DATA SHEET

# M9614A and M9615A PXIe 5-Channel Precision Source/Measure Units

500 kSa/s, 100 pA/10 pA, 30 V, 500 mA

The single-slot PXIe SMUs are meant for broad applications requiring high channel density with wide output up to 30 V/500 mA and fast throughput at a low cost per channel





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## Introduction

The Keysight M9614A and M9615A are PXIe five-channel precision source / measure units (SMUs). They support accurate measurement up to 30 V / 500 mA with resolution down to  $6 \mu \text{V}$  / 10 pA. While a PXIe SMU improves channel density compared with a benchtop SMU, the M9614A and M9615A enable higher channel density in the same footprint. They also provide a wider output range than a conventional PXIe four-channel SMU at a lower cost per channel. Pulsed and sampling capabilities allow the M9614A and M9615A to perform a variety of measurements, from DC to pulsed measurements, with pulse width down to 100 µs at a sampling rate of 500 kSa/s. Their seamless current measurement ranging function reduces test duration by eliminating the time it takes to change the range and expands the dynamic range to cover four measurement ranges. These capabilities make the M9614A and M9615A suitable for applications that require high channel density, such as semiconductor reliability testing and integrated circuit (IC) tests.

Features	Benefits		
5 channels, higher density per a single-slot module	Higher channel scalability and density at a lower		
Lower cost per channel	cost in the same footprint		
Wider output range, up to 30 V / 500 mA per channel			
Minimum 10 pA resolution for low current measurement	Broader application coverage by a single module		
Accurate and flexible measurements, from DC to pulsed measurements, with pulse width down to 100 $\mu$ s at 500 kSa/s sampling rate	including noise sensitive device/circuit evaluation such as quantum computing and analog/RF ICs		
25 $\mu$ Vrms low voltage source noise performance			
Seamless current measurement ranging			
PXIe advantages such as increased test speed thanks to PCIe bus speed and embedded PC controller	Faster throughput with PXIe advantages and seamless current measurement ranging		

## Overview

The M9614A and M9615A are suitable for a variety of applications that require multiple precision voltage or current sources, such as semiconductor reliability and IC testing. They enable higher channel scalability and density at a lower cost than conventional SMUs.

# Best fit for high-channel-density applications — higher channel scalability and density at lower cost

Semiconductor process shrink makes device reliability testing more important than ever. As a result, the number of test items increases. Channel scalability is critical to increase the number of devices measured simultaneously and reduce test time, but benchtop SMUs cannot meet the requirements from a footprint perspective. In IC testing, as circuits become more highly integrated, circuit evaluation requires a larger number of precision power supplies. For those applications, channel density, test speed, and cost are becoming significant challenges for conventional SMUs.

A PXIe SMU improves channel density in the same footprint compared with a benchtop SMU, especially for applications requiring numerous SMU channels. In addition, the M9614A and M9615A provide fivechannels-per-slot higher density at a lower cost per channel than conventional PXIe four-channel SMUs. That density improves the cost and space efficiency per channel and makes the M9614A and M9615A the best fit for high-channel-density applications.

#### Broader application coverage from a single module

Highly integrated circuit evaluations require multiple models of precision power supplies, depending on the requirements of the applications and circuit elements, because of the limited output range of conventional PXIe four-channel SMUs. The M9614A and M9615A enable accurate and flexible I/V measurements from DC to pulsed. They also enable the use of a single model for a variety of applications and circuit elements.

The M9614A and M9615A have five SMU channels in a single-slot PXIe module (Figure 1). Each channel has the capability of wide output range up to 30 V / 500 mA with resolution down to 6  $\mu$ V / 10 pA, pulsed measurement capability with pulse width down to 100  $\mu$ s, and high maximum sampling rate up to 500 kSa/s per channel.

The M9614A and M9615A have multiple ranges, enabling them to measure the different operating states of a device or circuit. The seamless current measurement ranging function expands the dynamic range. Select either of two ranging groups according to the characteristics of your device or circuit to cover four ranges in a measurement concurrently. This capability enables the M9614A and M9615A to evaluate static characteristics of the devices in both off and on states precisely. Users can capture the dynamic behavior of circuits, such as standby / sleep / active states, with a wide dynamic range from nA to sub-A or from pA to mA, depending on the selected ranging group.

The PX0107A Low Noise Filter Adapter for M9614/15 reduces the voltage source noise of the M9614A and M9615A to 25  $\mu$ Vrms in the frequency range of 10 Hz – 20 MHz, while still allowing it to source up to 30 V and 150 mA. It enables the M9614A and M9615A to evaluate noise sensitive devices and circuits such as quantum computing and many types of analog and RF ICs.

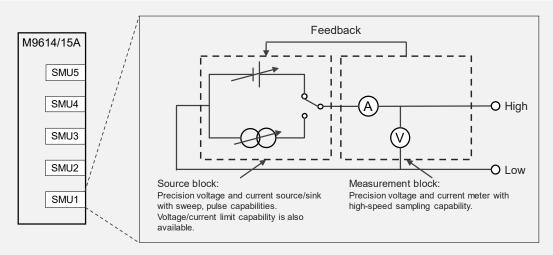


Figure 1. Simplified block diagram of the SMU channel in the M9614A and M9615A

#### Faster throughput with PXIe advantages and seamless current measurement ranging

Because conventional PXIe SMUs work with the 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 test time.

The seamless current measurement ranging function of the M9614A and M9615A enables the SMU channels 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 test time. The M9614A and M9615A fully utilize PXIe advantages such as increased test speed thanks to PCIe bus speed and embedded PC controller, improving test throughput.

#### Drivers and soft front panel

The M9614A and M9615A 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.

Standard Commands for Programmable Instruments (SCPI) are a popular and easy-to-understand instrument control protocol. The M9614A and M9615A support it as well, which will minimize code conversion work from the existing benchtop-based test system.

The soft front panel provides easy-to-use instrument control (Figure 2). Its user-friendly graphical user interface guides developers through module setup so users can quickly configure the SMUs.

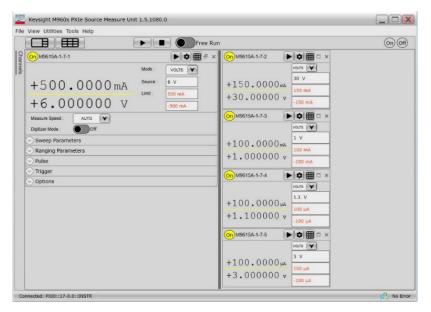


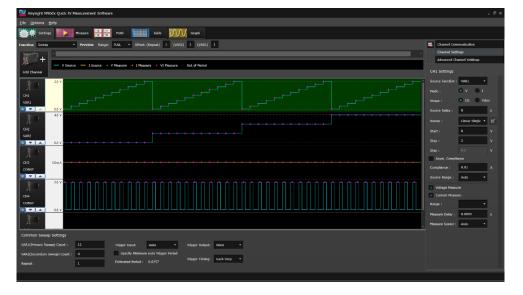
Figure 2. The M9615A's soft front panel

# PX0109A Quick I/V Measurement Software, essential and powerful software tool to control the PXIe Precision SMU

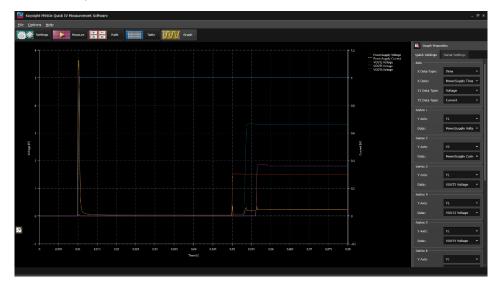
The Keysight PX0109A Quick I/V Measurement Software for PXIe Precision SMU has powerful measurement capabilities to control the M9601A, M9602A, M9603A, M9614A and M9615A. It supports a variety of functions such as a sweep measurement, a sampling measurement, graphical display functions and the ability to save test results into CSV files, which makes it easy to quickly setup and perform current-voltage (IV) measurements and to display the measurement data in tables and graphs without the need to program. It is licensed based and the licenses are sold as node-locked, floating, transportable and USB portable.

The PX0109A Quick I/V also allows you to control up to ten SMU channels so that you can measure devices or circuits requiring more than two SMU channels for characterization, verification, or test. In addition, the PX0109A Quick I/V has the capability to make not only primary sweep measurements but also measurements where a second terminal is swept, making it easy to generate a variety of IV curves.

The setup menu allows you to specify and preview the settings on up to ten SMU channels before you perform a measurement, giving you the flexibility and ease of setting up the SMU channels.



The built-in graph function supports both basic and advanced features (such as the family of curves shown here).



Numerical measurement results can be viewed in a table format, and this data can easily be copied into Excel for further analysis.

Keysight	M960x Quick IV N	leasurement Softw	are											
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	2.138678-006	-0.033538-005	100.00000-00	6 64.94579E-006	-473.533168-012	200.000000-006	26.187828-026	122.767861-012	100.000000-005	53.423158-006	613.839291-012	100.000306-005	35.615438-006	
	-14.97070E-005	-250.65104E-009	200.000000-00	6 14.66518E-006	-859.37500E-012	200.00000E-006	29.33035E-016	-999.68112E-012	200.00000E-005	26.18782E-006	70.15306E-012	200.00000E-006	47.13807E-006	-140.30512E-
	-10.69336E-006	10.79769E-005	300.00000E 00	6 37.71045E 006	-103.38010E-012	300.00000E-005	25.14031E 006	806.76020E-012	300.00000E-005	37.71046E 006	-2.00952E-009	300.00030E-005	59.70823E 006	-1.99936E
	8.55469E-006	6.62218E-006	400.00000C-00	6 -17.80772E-D06	508.63969E-012	400.00000E-006	51.32812E-016	1.21014E-009	400.00000E-005	-5.23756E-016	2.38520E-009	400.00000E-005	41.90051E-006	1.40306E-
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	-34.218758-006	-7.308278-005	200.00000E-00	6 10.47513E-006	-947.066338-012	700.0000E-005	48.185598-006	-2.315058-009	700.000000-005	23.045288-006	-648.91582E-012	700.00030E-005	28.282848-006	-894.45153E-
	16.04004E-006	30.740566-006	800.00000C-00			800.0000000-006	45.04305E-006	0.00000E+000	800.0000000-005	-23.04528E-006	-2.36767E-009	930.00030E-005	33.52041E-006	
	8.55469E-006	-15.15544E-006	900.00000E-00	6 21.99777E-006	-35.07653E-012	900.00000E-005	13.61767E-006	17.53827E-012	900.00000E-005	49.23310E-006	1.98182E-009	930.00030E-006	64.94579E-006	876.91327E-
	-10.69336E-006	17.81413E-006	1.00000E-00			1.0000tE-003	62.85077E-006	280.61224E-012	1.00000E-003	16.76028E-086	-1.06983E-009	1.00000E-003	55.51818E-006	-1.36798E-
	25.66406E-006	-6.40592E-00G	1.100086-08			1.10000E-013	34.56797E-006	508.60969E-012	1.100005-003	-17.80772E-006	2.37643E-009	1.10000E-003	35.615435-006	2.337596-
	-22.45605E-006	-27.76676E-006	1.20000E-000			1.20001€-013	42.94602E-016	-210.45918E-012	1.20000€-003	24.09279E-006	-999.68112E-012	1.20000E-003	42.94602E-006	-1.84152E-
	3.20001E-006	12.080498-006	1.300006-00			1-300000-003	40.85301E-016	-368-30357E-012	1-30000E-003	9.42761E-005	1.57844E-009	1.300005-003	80.658485-006	1-210146-
	7.485358-000	-11.528168-006	1.400000-000			1.40001E-003	27.235338-006	1.087376-009	1.400000-003	12.570158-006	-3.384896-009	1.460006-003	53.423150-006	350.765318-
	-18.17871E-806	-16.73722E-006	1.50000E-00			1.50000E-013	39.80548E-016	-508.60969E-012	1.50000E-003	34.56792E-016	1.26276E-009	1.50000E-003	54.47066E-006	-683.99235E-
	-18.17871E-006	18.88924E-005	1.50000E-00			1.50001E-003	21.99777E 016	438.45663E-012	1.50000E-003	25.14031E-006	2.68335E-009	1.50000E-003	64.94579E 006	-103.38010E
	24.59473E-006	12.89856E+006	1.70000E-00			1.70000€-003	47.13807E-006	280,61224E-012	1.70000E-003	21.99777E-006	-2.84120E-009	1.70000E-003	58.65071E-005	2.297516
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	37.42676E-006	-3.31038E-006	2.10000C-00			2.1000E-003	37.71046E-006	17.538276-012	2.10000E-003	9.42761E-006 27.23533E-006	-2.57812E-009	2.10000E-003	69.13584E-006	368.303570 -35.076538
1,23		-12.93359E-006	2.20000E-00			2.20001E-013	73.32581E-016	-438.45663E-012	2.20000E-003		-280.61224E-012	2.20000E-003	35.61543E-006	
1,24	7.48535E-006 2.13867E-006	27.88135E-006	2.30000E-00			2.3000E-003 2.4000E-003	39.80548E-006 42.94807E-006	824.29847E-012	2.30000E-003 2.40000E-003	12.57015E-016 39.80548E-016	-227.99745E-012 175.38765E-012	2.30000E-003 2.40000E-003	80.65648E-006 45.04305E-006	-385.84184E
1,25	16.04004E-006	21.13078E-006	2.50000E-00			2.50000E-003	38.75797E-016	806.76020E-012	2.50000E-003	27.23533E-016	2.84120E-009	2.50000E-003	47.13807E-006	2.01690E
1,25	7.485357-006	-6.069148-005	2.50000E-00.			2.50001E-003	38.75797E-006 14.66518F-006	789.221945-012	2.50000E-003	25.140316-006	-964.604597-012	2.50000E-003 2.50000F-003	14.56792E-006	-315.668785
1,28	0.000006+000	-31.72078E-006	2.700006-00			2.700006-003	40.053000-006	368.303576-012	2.70000E-003	43.995546-006	-491.071436-012	2.70000E-003	32.472908-006	-806.760201
1,78	7.48535E-106	-6,24837E-006	2.80001E-00			2.80000E-003	29,330365-006	403.38010F-012	2.80000E-003	10.47513E-006	947.06533F-012	2.80000E-003	18.85523E-006	-1,40306E
1,29	-35.28809E-000	-6.248372-000 -8.89185E-005	2.90000E-00			2.9000E-003	72.27838E-006	-2.36767E-009	2.9000E-003	5.23/56E-006	-491.07143E-012	2.90000E-003	36.65295E-006	-735.60714E
1,30	8.554695-006	19.645567-005	1.000000-000			3.00000E-003	56.56564F-006	947.05633E-012	3.000005-003	12.57015E-006	-1.66614E-009	3.00000E-003	35.61543E-006	1.385526
1,31	-11.76270E-106	17.06038E-005	3.10000E-00			3.10000E-003	57,61320E 006	-175.38265E-012	3.10000E-003	42.94802E-006	87,69123E-012	3.10000E-003	21.99777E 006	-2.26244E
1,32	22.45605F-006	3.00871E+006	3.200000-002			3.20000E-003	50.28061E-006	894.451530-012	3.20000F-003	-18.85523F-005	3.57761[-009	3.20000E-003	2.095030-006	701.530610
1,33	-0.41002E-006	-17.211678-006	1.10001E-01			3.30000E-003	19.90274E-006	-87.69133E-012	3.30000E-003	4.10005E-000	-683.992351-012	3.30000E-003	43.995548-006	473.533108
1,34	3.20901E-006	7.32349E-006	3.400010-01			3.40001E-013	24.09279E-006	210.45918E-012	3.40000E-003	42.94802E-016	0.00000E+000	3,40000E-003	54,47066E-006	-947.065330
1.06	12 515245 446	28 228705 000	2 500010-01			2 500016-010	58 660715 006	536 147055 013	2 510005-003	23 473015 016	401.071425.013	2 500005 003	20.050265.006	455 004005

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## 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 55 °C		
	Minimum	10% RH, non-condensing		
Humidity Maximum		80% RH up to 40 °C, decreases linearly to 35% RH at 55 °C $^{\rm 1},$ non-condensing		
Warm-up time		40 minutes		
		Performed within the last 24 hours		
Self-calibration		Ambient temperature changes less than $\pm$ 5 °C after self-calibration execution		
Calibration perio	d	One year		
Aperture time		1 PLC <sup>2</sup>		
Terminal connection		Kelvin connection		

1. From 40 °C to 55 °C, the maximum % Relative Humidity follows the line of constant dew point.

2. Power line cycle.

### Maximum voltage and current

#### Maximum voltage and current per channel

Maximum voltage	Channel	Maximum current	Maximum power
± 6.3 V	1, 2	+ 750 mA <sup>1</sup> , - 500 mA	+ 4.7 W, -3.2 W
± 6.3 V	3, 4, 5	± 500 mA	± 3.2 W
± 30 V	1, 2, 3, 4, 5	± 150 mA	± 4.5 W

1. Over range (150% of 500 mA range) for positive current.

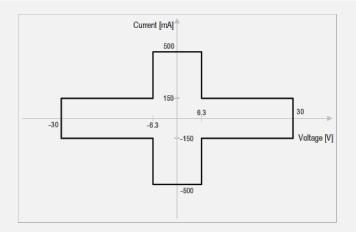


Figure 3. Voltage and current output capability per channel

#### Maximum voltage and current per module

Backplane pin current capacity of the chassis (12 V rail)	Quadrant	Maximum current per module (when channels work with ranges below)			
		6 V range	30 V range	6 V and 30 V ranges mixed <sup>1</sup>	
4 A	All	1.3 A	300 mA	$(I_{total(6V)}) / 1.3 + (I_{total(30V)}) / 0.3 \le 1$	
G A 2	1 <sup>st</sup>	2.8 A	750 mA	$(I_{total_p(6V)}) / 2.8 + (I_{total_n(6V)}) / 2 + (I_{total(30V)}) /$	
6 A <sup>2</sup>	2 <sup>nd</sup> to 4 <sup>th</sup>	2 A	750 mA	0.75 ≤ 1	

Limit current per module to satisfy the equation as below:

 $1. \quad I_{total(6V)}, \ I_{total\_P(6V)}, \ I_{total\_P(6V)}, \ I_{total\_n(6V)}, \ I_{total(30V)} \ are \ the \ sum \ of \ the \ following \ parameters \ for \ the \ channels \ working \ within \ the \ specified \ voltage$ range

	Range	Source function		Parameter
		Mode	Polarity	
	C )/	Voltage	Either	The larger one of absolute +Icomp/-Icomp
total(6V)	6 V	Current	Either	The absolute source value
	0.14	Voltage	Either	+ $I_{comp}$ when + $I_{comp} \ge 1.4 \text{ x abs}(-I_{comp})$
total_p(6V)	6 V	Current	Positive	The source value
	0.14	Voltage	Either	The absolute $-I_{comp}$ when $+I_{comp} < 1.4 \text{ x abs} (-I_{comp})$
total_n(6V)	6 V	Current	Negative	The absolute source value
1	20.17	Voltage	Either	The larger one of absolute +Icomp/-Icomp
Itotal(30V)	30 V	Current	Either	The absolute source value

1.

Where +l<sub>comp</sub>/-l<sub>comp</sub> are the positive / negative current compliance values. When a module works under temperatures lower than 45 °C. Keysight M9018B, M9019A or the other chassis supporting 6 A current capacity for 12 V rail. The M9614A and M9615A use an XJ4 connector manufactured by ERNI (PN 214443). 2.

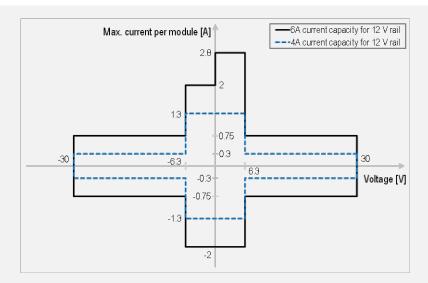


Figure 4. Voltage and total current output capability per module

## Source/measurement specifications and characteristics

Range	Programming and measurement		Tempco (% of reading + offset) / °C, 0 °C to 55 °C	Source noise (peak to peak) 0.1 Hz to 10 Hz <sup>2</sup>	Max current
	Resolution	Accuracy (% of reading + offset), Tcal <sup>1</sup> ± 5 °C			
±6 V	6 µV	± (0.015% + 600 μV)	± (0.0005%+1 μV)	≤ 20 µV	Varies <sup>3</sup>
± 30 V	30 µV	± (0.015% + 1.2 mV)	± (0.0005%+1 μV)	≤ 85 µV	± 150 mA

Voltage source/measurement specifications

Tcal: Ambient temperature when self-calibration was performed.
Supplemental characteristics, 0 V sourced, 500 mA range.
750 mA and -500 mA for channels 1 and 2; ± 500 mA for channels 3, 4, and 5.

	6 V range	105%
Over range (% of range)	30 V range	100% for source
		105% for measurement

#### Current source/measurement specifications

Range	Programming and measurement		Programming and measurement / °C, 0 °C to 55 °C		(% of reading + offset)	Source noise (peak to peak) 0.1 Hz to 10 Hz <sup>2</sup>	Max voltage
	Resolution	Accuracy (% of reading + offset), Tcal <sup>1</sup> ± 5 °C					
$\pm$ 10 $\mu A$ $^3$	10 pA	± (0.03% + 1.6 nA)	± (0.002% + 10 pA)	≤ 170 pA	Varies <sup>4</sup>		
± 100 μΑ	100 pA	± (0.03% + 16 nA)	± (0.002% + 100 pA)	≤ 440 pA	Varies <sup>4</sup>		
±1mA	1 nA	± (0.03% + 160 nA)	± (0.002% + 1 nA)	≤ 30 nA	Varies <sup>4</sup>		
± 10 mA	10 nA	± (0.03% + 1.6 μA)	± (0.002% + 10 nA)	≤ 35 nA	Varies <sup>4</sup>		
± 100 mA	100 nA	± (0.03% + 24 μA)	± (0.002% + 150 nA)	≤ 2.5 µA	Varies <sup>4</sup>		
± 500 mA	500 nA	± (0.05% + 125 μA)	± (0.004% + 1 μA)	≤ 3.5 µA	± 6.3 V		

Tcal: Ambient temperature when self-calibration was performed.
Supplemental characteristics, 0 A sourced.
10 μA range is available only with the M9615A.
± 30 V for voltage source, ± 31.5 V for voltage measurement.

	500 mA range	150% with positive current for Ch 1, 2
		100% with negative current for Ch 1, 2
Over range (% of range)		100% for Ch 3, 4, 5
Over lange (% of lange)	Other ranges	105%
		100% for 1 mA, 10 mA ranges if used with seamless measurement ranging function enabled with low group

#### Example of calculating accuracy with temperature coefficient

Calculate the accuracy of 500  $\mu$ A 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.

Temperature Variation = 
$$(23^{\circ}\text{C} - 5^{\circ}\text{C}) - 15^{\circ}\text{C} = 3^{\circ}\text{C}$$
  
Accuracy =  $(500 \,\mu\text{A} * 0.03\% + 160 \,\text{nA}) + \frac{500 \,\mu\text{A} * 0.002\% + 1 \,\text{nA}}{1^{\circ}\text{C}} * 3^{\circ}\text{C}$   
= 310 nA + 33 nA = 343 nA

Therefore, the actual output will be within 343 nA of 500  $\mu A.$ 

Source supplemental characteristics

	4 A current	6 V range	8.2 W, 1.3 A		
	capacity <sup>1</sup>	30 V range	9 W, 0.3 A		
Max output power and source / sink limits per module			17.6 W, 2.8 A in 1 <sup>st</sup> quadrant		
	6 A current capacity <sup>2</sup>	6 V range	12.6 W, 2 A in the other quadrants		
	сарасну	30 V range	22.5 W, 0.75 A		
Current compliance setting accuracy	Accuracy is same as current source; minimum value is 1% of range (10 µA to 500 mA ranges)				
Voltage compliance setting accuracy	Accuracy is same as voltage source; minimum value is 1% of range (6 V to 30 V ranges)				
Over-temperature protection	SMU shutdowns at over temperature sensed internally.				
Voltage output settling time	< 85 µs (PS mode with 6 V range, 1 mA or more ranges, open load) Time required to reach within 0.1% of final value at described load condition; step is 10% to 90% range with compliance set to 100% of the range, filter auto settings				
	0.15 V/µs (PS mode with 10 mA compliance)				
Slew rate	0.1 V/µs (Stand	ard mode with 1	0 mA compliance)		
	Step is 0 V to 30 V at open load condition				

1. For the chassis supporting 4 A backplane pin current capacity for 12 V rail.

 For Keysight M9018B, M9019A or the other chassis supporting 6 A backplane pin current capacity for 12 V rail, when a module works under temperatures lower than 45 °C. The M9614A and M9615A use an XJ4 connector manufactured by ERNI (PN 214443).

		< 2.0 ms (10 µA range, 1 k	Ω load)				
		< 1.4 ms (100 µA range, 1	*				
		< 200 µs (1 mA range, 10 0	< 200 μs (1 mA range, 10 Ω load)				
			< 140 $\mu$ s (10 mA range, 10 $\Omega$ load)				
Current output	t settling time	< 110 µs (100 mA range, 1	00 mΩ load)				
		< 90 µs (500 mA range, 10	0 mΩ load)				
			Time required to reach within 0.1% of final value at described load condition; step is 10% to 90% range with 6 V compliance, filter				
V source noise (BW = 20 MHz)		< 1 mVrms, < 12 mVp-p, 6 compliance)	V range (100 mA range, 30 mA				
V source noise (BW = 200 MHz)		< 3.3 mVrms, < 40 mVp-p, compliance)	< 3.3 mVrms, < 40 mVp-p, 6 V range (100 mA range, 30 mA				
		Time to recover to within the settling band					
		With 2.2 $\mu$ F cap (ESR = 50 m $\Omega$ ) at load, remote sensing at cap					
Load transien	t response time in	6 V range with 500 mA compliance in PS mode					
voltage sourc	e mode	Rise time (10% to 90%)	1 µs				
		Settling band	± 20 mV				
		Recovery time	< 70 µs				
		Up to 1 V drop per lead					
		6 V range	Hi-Lo: ± 6.5 V maximum				
Remote sense drop	e maximum lead	30 V range	Hi-Lo: ± 25.5 V maximum (Seamless current measurement ranging function enabled with Low Group)				
			Hi-Lo: ± 30.5 V maximum (For the other conditions)				
		V₀³  ≤ 10 V	0 ppm				
Current load	1 mA, 100 mA	10 V <  V₀  ≤ 20 V	( V₀  -10 V) * 5 ppm of range				
regulation	ranges	20 V <  V <sub>o</sub>	(( V₀  -20 V) * 10 ppm + 50 ppm) of range				
	Other ranges	0 ppm					

3. Vo is the output voltage.

Pulse source supplemental characteristics

Programmable pulse width	50 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 5)

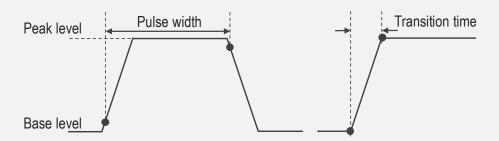


Figure 5. Definition of the pulse parameters and the transition time

Transition time at the given	voltago curront	and cottling conditions	(obconvod data)
	vollage, current.		
J	J , ,	5	\ /

Source value	Limit value	Operation mode	Load	Source settling band (% of range)	Transition time
6.3 V	500 mA	Standard	15 Ω	0.1%	270 µs
6.3 V	500 mA	PS	15 Ω	0.1%	75 µs
30 V	150 mA	Standard	220 Ω	0.1%	4.9 ms
30 V	150 mA	PS	220 Ω	0.1%	230 µs
500 mA	6 V	Standard	100 mΩ	0.1%	85 µs

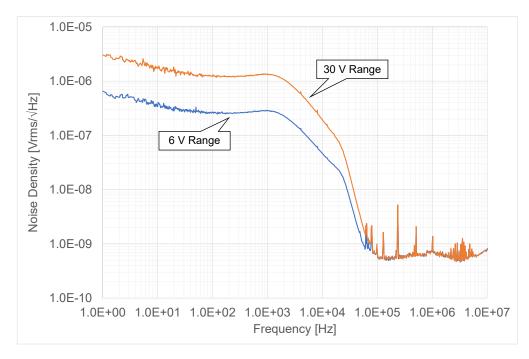
Transition time definition: The time from "Source settling band" to "100% — Source settling band" leading edges (Figure 5)

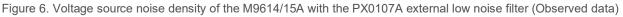
External low noise filter supplemental characteristics

The M9614A and M9615A support dedicated external low-noise filter (PX0107A); it is available as an accessory. It connects to the Dsub-25 outputs of M9614A and M9615A output channels.

Maximum output range		30 V / 150 mA (DC)	
Output connector		SMB	
Output residual resistance		65 mΩ nominal	
0.1 to 10 Hz		Same as voltage specification	
Voltage source noise	10 Hz to 20 MHz	25 μVrms (6 V range), 110 μVrms (30 V range)	
Voltage source settling time <sup>1</sup>		5.5 ms (6 V range), 17.5 ms (30 V range)	
Supported ranges	Voltage	6 V, 30 V ranges	
	Current	10 $\mu$ A to 500 mA ranges (± 150 mA maximum)	
Maximum capacitive load		5 µF	
Dimensions		19.5 mm (W) x 62.7 mm (H) x 94.8 mm (D)	
		Depth including connector: 107.5 mm	
Weight		0.17 kg	

1. Time required to reach within 0.1 % of final value at open load condition. Step is 10 % to 90 % range. At 6 V / 30 V ranges, 100 mA limit/100 mA range.





#### Measurement supplemental characteristics

Measurement noise (1 PLC)

35 pArms for 10  $\mu$ A range, and 75 pArms for 100  $\mu$ A range

Measurement and timing characteristics

Available sampling rates		(500 kSa/s)/N where N=1, 2, 3, …, 2 <sup>20</sup>	
Sample rate accuracy		Frequency accuracy is inherited from PXIe_CLK100	
Maximum measure rate to host		500 kSa/s	
Maximum source update rate		250 kSa/s	
In put trigger to	Source / sense trigger delay	≤ 5 µs	
Input trigger to	Source / sense trigger jitter	≤ 4 µs	

#### Seamless current measurement ranging

The seamless current measurement ranging function enables the SMU channels to make a wide dynamic range measurement without range changing. It automatically detects which current measurement range will return the most precise measurement.

Range group	Available ranges
High group	500 mA, 100 mA, 10 mA, 1 mA ranges
Low group	10 mA, 1 mA, 10 μA ranges

Note:

- The range group is selected automatically by the compliance setting value. When it is set to more than 10 mA, the range group is set to 'High'. Otherwise, it is set to 'Low'.
- When the range group is set to 'Low', 5% (typical) error is added to its compliance setting accuracy.

# 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 500,000 (count)

Input triggers		
Sources (PXI trigger lines 0 to 7, external trigger 0 and 1)	Polarity	Configurable
	Minimum pulse width	200 ns, nominal
	Level	3.3 V CMOS

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 $\mu$ s, nominal
	Level	3.3 V CMOS

Output characteristics timer		
Sensing modes	2-wire or 4-wire (remote-sensing) connections	
Low terminal connection	Chassis grounded or floating	
Output connectors	Dsub 25 pin jack	
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 = 1 V	
Maximum load capacitance	10 μF (ESR ≥ 50 mΩ)	
Guard output impedance	6.8 kΩ (nominal)	
Maximum DC floating voltage	± 40 V between low force and chassis	

## **Environmental specifications**

Environment			For indoor use	
	Temperature		0 °C to 55 °C	
Operating		Minimum	10% RH, non-condensing	
operating	Humidity	Maximum	80% RH up to 40°C, decreases linearly to 35% RH at 55 °C $^{\rm 1},$ non-condensing	
Characte	Temperatu	ire	-40 °C to 70 °C	
Storage	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 $\pm$ 5%, 4 A <sup>2</sup> or 6 A <sup>3</sup>	
EMC			IEC61326-1/EN61326-1, 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	
Compliance	and certificat	ions	CE, 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	

From 40°C to 55°C, the maximum % Relative Humidity follows the line of constant dew point.
With mode for the chassis supporting 4 A backplane pin current capacity for 12 V rail.
With mode for Keysight M9018B 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
Туре	DC or pulse
Min programmable value to create list sweep waveform	4 µs
Digitizing / sampling measurement	
Max sampling rate	500 kSa/s
Data buffers	
Max buffer size	500,000 points
Program, software, and drivers	
Programming	SCPI (Rev 4.0 or later)
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

### System and Installation Requirements for PX0109A

Computer operating system		
Operating system	Windows 10 (64-bit) Pro, Windows 10 (64-bit) Enterprise	
Supporting language	English (US)	
.NET Framework	Microsoft .NET, Framework 4.7.1	
IO Libraries	Keysight IO Libraries Suite 2019 or later	
PathWave License Manager	2.4.1 or later	
Interfaces	PXIe	

## **Furnished Accessories**

#### Furnished accessories

Short bar, connector-terminal block 2.5 mm 5-terminal, certificate of calibration (without test data), quick startup poster

## Ordering Information

Model number				
M9614A	PXIe 5-channel SMU, 500	PXIe 5-channel SMU, 500 kSa/s, 100 pA, 30 V, 500 mA		
M9615A	PXIe 5-channel precision	PXIe 5-channel precision SMU, 500 kSa/s, 10 pA, 30 V, 500 mA		
Options				
1A7	Calibration + uncertainties	Calibration + uncertainties + guardbanding (not accredited)		
A6J	ANSI Z540-1-1994 calibra	ANSI Z540-1-1994 calibration		
UK6	Commercial calibration ce	Commercial calibration certificate with test data		
Accessories				
PX0101A-001	BNC-to-ferrule terminal ca	BNC-to-ferrule terminal cable, 1.5 m		
PX0101A-002	BNC-to-ferrule terminal ca	BNC-to-ferrule terminal cable, 3 m		
PX0106A	Dsub25-to-5 SMB adapte	Dsub25-to-5 SMB adapter for M9614/15		
PX0107A	Low Noise Filter Adapter	Low Noise Filter Adapter for M9614/15		
PX0108A-001	BNC-to-SMB cable, 1.5 m	BNC-to-SMB cable, 1.5 m		
PX0108A-002	BNC-to-SMB cable, 3 m	BNC-to-SMB cable, 3 m		
Accessories				
Product	License type	License term (36 months subscription) License & support		
PX0109A	Node-locked (fixed)	R-X45-001-Y		
	Transportable	R-X45-004-Y		
	USB Portable <sup>1</sup>	R-X45-005-Y		
	Floating (single site)	R-X45-002-Y		
	Floating (single region)	R-X45-006-Y		
	Node-locked (fixed)	R-X45-001-Y		

1. USB portable license requires a certified USB dongle (available for additional purchase. Keysight part number PX0100-D10)

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