

M9614A and M9615A PXle 5-Channel Precision Source/Measure Units

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

The single-slot PXle 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



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

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 five-channels-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 μ V / 10 pA, pulsed measurement capability with pulse width down to 100 μ 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 μ 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.

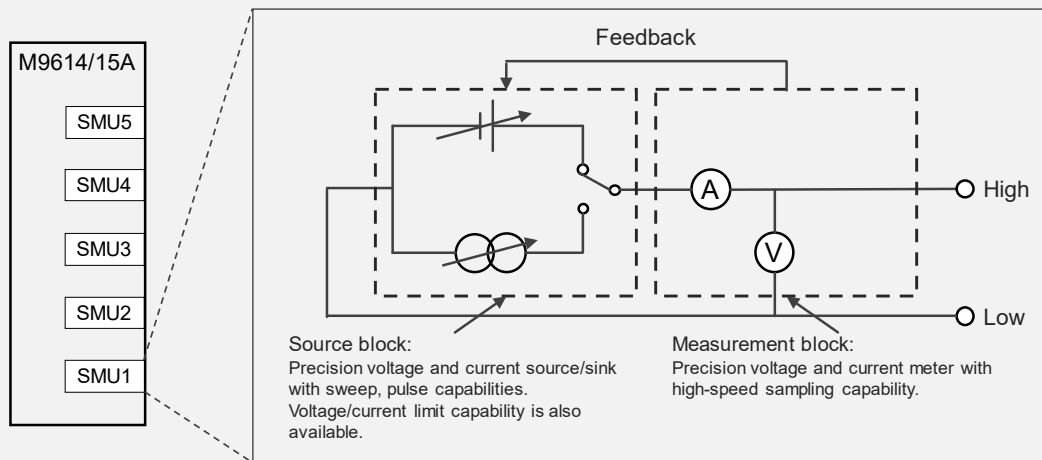


Figure 1. Simplified block diagram of the SMU channel in the M9614A and M9615A

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.

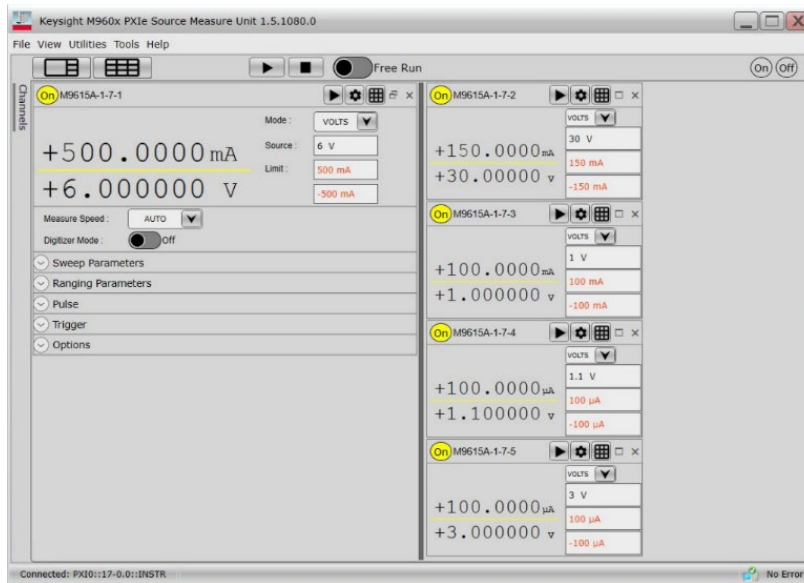


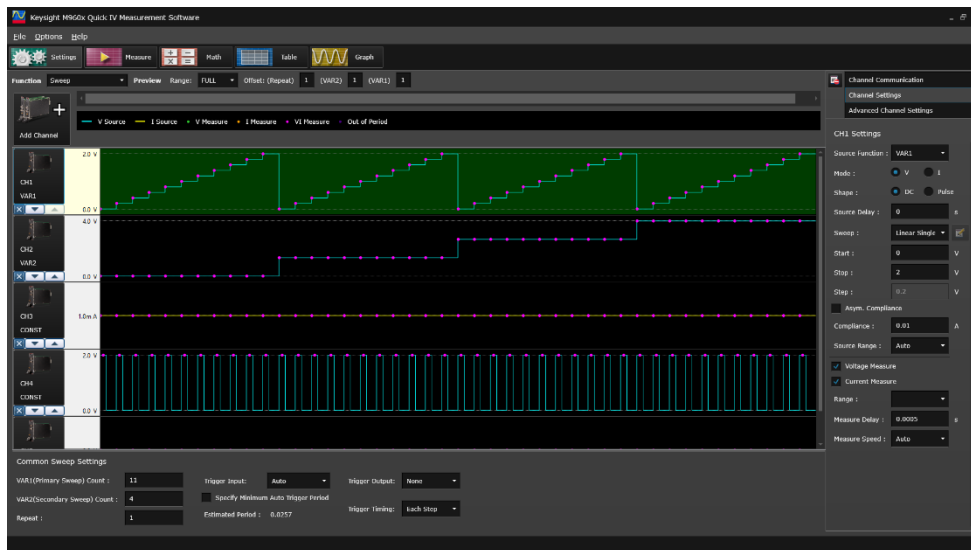
Figure 2. The M9615A's soft front panel

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

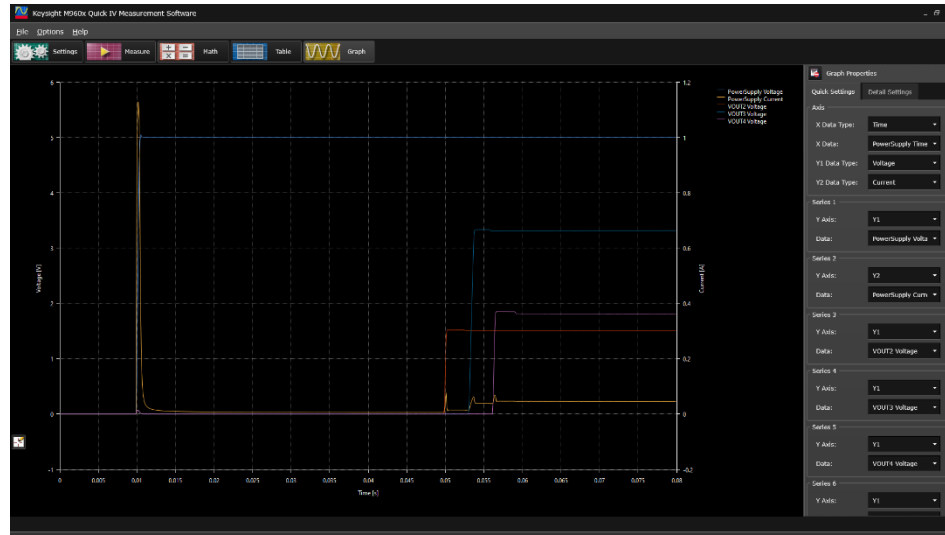
The Keysight PX0109A Quick I/V Measurement Software for PXIe Precision SMU has powerful measurement capabilities to control the M9601A, M9602A, M9603A, M9614A and M9615A. It supports a variety of functions such as a sweep measurement, a sampling measurement, graphical display functions and the ability 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.

PowerSupply Volt	PowerSupply Curr	PowerSupply Time	VOUT1 Voltage	VOUT1 Current	VOUT1 Time	VOUT2 Voltage	VOUT2 Current	VOUT2 Time	VOUT3 Voltage	VOUT3 Current	VOUT3 Time	VOUT4 Voltage	VOUT4 Current	VOUT4 Time
1.1	7.48535E-06	1.15720E-06	0.0000E+00	43.9554E-06	758.15251E-017	0.0000E+00	78.5654E-06	664.6049E-017	0.0000E+00	33.5504E-06	1.9599E-059	0.0000E+00	76.3303E-06	2.1572E-016
1.2	2.1397E-06	6.5222E-06	330.0000E-060	9.14937E-06	472.5326E-012	330.0000E-060	28.1878E-06	122.7576E-012	330.0000E-060	52.4213E-06	612.8927E-012	330.0000E-060	25.6157E-06	621.2775E-016
1.3	-14.6702E-06	-9.5561E-06	200.0000E-060	14.6651E-06	-403.3750E-013	200.0000E-060	78.3302E-06	-499.6811E-016	200.0000E-060	76.1870E-06	70.1558E-012	200.0000E-060	47.1300E-06	-145.2603E-016
1.4	10.6750E-06	10.7979E-06	300.0000E-060	37.1058E-06	-93.3820E-012	300.0000E-060	23.9318E-06	806.7620E-012	300.0000E-060	37.1058E-06	2.8952E-060	300.0000E-060	39.7823E-06	1.9993E-016
1.5	8.5466E-06	6.8221E-06	400.0000E-060	-17.8027E-06	508.6096E-012	400.0000E-060	51.3212E-06	1.2104E-060	400.0000E-060	-5.2374E-06	2.3012E-059	400.0000E-060	41.8005E-06	1.4026E-016
1.6	10.6932E-06	186.1379E-069	500.0000E-060	15.2128E-06	1.1520E-060	500.0000E-060	78.1823E-06	1.2978E-060	500.0000E-060	13.6170E-06	1.8693E-060	500.0000E-060	28.3303E-06	227.0937E-016
1.7	18.9004E-06	-20.9328E-060	600.0000E-060	17.8027E-06	1.0348E-060	600.0000E-060	11.5228E-06	1.9412E-060	600.0000E-060	2.8952E-060	999.6811E-012	600.0000E-060	45.0428E-06	208.6112E-016
1.8	34.1837E-06	-7.3887E-060	700.0000E-060	10.4713E-06	947.0663E-012	700.0000E-060	48.1855E-06	2.3155E-060	700.0000E-060	23.0428E-06	-648.9182E-012	700.0000E-060	28.2838E-06	894.4513E-016
1.9	18.9004E-06	30.7405E-060	800.0000E-060	5.2273E-06	70.1536E-012	800.0000E-060	45.6426E-06	0.8000E+000	800.0000E-060	-2.0452E-06	-2.3673E-060	800.0000E-060	33.5204E-06	-1.5423E-016
1.10	8.5360E-06	-15.1554E-060	900.0000E-060	31.8077E-06	-35.0753E-012	900.0000E-060	13.6170E-06	17.3337E-012	900.0000E-060	49.2313E-06	1.0818E-060	900.0000E-060	64.4578E-06	876.4327E-016
1.11	-18.9318E-06	12.6545E-060	1.0000E-063	28.8049E-060	288.8224E-012	1.0000E-063	62.8021E-06	288.8224E-012	1.0000E-063	16.7652E-06	-1.8998E-060	1.0000E-063	53.5183E-06	-5.2676E-016
1.12	25.6646E-06	-6.4659E-060	1.1000E-063	42.9489E-060	403.3880E-012	1.1000E-063	34.5797E-06	508.6096E-012	1.1000E-063	17.8027E-06	2.3763E-060	1.1000E-063	76.6154E-06	2.3359E-016
1.13	-22.4950E-06	-2.7857E-060	1.2000E-063	31.4228E-060	-1.7262E-060	1.2000E-063	42.9489E-060	-210.4928E-012	1.2000E-063	24.0927E-060	999.6812E-012	1.2000E-063	42.9489E-060	-1.8152E-016
1.14	3.2028E-060	12.8886E-060	1.3000E-063	50.2608E-060	2.2799E-060	1.3000E-063	49.8308E-060	-308.3077E-012	1.3000E-063	9.4378E-060	1.2794E-060	1.3000E-063	80.0348E-060	1.2138E-016
1.15	7.8102E-060	-11.5228E-060	1.4000E-063	22.4228E-060	12.0282E-012	1.4000E-063	22.2228E-060	1.8071E-060	1.4000E-063	12.5103E-060	3.2889E-060	1.4000E-063	22.4228E-060	228.0221E-016
1.16	-18.1787E-060	-16.7327E-060	1.5000E-063	20.8508E-060	-1.0877E-060	1.5000E-063	36.8508E-060	-508.6096E-012	1.5000E-063	34.5797E-060	1.5278E-060	1.5000E-063	54.4766E-060	-683.9035E-016
1.17	18.1787E-060	18.8974E-060	1.6000E-063	18.8523E-060	608.4598E-012	1.6000E-063	21.9977E-060	1.8000E-063	25.1931E-060	2.6823E-060	1.6000E-063	54.9578E-060	403.8838E-016	
1.18	24.5847E-060	12.8886E-060	1.7000E-063	18.4973E-060	-1.1228E-060	1.7000E-063	47.1300E-060	288.8224E-012	1.7000E-063	21.9877E-060	-2.8428E-060	1.7000E-063	56.6807E-060	2.2971E-016
1.19	18.6328E-060	16.5085E-060	1.8000E-063	21.4977E-060	1.1323E-060	1.8000E-063	52.6128E-060	648.9182E-012	1.8000E-063	14.5078E-060	944.6079E-012	1.8000E-063	68.4783E-060	1.9481E-016
1.20	-31.0304E-060	-12.8618E-060	1.9000E-063	12.5735E-060	-227.9485E-012	1.9000E-063	57.6128E-060	806.7620E-012	1.9000E-063	-2.0953E-060	1.4493E-060	1.9000E-063	54.4766E-060	-2.3624E-016
1.21	9.4292E-060	15.0078E-060	2.0000E-063	35.1158E-060	288.6328E-012	2.0000E-063	32.4728E-060	245.3371E-012	2.0000E-063	16.7628E-060	1.1399E-060	2.0000E-063	47.1380E-060	1.1756E-016
1.22	37.4828E-060	-2.8102E-060	2.1000E-063	1.9471E-060	-298.8501E-012	2.1000E-063	37.7104E-060	12.5302E-012	2.1000E-063	9.4201E-060	-2.8782E-060	2.1000E-063	86.2386E-060	368.2025E-016
1.23	-57.7441E-060	-12.9359E-060	2.2000E-063	8.3835E-060	245.5551E-012	2.2000E-063	71.5258E-060	-18.4563E-012	2.2000E-063	27.2713E-060	-280.6124E-012	2.2000E-063	16.6154E-060	-35.0723E-016
1.24	7.4853E-060	2.8812E-060	2.3000E-063	58.2881E-060	298.1503E-012	2.3000E-063	39.8058E-060	824.2947E-012	2.3000E-063	12.5735E-060	-22.9910E-012	2.3000E-063	86.6548E-060	-383.8184E-016
1.25	2.1386E-060	1.6335E-060	2.4000E-063	13.1767E-060	895.3756E-012	2.4000E-063	42.6480E-060	-3.2624E-060	2.4000E-063	38.8058E-060	175.3825E-012	2.4000E-063	45.0435E-060	-1.8415E-016
1.26	18.9004E-060	21.2107E-060	2.5000E-063	7.8228E-060	242.5221E-012	2.5000E-063	26.2578E-060	806.7620E-012	2.5000E-063	21.2223E-060	2.8428E-060	2.5000E-063	47.1380E-060	2.0108E-016
1.27	7.4853E-060	-6.4659E-060	2.6000E-063	-16.7650E-060	-990.6811E-016	2.6000E-063	14.6651E-060	789.2718E-012	2.6000E-063	251.4051E-060	-664.6049E-012	2.6000E-063	34.5797E-060	-346.8587E-016
1.28	0.0000E+000	-21.2728E-060	2.7000E-063	51.2823E-060	1.1920E-060	2.7000E-063	80.8208E-060	308.3077E-012	2.7000E-063	89.8734E-060	492.6713E-012	2.7000E-063	22.4228E-060	808.1620E-016
1.29	7.4853E-060	-6.4483E-060	2.8000E-063	9.4278E-060	-175.3825E-012	2.8000E-063	24.3335E-060	403.3880E-012	2.8000E-063	16.4791E-060	847.0663E-012	2.8000E-063	18.8532E-060	1.4336E-016
1.30	22.4950E-060	8.8102E-060	2.9000E-063	41.9023E-060	252.9221E-012	2.9000E-063	72.1878E-060	1.2678E-060	2.9000E-063	2.2222E-060	0.0000E+000	2.9000E-063	26.8622E-060	728.0714E-016
1.31	8.5360E-060	19.6488E-060	3.0000E-063	-2.8959E-060	1.8453E-060	3.0000E-063	56.6688E-060	947.0663E-012	3.0000E-063	12.5735E-060	-1.6644E-060	3.0000E-063	16.6154E-060	1.3852E-016
1.32	11.7627E-060	17.6002E-060	3.1000E-063	23.8928E-060	1.6122E-060	3.1000E-063	57.6128E-060	175.3825E-012	3.1000E-063	42.9489E-060	87.6923E-012	3.1000E-063	21.9977E-060	2.2624E-016
1.33	22.4950E-060	38.0821E-060	3.2000E-063	38.7570E-060	-182.4086E-012	3.2000E-063	58.3886E-060	894.4513E-012	3.2000E-063	-18.8532E-060	1.5781E-060	3.2000E-063	2.8952E-060	701.5361E-016
1.34	6.1000E-060	-11.2118E-060	3.3000E-063	15.7228E-060	312.0703E-012	3.3000E-063	19.8027E-060	87.6923E-012	3.3000E-063	6.1000E-060	483.9023E-012	3.3000E-063	43.9958E-060	172.3318E-016
1.35	2.2080E-060	7.2378E-060	3.4000E-063	41.9023E-060	992.1486E-012	3.4000E-063	24.9927E-060	218.4998E-012	3.4000E-063	42.9489E-060	6.0000E+000	3.4000E-063	54.4766E-060	-947.6653E-016
1.36	33.5504E-060	78.3303E-060	3.5000E-063	345.5513E-013	3.5000E-063	88.6673E-060	376.1480E-012	3.5000E-063	33.5504E-060	403.3880E-012	403.3880E-012	3.5000E-063	86.2386E-060	455.0000E-016

For free 30-day trials, visit: www.keysight.com/find/px0109a

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	
Humidity	Minimum	10% RH, non-condensing
	Maximum	80% RH up to 40 °C, decreases linearly to 35% RH at 55 °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	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 ¹ , - 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.

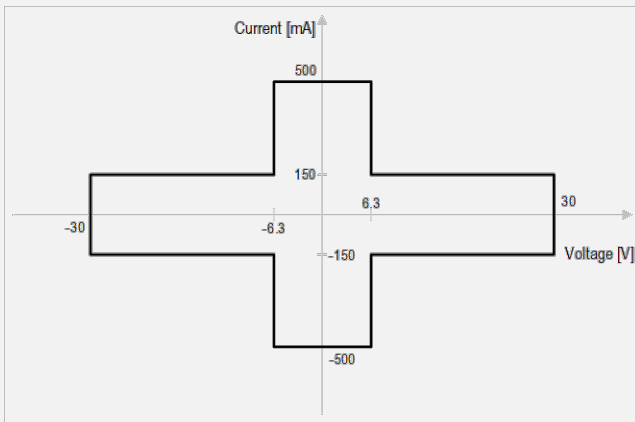


Figure 3. Voltage and current output capability per channel

Maximum voltage and current per module

Limit current per module to satisfy the equation as below:

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 ¹
4 A	All	1.3 A	300 mA	$(I_{total(6V)}) / 1.3 + (I_{total(30V)}) / 0.3 \leq 1$
6 A ²	1 st	2.8 A	750 mA	$(I_{total_p(6V)}) / 2.8 + (I_{total_n(6V)}) / 2 + (I_{total(30V)}) / 0.75 \leq 1$
	2 nd to 4 th	2 A	750 mA	

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

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

- Where $+I_{comp}/-I_{comp}$ 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).

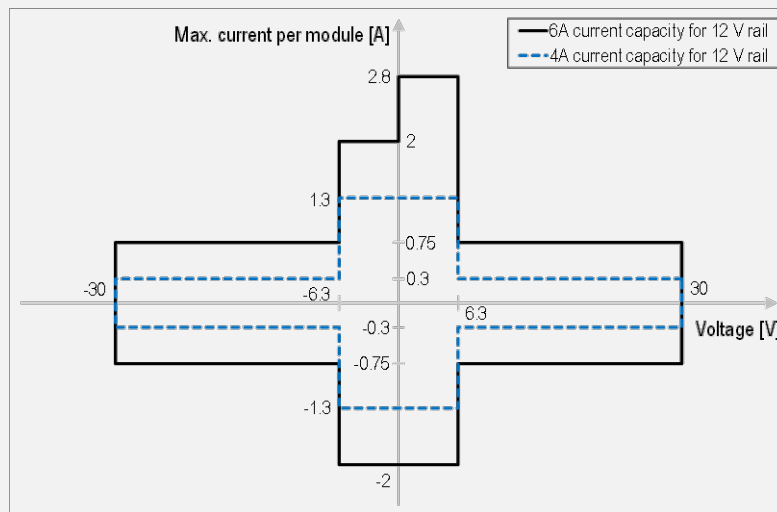


Figure 4. Voltage and total current output capability per module

Source/measurement specifications and characteristics

Voltage source/measurement specifications

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 ²	Max current
	Resolution	Accuracy (% of reading + offset), Tcal ¹ ± 5 °C			
± 6 V	6 µV	± (0.015% + 600 µV)	± (0.0005%+1 µV)	≤ 20 µV	Varies ³
± 30 V	30 µV	± (0.015% + 1.2 mV)	± (0.0005%+1 µV)	≤ 85 µV	± 150 mA

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

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

Current source/measurement specifications

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 ²	Max voltage
	Resolution	Accuracy (% of reading + offset), Tcal ¹ ± 5 °C			
± 10 µA ³	10 pA	± (0.03% + 1.6 nA)	± (0.002% + 10 pA)	≤ 170 pA	Varies ⁴
± 100 µA	100 pA	± (0.03% + 16 nA)	± (0.002% + 100 pA)	≤ 440 pA	Varies ⁴
± 1 mA	1 nA	± (0.03% + 160 nA)	± (0.002% + 1 nA)	≤ 30 nA	Varies ⁴
± 10 mA	10 nA	± (0.03% + 1.6 µA)	± (0.002% + 10 nA)	≤ 35 nA	Varies ⁴
± 100 mA	100 nA	± (0.03% + 24 µA)	± (0.002% + 150 nA)	≤ 2.5 µA	Varies ⁴
± 500 mA	500 nA	± (0.05% + 125 µA)	± (0.004% + 1 µA)	≤ 3.5 µA	± 6.3 V

1. Tcal: Ambient temperature when self-calibration was performed.
2. Supplemental characteristics, 0 A sourced.
3. 10 µA range is available only with the M9615A.
4. ± 30 V for voltage source, ± 31.5 V for voltage measurement.

Over range (% of range)	500 mA range	150% with positive current for Ch 1, 2
		100% with negative current for Ch 1, 2
		100% for Ch 3, 4, 5
	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 μA output in the 1 mA range. Assume the ambient temperature is 15 $^{\circ}\text{C}$ within the last 24 hours after self-calibration was performed at 19 $^{\circ}\text{C}$. The ambient temperature changes less than ± 5 $^{\circ}\text{C}$ after self-calibration execution but falls outside of 23 $^{\circ}\text{C} \pm 5$ $^{\circ}\text{C}$.

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

Therefore, the actual output will be within 343 nA of 500 μA .

Source supplemental characteristics

Max output power and source / sink limits per module	4 A current capacity ¹	6 V range	8.2 W, 1.3 A
		30 V range	9 W, 0.3 A
	6 A current capacity ²	6 V range	17.6 W, 2.8 A in 1 st quadrant
		30 V range	12.6 W, 2 A in the other quadrants
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		
Slew rate	0.15 V/ μs (PS mode with 10 mA compliance)		
	0.1 V/ μs (Standard mode with 10 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.

2. 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 $^{\circ}\text{C}$. The M9614A and M9615A use an XJ4 connector manufactured by ERNI (PN 214443).

Current output settling time		< 2.0 ms (10 μ A range, 1 k Ω load)	
		< 1.4 ms (100 μ A range, 1 k Ω load)	
		< 200 μ s (1 mA range, 10 Ω load)	
		< 140 μ s (10 mA range, 10 Ω load)	
		< 110 μ s (100 mA range, 100 m Ω load)	
		< 90 μ s (500 mA range, 100 m Ω 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 auto settings	
V source noise (BW = 20 MHz)		< 1 mVrms, < 12 mVp-p, 6 V range (100 mA range, 30 mA compliance)	
V source noise (BW = 200 MHz)		< 3.3 mVrms, < 40 mVp-p, 6 V range (100 mA range, 30 mA compliance)	
Load transient response time in voltage source mode		Time to recover to within the settling band	
		With 2.2 μ F cap (ESR = 50 m Ω) at load, remote sensing at cap	
		6 V range with 500 mA compliance in PS mode	
		Rise time (10% to 90%)	1 μ s
		Settling band	\pm 20 mV
Recovery time		< 70 μ s	
Remote sense maximum lead drop		Up to 1 V drop per lead	
		6 V range	Hi-Lo: \pm 6.5 V maximum
		30 V range	Hi-Lo: \pm 25.5 V maximum (Seamless current measurement ranging function enabled with Low Group) Hi-Lo: \pm 30.5 V maximum (For the other conditions)
Current load regulation	1 mA, 100 mA ranges	$ V_o^3 \leq 10$ V	0 ppm
		10 V < $ V_o \leq 20$ V	$(V_o - 10$ V) * 5 ppm of range
		20 V < $ V_o $	$(V_o - 20$ V) * 10 ppm + 50 ppm) of range
	Other ranges	0 ppm	

3. V_o is the output voltage.

Pulse source supplemental characteristics

Programmable pulse width	50 μ s to 1 s
Minimum pulse width programming resolution	0.2 μ s
Pulse width programming accuracy	0.5% \pm 2 μ s
Pulse period programming accuracy	0.5% \pm 4 μ s
Pulse width definition	The time from 10% leading to 90% trailing edge (Figure 5)

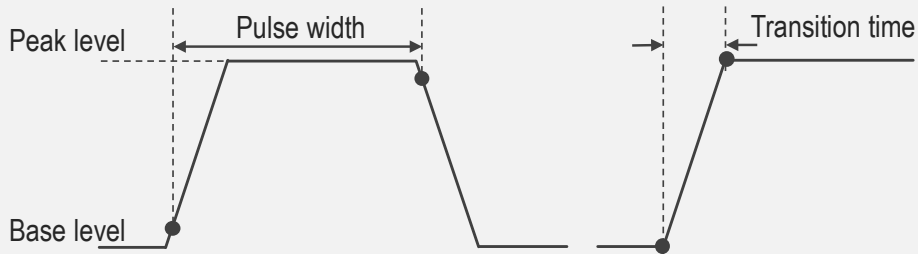


Figure 5. Definition of the pulse parameters and the transition time

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

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 μ s
6.3 V	500 mA	PS	15 Ω	0.1%	75 μ s
30 V	150 mA	Standard	220 Ω	0.1%	4.9 ms
30 V	150 mA	PS	220 Ω	0.1%	230 μ s
500 mA	6 V	Standard	100 m Ω	0.1%	85 μ s

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
Voltage source noise	0.1 to 10 Hz	Same as voltage specification
	10 Hz to 20 MHz	25 μVrms (6 V range), 110 μVrms (30 V range)
Voltage source settling time ¹		5.5 ms (6 V range), 17.5 ms (30 V range)
Supported ranges	Voltage	6 V, 30 V ranges
	Current	10 μA 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.

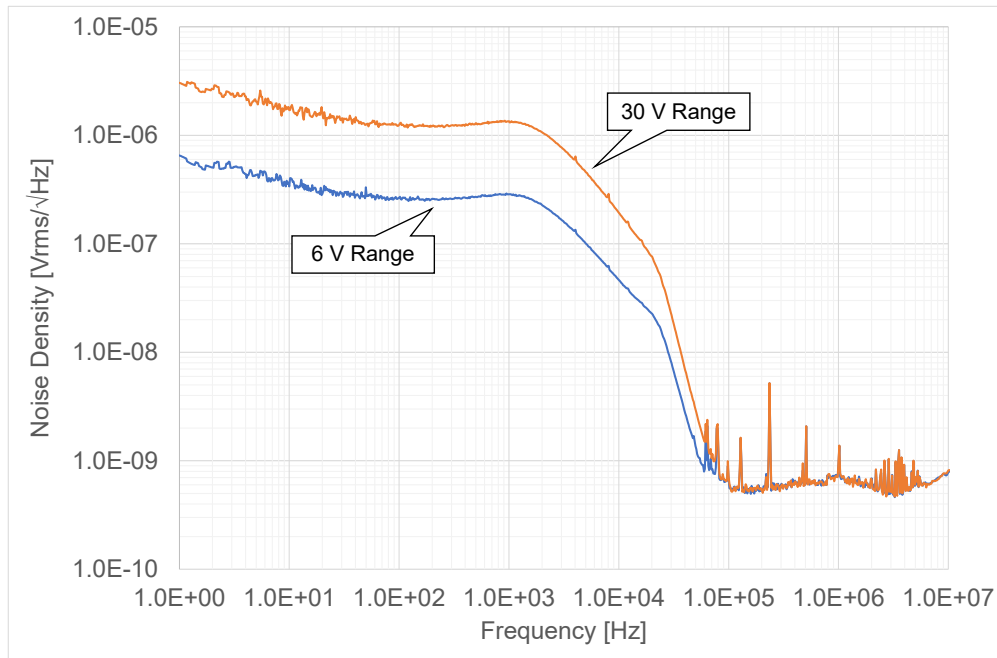


Figure 6. Voltage source noise density of the M9614/15A with the PX0107A external low noise filter (Observed data)

Measurement supplemental characteristics

Measurement noise (1 PLC)	35 pArms for 10 μ A range, and 75 pArms for 100 μ A range
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Measurement and timing characteristics

Available sampling rates	(500 kSa/s)/N where N=1, 2, 3, ..., 2 ²⁰	
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	
Input trigger to	Source / sense trigger delay	$\leq 5 \mu$ s
	Source / sense trigger jitter	$\leq 4 \mu$ s

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 μ A 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 μ s to 100 ms
Clock source	PXIe_CLK100
Arm / trigger delay	0 μ s to 100,000 s
Arm / trigger interval	4 μ s 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 μ 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 μ F (ESR \geq 50 m Ω)
Guard output impedance	6.8 k Ω (nominal)
Maximum DC floating voltage	\pm 40 V between low force and chassis

Environmental specifications

Environment		For indoor use	
Operating	Temperature	0 °C to 55 °C	
	Humidity	Minimum	10% RH, non-condensing
		Maximum	80% RH up to 40°C, decreases linearly to 35% RH at 55 °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, 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 certifications		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	

1. From 40°C to 55°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 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 μ s
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 kSa/s, 100 pA, 30 V, 500 mA	
M9615A	PXIe 5-channel precision SMU, 500 kSa/s, 10 pA, 30 V, 500 mA	
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	
PX0106A	Dsub25-to-5 SMB adapter for M9614/15	
PX0107A	Low Noise Filter Adapter for M9614/15	
PX0108A-001	BNC-to-SMB cable, 1.5 m	
PX0108A-002	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 ¹	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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