32-bit and 64-bit), and Windows 10 (32-bit and 64-bit). These software drivers work in the most common test and measurement development environments, including Visual Studio (VB.NET, C#, C, and C++), LabVIEW, MATLAB, and VEE.

The soft front panel provides easy-to-use instrument control (Figure 5). Its user-friendly graphical user interface guides developers through module setup so users can quickly configure the SMUs.

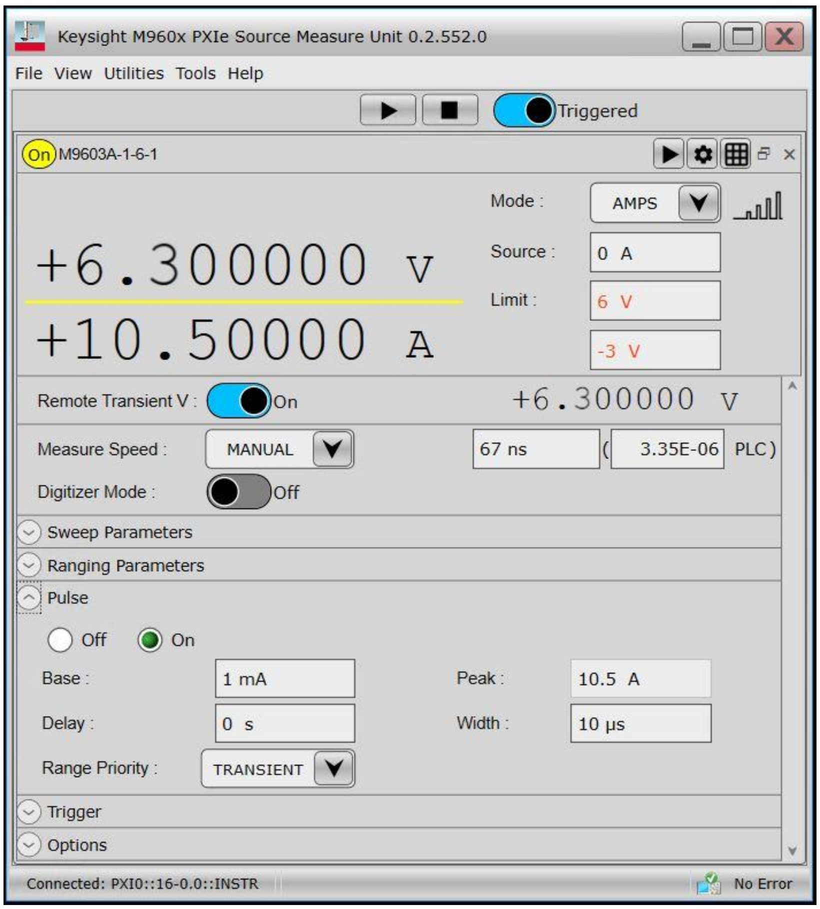

Figure 5. The M9603A's soft front panel

Specification

Specification conditions

The measurement and programming accuracy are specified at the front-panel connector terminals. Accuracy is specified under the following conditions:

Temperature		0 °C to 45 °C
Humidity	Minimum	10% RH, non-condensing
	Maximum	80% RH up to 40 °C, decreases linearly to 60% RH at 45 °C [1], non-condensing
Warm-up time		40 minutes
Self-calibration		Performed within the last 24 hours
		Ambient temperature changes less than ± 5 °C after self-calibration execution
Calibration period		One year
Aperture time		1 PLC [2]
Terminal connection		4-wire connection (Kelvin connection)

1. From 40 °C to 45 °C, the maximum % Relative Humidity follows the line of constant dew point.
2. Power line cycle.

Maximum voltage and current

DC output ranges

Voltage range		Current range	
Min	Max	Min	Max
- 0.6 V	+ 5.5 V	-130 mA	+ 3.5 A
- 2 V	+ 6.3 V		+ 3 A
- 2 V	+ 14 V		+ 2 A
- 6.3 V	+ 20 V		+ 1.5 A
- 12 V	+ 20 V		+ 0.8 A
- 20 V	+ 20 V		+ 0.5 A
- 50 V	+ 50 V		+ 130 mA
- 60 V	- 50 V	- 130 mA	+ 100 mA
+ 50 V	+ 60 V	- 100 mA	+ 130 mA

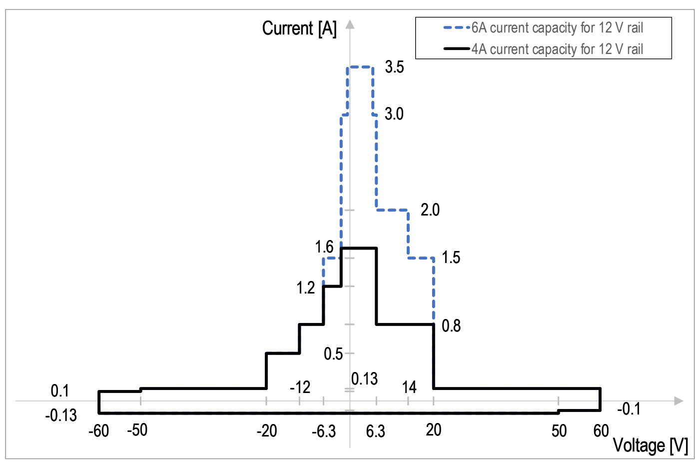

Figure 6. DC voltage and current output range

Pulsed output ranges

Voltage range		Current range	
Min	Max	Min	Max
- 3 V	+ 6.3 V	- 1 A	+ 10.5 A
- 10.5 V	+ 10.5 V		+ 5 A
-10.5 V	+ 20 V		+ 3.5 A

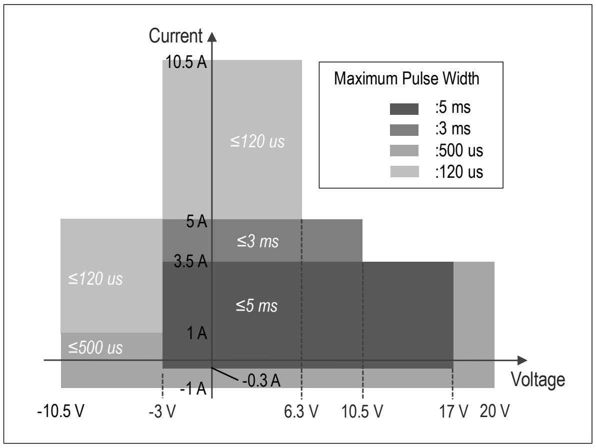

Figure 7. Pulsed voltage and current output range

Source/measurement specifications and characteristics

Voltage source/measurement specifications

Range	Programming and measurement		Tempco (% of reading + offset)/°C, 0 °C to 45 °C
	Resolution	Accuracy (% of reading + offset), Tcal [1] ± 5 °C	
± 6 V	6 μV	± (0.02% + 300 μV)	± (0.0005%+1 μV)
± 20 V	60 μV	± (0.02% + 3 mV)	± (0.0005%+1 μV)
± 60 V	60 μV	± (0.02% + 3 mV)	± (0.0005%+1 μV)

1. Tcal: Ambient temperature when self-calibration was performed.

Remote transient voltage measurement specifications

Range	Measurement		Tempco (% of reading + offset)/°C, 0 °C to 45 °C
	Resolution	Accuracy (% of reading + offset), Tcal [1] ± 5 °C	
± 6 V	6 μV	± (0.055% + 300 μV)	± (0.0005%+1 μV)
± 20 V	60 μV	± (0.055% + 3 mV)	± (0.0005%+1 μV)
± 60 V	60 μV	± (0.055% + 3 mV)	± (0.0005%+1 μV)

1. Tcal: Ambient temperature when self-calibration was performed.

Over range (% of range)	
6 V range	105%
Other ranges	100%

Current source/measurement specifications

Range	Programming and Measurement		Tempco (% of reading + offset)/°C, 0 °C to 45 °C
	Resolution	Accuracy (% of reading + offset), Tcal [1] ± 5 °C	
± 100 nA [2]	100 fA	± (0.07% + 100 pA)	± (0.0006% + 2 pA)
± 1 μA	1 pA	± (0.07% + 100 pA)	± (0.0006% + 4 pA)
± 10 μA	10 pA	± (0.05% + 700 pA)	± (0.0006% + 135 pA)
± 100 μA	100 pA	± (0.05% + 6 nA)	± (0.0006% + 200 pA)
± 1 mA	1 nA	± (0.05% + 60 nA)	± (0.0006% + 2 nA)
± 10 mA	10 nA	± (0.05% + 600 nA)	± (0.0006% + 20 nA)
± 500 mA	500 nA	± (0.13% + 30 μA)	± (0.0006% + 1 μA)
± 1 A	1 μA	± (0.13% + 60 μA)	± (0.0006% + 2 μA)
± 3 A	3.5 μA	± (0.3% + 1 mA)	± (0.0025% + 33 μA)
± 3.5 A	3.5 μA	± (0.3% + 1 mA)	± (0.0025% + 33 μA)
± 5 A	5 μA	± (0.13% + 1 mA) [3, 4]	± (0.002% + 33 μA) [3, 4]
		± (0.3% + 1 mA) [5]	± (0.002% + 33 μA) [5]
± 10 A [3]	10 μA	± (0.13% + 1 mA) [4]	± (0.002% + 33 μA) [4]

1. Tcal: Ambient temperature when self-calibration was performed.
2. 100 nA range is available only with the M9603A.
3. Typical. Only current source mode is available.
4. Aperture time: 0.002 PLC (40 μs). Repeat measurements 10 times and average them.
5. When Pulse Range Priority is set to Power. Aperture time: 0.1 PLC (2 ms). Repeat measurements 10 times and average them.

Seamless current measurement ranging specifications

Range	Measurement		Tempco (% of reading + offset)/°C, 0 °C to 45 °C
	Resolution	Accuracy (% of reading + offset), Tcal [1] ± 5 °C	
± 10 mA	10 nA	± (0.23% + 5.5 μA)	± (0.0006% + 20 nA)

Over range (% of range)	
10 A range	105% for positive current
	10% for negative current
5 A range	100% for positive current
	20% for negative current (6% when Pulse Range Priority is set to Power)
3 A, 3.5 A ranges	100% for positive current (Negative current is limited to -130 mA)
500 mA, 1 A ranges	105% for positive current (Negative current is limited to -130 mA)
Other ranges	105%

Example of calculating accuracy with temperature coefficient

Calculate the accuracy of a 500 μA output in the 1 mA range. Assume the ambient temperature is 15 °C within the last 24 hours after self-calibration was performed at 19 °C. The ambient temperature changes less than ± 5 °C after self-calibration execution but falls outside of 23 °C ± 5 °C.

$$\text{Temperature Variation} = (23℃ - 5℃) - 15℃ = 3℃$$

$$\text{Accuracy} = (500\ \mu\text{A} * 0.03\% + 60\ \text{nA}) + \frac{500\ \mu\text{A} * 0.0006\% + 2\ \text{nA}}{1℃} * 3℃$$

$$= 210\ \text{nA} + 15\ \text{nA} = 225\ \text{nA}$$

Therefore, the actual output will fall within 225 nA of 500 μA.

Operation Mode

Operation Mode	Normal mode	
	PS mode	Only V source mode is available.
	High capacitance mode	Only V source mode is available. Current ranges from 10 μA to 3.5 A are available.

Source supplemental characteristics

Current compliance setting accuracy	Accuracy is same as current source; minimum value is 1% of range (100 nA to 3.5 A ranges)	
Voltage compliance setting accuracy	Accuracy is same as voltage source; minimum value is 1% of range (6 V to 60 V ranges)	
Over-temperature protection	SMU shutdowns at over temperature sensed internally	
Voltage output settling time	Time required to reach within 0.1% of final value at described load condition; step is 10% to 90% range with 10 mA compliance, filter auto settings	
	6 V range, open load	< 10 µs
	20 V range, 50 kΩ load	< 13 µs
	60 V range, 200 kΩ load	< 26 µs
Slew Rate [1]	2.3 V/µs (Standard mode with 10 mA range 10.5 mA compliance)	
	3.5 V/µs (PS mode with 500 mA range 130 mA compliance)	
Current output settling time (DC)	Time required to reach within 0.1% of final value at described load condition; step is 10% to 90% range; with 6 V or 5.5 V compliance, filter auto settings	
	100 nA, 1 µA ranges, 500 kΩ load	< 3.2 ms
	10 uA, 100 µA ranges, 5 kΩ load	< 600 µs
	1 mA, 10 mA ranges, 50 Ω load	< 80 µs
	500 mA, 1 A ranges, 100 mΩ load	< 20 µs
	3 A, 3.5 A ranges, 100 mΩ load	< 70 µs
Current output settling time (Pulse) [1]	Time required to reach within 1% of final value at described load condition; step is 100 mA to 90% range for transient priority mode and is 10% to 90% range for power priority mode; with 6 V compliance; filter auto settings; load is connected through 1.5 m low inductance BNC cable (PX0105A-001)	
	Power priority mode, 5 A range, 100 mΩ load	< 45 µs
	transient priority mode, 5 A range, 100 mΩ load	< 4.5 µs
	transient priority mode, 10 A range, 100 mΩ load	< 6 µs
V source noise: BW = 20 MHz	< 3.5 mVrms, < 40 mVp-p	
V source noise: BW = 200 MHz	< 6 mVrms, < 70 mVp-p	
Load transient response time in voltage source mode	Time to recover to within the settling band With 4.7 µF cap (ESR = 50 mΩ) at load, remote sensing at cap 6 V range with 4 V source, + 3.5 A/- 130 mA compliance in Normal mode	
	Rise time (10% to 90%)	1 µs
	Settling band (with a step from 0.3 A/1.5 A to 1.5 A/0.3 A)	± 20 mV
	Recovery time	< 20 µs
Voltage load regulation	Load regulation error is included in voltage accuracy specification (typical)	
Current load regulation	Load regulation error is included in current accuracy specification as specification for |Vo [2]| ≤ 40 V, as typical for 40 V < |Vo [2]|	

1. Observed data.
2. Vo is the output voltage.

Pulse source supplemental characteristics

Programmable pulse width	5 μs to 1 s
Minimum pulse width programming resolution	0.2 μs
Pulse width programming accuracy	0.5% ± 2 μs
Pulse period programming accuracy	0.5% ± 4 μs
Pulse width definition	The time from 10% leading to 90% trailing edge (Figure 8)

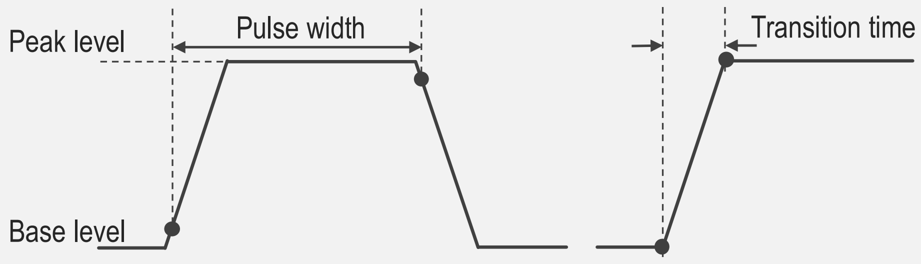

Figure 8. Definition of the pulse parameters and the transition time

Maximum pulse width and duty cycle in 1st quadrant

Range	Pulsed					DC	
	Max Voltage	Max Peak Current	Max Base Current	Programmable Pulse Width	Max Duty Cycle	Max Voltage	Max Current
DC ranges	+ 60 V	+130 mA	+130 mA	5 μs to 1 s	99.9999%	+ 60 V	+130 mA
	+ 20 V	+ 1.5 A	+ 1.5 A	5 μs to 1 s	99.9999%	+ 20 V	+ 1.5 A
	+ 14 V	+ 2 A	+ 2 A	5 μs to 1 s	99.9999%	+ 14 V	+ 2 A
	+ 6.3 V	+ 3 A	+ 3 A	5 μs to 1 s	99.9999%	+ 6.3 V	+ 3 A
	+ 5.5 V	+ 3.5 A	+ 3.5 A	5 μs to 1 s	99.9999%	+ 5.5 V	+ 3.5 A
Pulse ranges	+ 6.3 V	+10.5 A	105 mA	5 μs to 120 μs	1%		
	+ 6.3 V	+ 5 A	105 mA	5 μs to 500 μs	3%		
	+ 10.5 V	+ 5 A	105 mA	5 μs to 120 μs	1%		
	+ 20 V	+ 3.5 A	105 mA	5 μs to 500 μs	5%		
	+ 20 V	+ 1 A	105 mA	5 μs to 500 μs	3%		
	+ 10.5 V [1]	+ 5 A [1]	1.05 A [1]	5 μs to 3 ms [1]	10% [1]		
	+17 V [1]	+ 3.5 A [1]	1.05 A [1]	5 μs to 5 ms [1]	15% [1]		

1. When Pulse Range Priority is set to Power with 5 A range.

Transition time at the given voltage, current, and settling conditions (observed data)

Source value	Limit value	Operation mode	Load	Source settling band (% of range)	Transition time
60 V	130 mA	Standard	200 kΩ	0.1%	1.1 ms
60 V	130 mA	PS	200 kΩ	0.1%	30 µs
3.5 A	6 V	Standard	100 mΩ	1%	40 µs
5 A	6 V	Standard	100 mΩ	5%	30 µs

Transition time definition: The time from “Source settling band” to “100% — Source settling band” leading edges (Figure 8).

Measurement and timing characteristics

Available sampling rates		(15 MSa/s)/N where N=1, 2, 3, …, 2^{25}
Sample rate accuracy		Frequency accuracy is inherited from PXIe_CLK100
Maximum measure rate to host		15 MSa/s
Maximum source update rate		250 kSa/s
Input trigger to	Source/sense trigger delay	≤ 5 µs
	Source/sense trigger jitter	≤ 4 µs

Other supplemental characteristics

Timer	
Timestamp	Timer value automatically saved when each measurement is triggered
Trigger timing resolution	4 µs to 100 ms
Clock source	PXIe_CLK100
Arm/trigger delay	0 µs to 100,000 s
Arm/trigger interval	4 µs to 100,000 s
Arm/trigger event	1 to 1,000,000 (count)

Input Triggers		
Sources (PXI trigger lines 0 to 7, external trigger 0 and 1)	Polarity	Configurable
	Minimum pulse width	200 ns, nominal

Output Triggers		
Destinations (PXI trigger lines 0 to 7, external trigger 0 and 1)	Polarity	Configurable
	Pulse width	Configurable between 200 ns and 12.8 µs, nominal

Output characteristics			
Sensing modes		2-wire or 4-wire (remote-sensing) connections	
Low terminal connection		Chassis grounded or floating	
Output connectors		Triaxial jack for high force and high sense, SMB jack for low sense	
Maximum guard offset voltage		< 2 mV	
Remote sense operation range		Max voltage between high force and high sense = 1 V	
		Max voltage between low force and low sense = 0.3 V	
Maximum load capacitance	Operation mode	Normal mode	High capacitance mode
	100 nA range	10 nF	Not supported
	1 μA range	100 nF	Not supported
	10 μA range	1 μF	100 μF, ESR ≥ 25 mΩ
	100 μA range	10 μF	100 μF, ESR ≥ 25 mΩ
	Other ranges	100 μF, ESR ≥ 25 mΩ	100 μF, ESR ≥ 25 mΩ
Guard output impedance		3.1 kΩ (nominal)	
Maximum DC floating voltage		± 40 V between low force and chassis	

Environmental specifications

Environment			For indoor use
Operating	Temperature		0 °C to 45 °C
	Humidity	Minimum	10% RH, non-condensing
		Maximum	80% RH up to 40 °C, decreases linearly to 60% RH at 45 °C [1], non-condensing
Storage	Temperature		-40 °C to 70 °C
	Humidity		5% to 90% RH, non-condensing
Altitude			Operating: 0 m to 2,000 m; storage: 0 to 4,600 m
Power consumption			+ 3.3 V ± 5%, 1 A
			+ 12 V ± 5%, 4 A [2] or 6 A [3]
EMC			IEC61326-1/EN61326-1, IEC61326-2-1/EN61326-2-1, CISPR 11/EN55011 Group 1 Class A, ICES-001, AS/NZS CISPR11, KN61000-6-1, KN11
Safety			IEC61010-1/EN61010-1, IEC61010-2-030/EN61010-2-030, CAN/CSA-C22.2 No. 61010-1, CAN/CSA-C22.2 No. 610102-030
Compliance and certifications			CE, cCSAus, RCM, KC
Warm-up			40 minutes
Dimensions			3U, 1-slot PXIe module, Height 20.1 mm x depth 131 mm x width 210 mm
Weight			0.28 kg

1. From 40 °C to 45 °C, the maximum % Relative Humidity follows the line of constant dew point.
2. With mode for the chassis supporting 4 A backplane pin current capacity for 12 V rail.
3. With mode for Keysight M9018B, M9019A or the other chassis supporting 6 A backplane pin current capacity for 12 V rail.

Source/measurement capabilities

Sweep measurement	
Number of steps	1 to 2,000
Sweep mode	Linear or list
Sweep direction	Single or double
Type	DC or pulse
Min programmable value to create list sweep waveform	4 µs

Digitizing/Sampling measurement	
Max sampling rate	15 MSa/s

Data buffers	
Max buffer size	500,000 points
	Limited to 100,000 points when measuring with the rate at 15 MSa/s
	Limited to 300,000 points when enabling Remote Transient Voltage Measurement function and setting Trigger Count to >1
	Limited to 30,000 points when enabling Remote Transient Voltage Measurement function and measuring with the rate at 15 MSa/s

Program, software, and drivers	
Supported operating systems	Microsoft Windows 7 Professional SP1 or later (32-bit/64-bit), Windows 8.1 Professional (32-bit/64-bit), Windows 10 (32-bit/64-bit)
Standard-compliant drivers	IVI-C, IVI.NET, LabVIEW
Supported application development environment (ADE)	Visual Studio (VB.NET, C#, C/C++), LabVIEW, MATLAB, VEE
.NET Framework	Microsoft .NET Framework 4.5.2 or later
Keysight IO libraries	Keysight IO Libraries Suite 2019 or later

Furnished Accessories

Furnished accessories
Short bar, connector-terminal block 2.5 mm 6-terminal, certificate of calibration (without test data), quick startup poster

Ordering Information

Model number	
M9602A	PXIe Source/Measure Unit, 15 MSa/s, 1 pA, 60 V, 3.5 A DC/10.5 A pulse
M9603A	PXIe Precision Source/Measure Unit, 15 MSa/s, 100 fA, 60 V, 3.5 A DC/10.5 A pulse

Options	
1A7	Calibration + uncertainties + guardbanding (not accredited)
A6J	ANSI Z540-1-1994 calibration
UK6	Commercial calibration certificate with test data

Accessories	
PX0101A-001	BNC-to-ferrule terminal cable, 1.5 m
PX0101A-002	BNC-to-ferrule terminal cable, 3 m
PX0103A-001	Triaxial to SMB Cable, 1.5 m
PX0103A-002	Triaxial to SMB Cable, 3 m
PX0104A-001	High Current Triaxial Cable, 4 A, 1.5 m
PX0104A-002	High Current Triaxial Cable, 4 A, 3 m
PX0105A-001	Low Inductance BNC Cable, 1.5 m
PX0105A-002	Low Inductance BNC Cable, 3 m
PX0108A-001	BNC-to-SMB cable, 1.5 m
PX0108A-002	BNC-to-SMB cable, 3 m

Learn more at: www.keysight.com

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