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SPECIFICATIONS

PXIe-4135

Precision, 10 fA Sensitivity Low-Current PXI Source Measure Unit

These specifications apply to the PXIe-4135.

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Definitions

Warranted specifications describe the performance of a model under stated operating conditions and are covered by the model warranty.

Characteristics describe values that are relevant to the use of the model under stated operating conditions but are not covered by the model warranty.

- *Typical* specifications describe the expected performance met by a majority of the models.
- *Nominal* specifications describe parameters and attributes that may be useful in operation.

Specifications are *Warranted* unless otherwise noted.

Conditions

Specifications are valid under the following conditions unless otherwise noted.

- Ambient temperature[1] of 23 °C ± 5 ºC
- Relative humidity between 10% and 70%, noncondensing up to 35 °C. Derate max relative humidity 3% per °C for ambient temperatures between 35 °C and 50 °C. From 50 °C to 55 °C, relative humidity between 10% and 25%, noncondensing. See *Current Programming and Measurement Accuracy/Resolution* for humidity performance restrictions.
- Calibration interval of 1 year
- 30 minutes warm-up time
- Self-calibration performed within the last 24 hours
- **niDCPower Aperture Time** property or `NIDCPOWER_ATTR_APERTURE_TIME` attribute set to 2 power-line cycles (PLC)
- Fans set to the highest setting if the PXI Express chassis has multiple fan speed settings
- Triax cover installed on unused triax connections

Cleaning Statement

Caution Clean the hardware with a soft, nonmetallic brush. Make sure that the hardware is completely dry and free from contaminants before returning it to service.

[1] The ambient temperature of a PXI system is defined as the temperature at the chassis fan inlet (air intake).

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Caution Due to high-impedance circuits used in the hardware, care should be taken to avoid contamination during handling or operation. Avoid use or storage of the hardware in an environment that allows dust to settle on the hardware. Avoid direct contact with the inner surfaces of triax connections. Triax covers should be used whenever triax connections are not in use.

Device Capabilities

The following table and figure illustrate the voltage and the current source and sink ranges of the PXIe-4135.

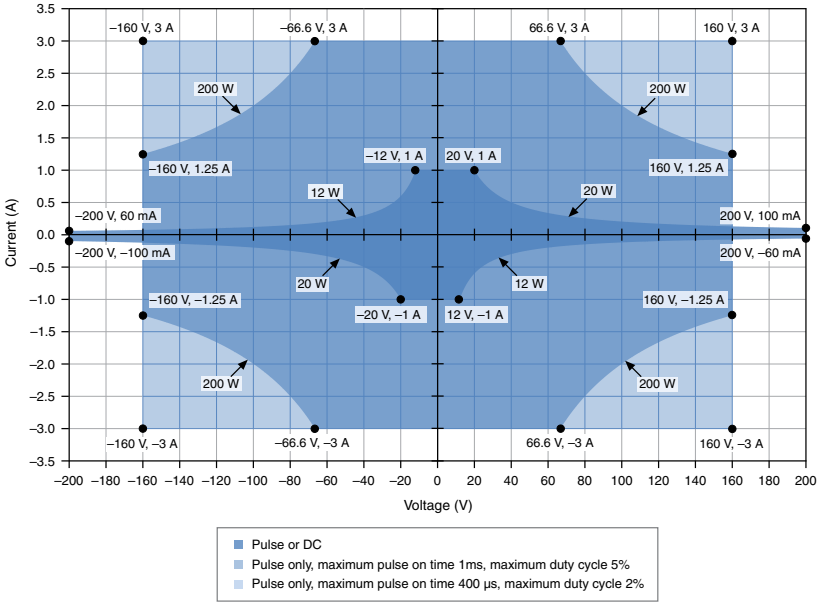
Table 1. Current Source and Sink Ranges

DC voltage ranges	DC current source and sink ranges
600 mV	10 nA
6 V	1 µA
20 V	100 µA
200 V[2]	1 mA
	10 mA
	100 mA
	1 A
	3 A[3]

[2] Voltage levels and limits >|40 VDC| require the safety interlock input to be closed.
[3] Current is limited to 1 A DC. Higher levels are pulsing only.

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Figure 1. Quadrant Diagram



DC sourcing power is limited to 20 W, regardless of output voltage.[4]

Caution Limit DC power sinking to 12 W. Additional derating applies to sinking power when operating at an ambient temperature of >45 °C. If the PXI Express chassis has multiple fan speed settings, set the fans to the highest setting.

[4] Power limit defined by voltage measured between HI and LO terminals.

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Voltage Programming and Measurement Accuracy/Resolution

Table 2. Voltage Programming and Measurement Accuracy/Resolution

Range	Resolution (noise limited)	Noise (0.1 Hz to 10 Hz, peak to peak), Typical	Accuracy (23 °C ±5 °C) ± (% of voltage + offset)[5]		Tempco ± (% of voltage + offset)/°C, 0 °C to 55 °C
			T_{cal} ±5 °C[6]	T_{cal} ±1 °C	
600 mV	100 nV	2 µV	0.020% + 50 µV	0.017% + 30 µV	0.0005% + 1 µV
6 V	1 µV	6 µV	0.020% + 320 µV	0.017% + 90 µV	
20 V	10 µV	20 µV	0.022% + 1 mV	0.017% + 400 µV	
200 V	100 µV	200 µV	0.025% + 10 mV	0.020% + 2.5 mV	

Related Information

Load Regulation on page 13
Remote Sense on page 15

[5] Accuracy is specified for no load output configurations. Refer to *Load Regulation* and *Remote Sense* sections for additional accuracy derating and conditions.

[6] T_{cal} is the internal device temperature recorded by the PXIe-4135 at the completion of the last self-calibration.

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Current Programming and Measurement Accuracy/Resolution

Table 3. Current Programming and Measurement Accuracy/Resolution

Range	Resolution (noise limited)	Noise (0.1 Hz to 10 Hz, peak to peak), Typical	Accuracy (23 °C ±5 °C) ± (% of current + offset)[7, 8]		Tempco ± (% of current + offset)/°C, 0 °C to 55 °C
			T_{cal} ±5 °C[9]	T_{cal} ±1 °C	
10 nA	10 fA	1 pA	0.06% + 6 pA	0.05% + 5 pA	0.0006% + 400 fA
1 µA	100 fA	4 pA	0.03% + 100 pA	0.022% + 40 pA	0.0006% + 4 pA
100 µA	10 pA	200 pA	0.03% + 6 nA	0.022% + 2 nA	0.0006% + 200 pA
1 mA	100 pA	2 nA	0.03% + 60 nA	0.022% + 20 nA	0.0006% + 2 nA
10 mA	1 nA	20 nA	0.03% + 600 nA	0.022% + 200 nA	0.0006% + 20 nA
100 mA	10 nA	200 nA	0.03% + 6 µA	0.022% + 2 µA	0.0006% + 200 nA
1 A	100 nA	2 µA	0.04% + 60 µA	0.035% + 20 µA	0.0006% + 2 µA
3 A[10]	1 µA	20 µA	0.08% + 900 µA	0.075% + 600 µA	0.0018% + 20 µA

[7] Relative humidity between 10% and 70%, noncondensing up to 35 °C. Derate max relative humidity 3% per °C for ambient temperatures between 35 °C and 50 °C. From 50 °C to 55 °C, relative humidity between 10% and 25%, noncondensing.

[8] Add 30 pA to accuracy specifications when operating with relative humidity greater than 50%.

[9] T_{cal} is the internal device temperature recorded by the PXIe-4135 at the completion of the last self-calibration.

[10] 3 A range above 1 A is for pulsing only.

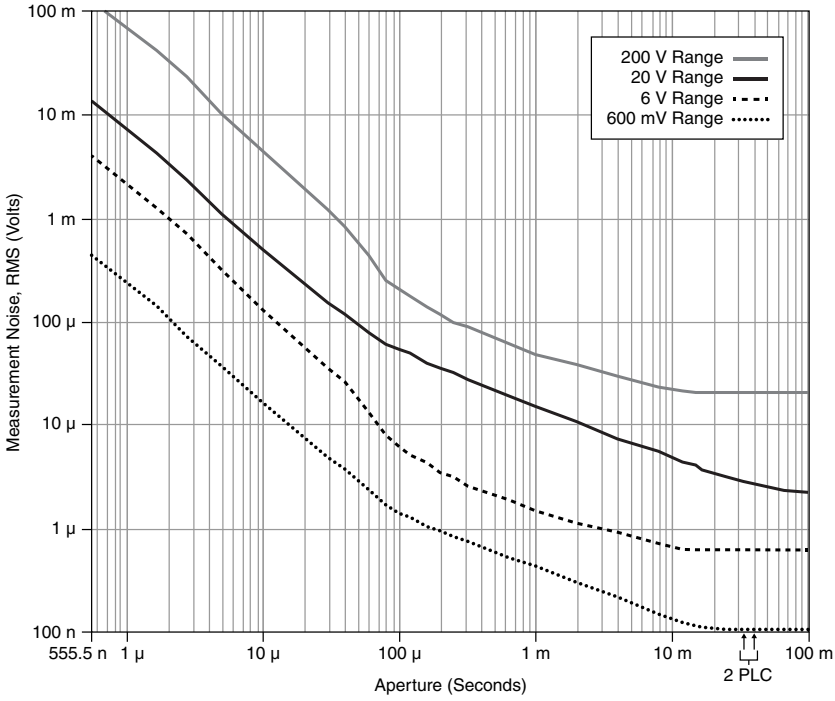
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Noise

Wideband source noise	<25 mV peak-to-peak in 20 V range, device configured for normal transient response, 10 Hz to 20 MHz, typical

The following figures illustrate noise as a function of measurement aperture for the PXIe-4135.

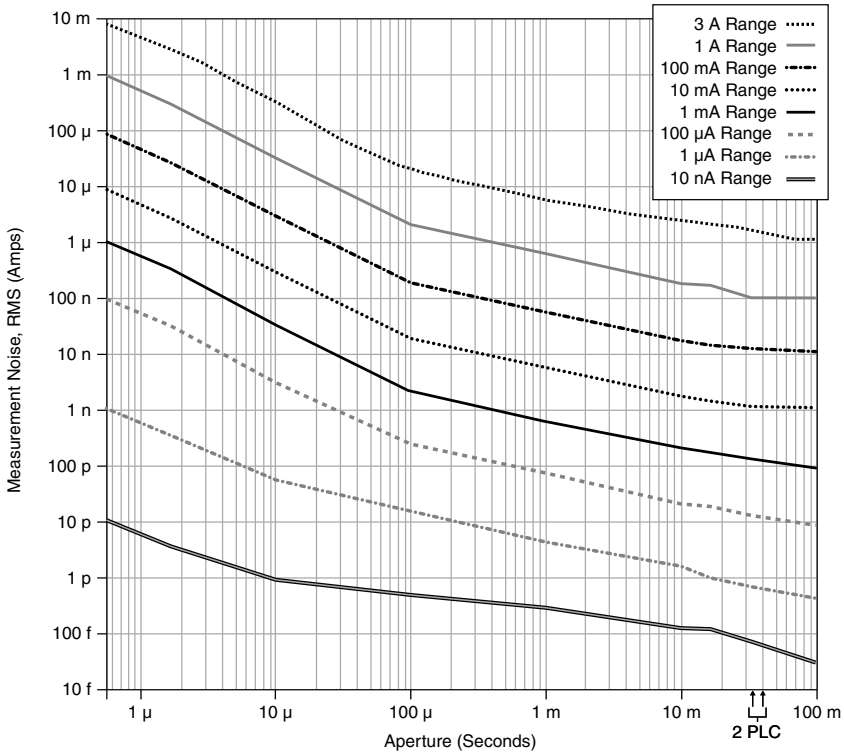
Figure 2. Voltage Measurement Noise vs. Measurement Aperture, Nominal



Note When the aperture time is set to 2 power-line cycles (PLCs), measurement noise differs slightly depending on whether the **niDCPower Power Line Frequency** property or `NIDCPOWER_ATTR_POWER_LINE_FREQUENCY` attribute is set to 50 Hz or 60 Hz.

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Figure 3. Current Measurement Noise vs. Measurement Aperture, Nominal



Note When the aperture time is set to 2 power-line cycles (PLCs), measurement noise differs slightly depending on whether the **niDCPower Power Line Frequency** property or `NIDCPOWER_ATTR_POWER_LINE_FREQUENCY` attribute is set to 50 Hz or 60 Hz.

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Figure 4. Measurement Noise, 10 nA Range, No Load, 0 V, 3 m Cables, Nominal

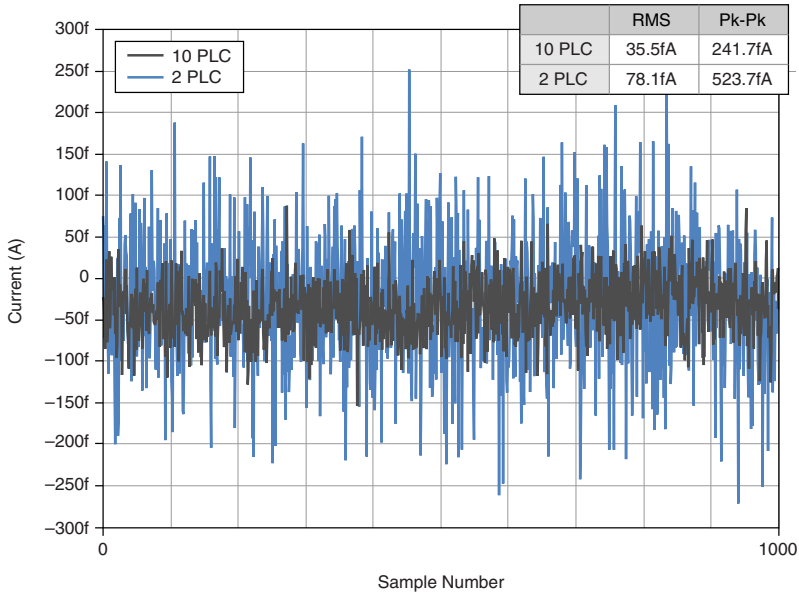
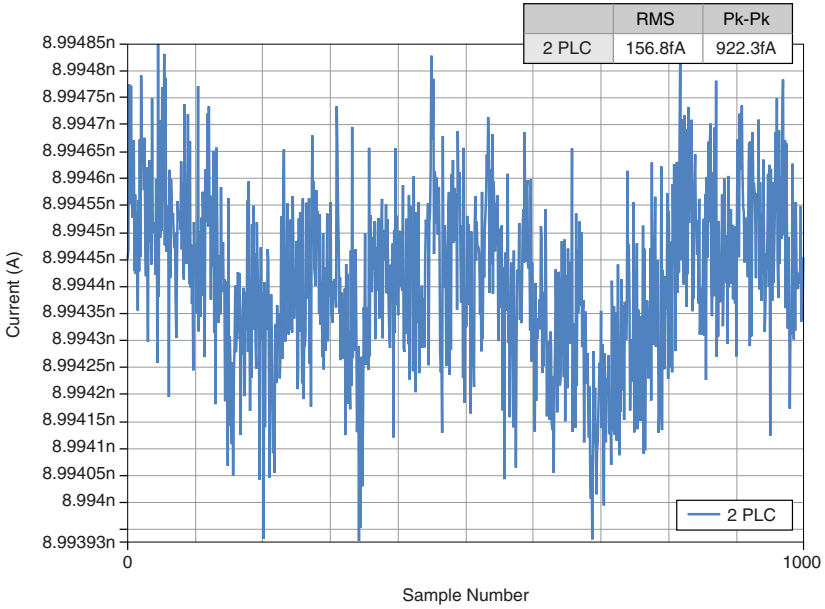


Figure 5. Measurement Noise, 10 nA Range, 1 GΩ Load, 9 V, 3 m Cables, Nominal



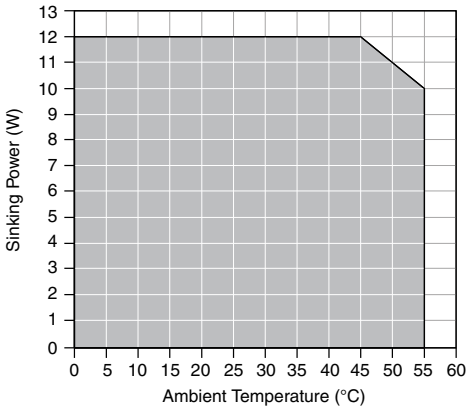
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Note Measurement noise vs. aperture plot measurements were taken with no load and no cabling. When using small aperture times, measurement noise may be impacted by system cabling.

Sinking Power vs. Ambient Temperature Derating

The following figure illustrates sinking power derating as a function of ambient temperature for the PXIe-4135.

Figure 6. Sinking Power vs. Ambient Temperature Derating



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Output Resistance Programming Accuracy

Table 4. Output Resistance Programming Accuracy

Current Level/Limit Range	Programmable Resistance Range, Voltage Mode	Programmable Resistance Range, Current Mode	Accuracy ± (% of resistance setting), T_{cal} ±5 °C[11]
10 nA	0 to ±500 MΩ	±500 MΩ to ±infinity	0.03%
1 µA	0 to ±5 MΩ	±5 MΩ to ±infinity	
100 µA	0 to ±50 kΩ	±50 kΩ to ±infinity	
1 mA	0 to ±5 kΩ	±5 kΩ to ±infinity	
10 mA	0 to ±500 Ω	±500 Ω to ±infinity	
100 mA	0 to ±50 Ω	±50 Ω to ±infinity	
1 A	0 to ±5 Ω	±5 Ω to ±infinity	
3 A[12]	0 to ±500 mΩ	±500 mΩ to ±infinity	

Overvoltage Protection

Accuracy[13] (% of OVP limit + offset)	1% + 200 mV, typical
Temperature coefficient (% of OVP limit + offset)/°C	0.01% + 3 mV/°C, typical
Measurement location	Local sense
Maximum OVP limit value	210 V
Minimum OVP limit value	2 V

[11] T_{cal} is the internal device temperature recorded by the PXIe-4135 at the completion of the last self-calibration.

[12] 3 A range above 1 A is for pulsing only.

[13] Overvoltage protection accuracy is valid with an ambient temperature of 23 °C ± 5 °C and with T_{cal} ±5 °C. T_{cal} is the internal device temperature recorded by the PXIe-4135 at the completion of the last self-calibration.

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Extended Range Pulsing [14]

Maximum pulse	
Voltage	160 V
Current	3 A
On time[15]	1 ms
Minimum pulse cycle time	5 ms
Energy	200 mJ
Cycle average power	10 W
Duty cycle	5%

Transient Response and Settling Time

Transient response[16]	
3 A to 100 µA ranges	<70 µs, typical
1 µA range[17]	<1 ms, typical
10 nA range[17]	<10 ms, typical
Settling time[18]	
Voltage mode, 180 V step, unloaded[19]	<500 µs, typical
Voltage mode, 5 V step or smaller, unloaded[20]	<70 µs, typical
Current mode, full-scale step, 3 A to 100 µA ranges[21]	<50 µs, typical
Current mode, full-scale step, 3 A to 1 µA range[17, 21]	<2 ms, typical
Current mode, full-scale step, 3 A to 10 nA range[17, 21]	<15 ms, typical

[14] Extended range pulse currents fall outside DC range limits. In-range pulse currents fall within DC range limits. In-range pulses are not subject to extended range pulsing limitations.
[15] *Pulse on time* is measured from the start of the leading edge to the start of the trailing edge.
[16] Time to recover within 0.1% of voltage range after a load current change from 10% to 90% of range, device configured for fast transient response.
[17] Measured with guarded load and HI/Sense HI triax cable ≤ 3 m
[18] Measured as the time to settle to within 0.1% of step amplitude, device configured for fast transient response.
[19] Current limit set to ≥60 µA and ≥60% of the selected current limit range.
[20] Current limit set to ≥20 µA and ≥20% of selected current limit range.
[21] Voltage limit set to ≥2 V, resistive load set to 1 V/selected current range.

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The following figures illustrate the effect of the transient response setting on the step response of the PXIe-4135 for different loads.

Figure 7. 1 mA Range, No Load Step Response, Nominal

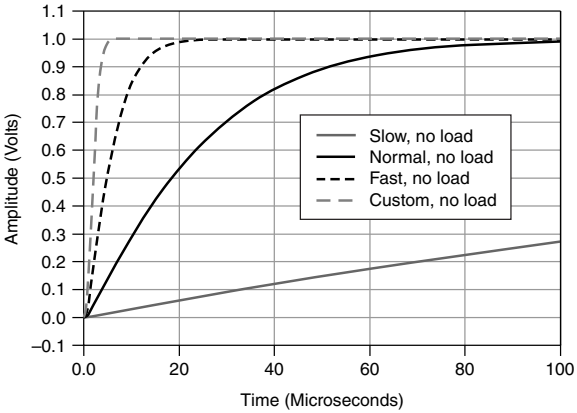
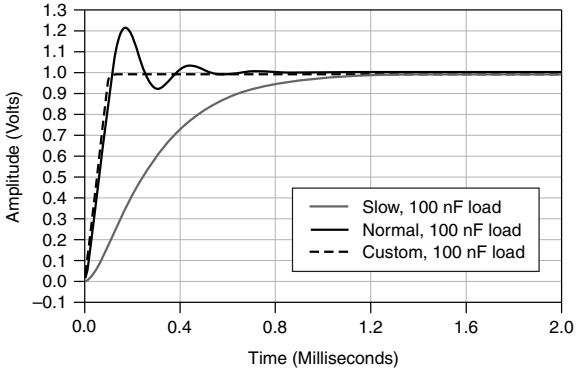


Figure 8. 1 mA Range, 100 nF Load Step Response, Nominal



Load Regulation

Voltage

Device configured for local sense	225 mV per A of output load change (measured between output channel terminals) , typical
Device configured for remote sense	100 µV per A of output load change (measured between sense terminals) , typical

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Current, device configured for local or remote sense	Load regulation effect included in current accuracy specifications, typical

Related Information

Voltage Programming and Measurement Accuracy/Resolution on page 5

Measurement and Update Timing Characteristics

Available sample rates[22]	(1.8 MS/s)/*N* where *N* = 1, 2, 3, … 2^{24}, nominal
Sample rate accuracy	Equal to PXIe_CLK100 accuracy, nominal
Maximum measure rate to host	1.8 MS/s per channel, continuous, nominal
Maximum source update rate[23]	100,000 updates/s, nominal
Input trigger to	
Source event delay	10 µs, nominal
Source event jitter	1 µs, nominal
Measure event jitter	1 µs, nominal
Pulse timing and accuracy	
Minimum pulse on time[24]	50 µs, nominal
Minimum pulse off time[25]	50 µs, nominal
Pulse on time or off time programming resolution	100 ns, nominal
Pulse on time or off time programming accuracy	±5 µs, nominal
Pulse on time or off time jitter	1 µs, nominal

[22] When sourcing while measuring, both the **niDCPower Source Delay** and **niDCPower Aperture Time** properties affect the sampling rate. When taking a measure record, only the **niDCPower Aperture Time** property affects the sampling rate.

[23] As the source delay is adjusted, maximum source rates vary.

[24] *Pulse on time* is measured from the start of the leading edge to the start of the trailing edge.

[25] Pulses fall inside DC limits. *Pulse off time* is measured from the start of the trailing edge to the start of a subsequent leading edge.

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Remote Sense

Voltage accuracy	Add 3 ppm of voltage range per volt of HI lead drop plus 1 µV per volt of lead drop per Ω of corresponding sense lead resistance to voltage accuracy specifications
Maximum sense lead resistance	100 Ω
Maximum lead drop per lead	3 V, maximum 202 V between HI and LO terminals

Note Exceeding the maximum lead drop per lead value may cause the driver to report a sense lead error.

Related Information

Voltage Programming and Measurement Accuracy/Resolution on page 5

Safety Interlock

The safety interlock feature is designed to prevent users from coming in contact with hazardous voltage generated by the SMU in systems that implement protective barriers with controlled user access points.

Caution Hazardous voltages of up to the maximum voltage of the PXIe-4135 may appear at the output terminals if the safety interlock terminal is closed. Open the safety interlock terminal when the output connections are accessible. With the safety interlock terminal open, the output voltage level/limit is limited to ±40 V DC, and protection will be triggered if the voltage measured between the device HI and LO terminals exceeds ±(42 Vpk ±0.4 V).

Caution Do not apply voltage to the safety interlock connector inputs. The interlock connector is designed to accept passive, normally open contact closure connections only.

Safety interlock terminal open	
Output	<±42.4 Vpk
Setpoint	<±40 VDC
Safety interlock terminal closed	
Output	Maximum voltage of the device
Setpoint	Maximum selected voltage range

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Examples of Calculating Accuracy Specifications[26]

Example 1: Calculating 5 °C Accuracy

Calculate the accuracy of 900 nA output in the 1 µA range under the following conditions:

Ambient temperature	28 °C
Internal device temperature	within T_{cal} ±5 °C[27]
Self-calibration	within the last 24 hours

Solution

Because the device internal temperature is within T_{cal} ±5 °C and the ambient temperature is within 23 °C ±5 °C, the appropriate accuracy specification is the following value:

0.03% + 200 pA

Calculate the accuracy using the following formula:

$$\text{Accuracy} = 900\,\text{nA} * 0.03\,\% + 200\,\text{pA}$$

$$= 270\,\text{pA} + 200\,\text{pA}$$

$$= 470\,\text{pA}$$

Therefore, the actual output is within 470 pA of 900 nA.

Example 2: Calculating Remote Sense Accuracy

Calculate the remote sense accuracy of 500 mV output in the 600 mV range. Assume the same conditions as in Example 1, with the following differences:

HI path lead drop	3 V
HI sense lead resistance	2 Ω

[26] Specifications listed in examples are for demonstration purposes only and do not necessarily reflect specifications for this device.

[27] T_{cal} is the internal device temperature recorded by the PXIe-4135 at the completion of the last self-calibration.

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LO path lead drop	2.5 V
LO sense lead resistance	1.5 Ω

Solution

Because the device internal temperature is within T_{cal} ±5 °C and the ambient temperature is within 23 °C ±5 °C, the appropriate accuracy specification is the following value:

0.02% + 100 µV

Because the device is using remote sense, use the following remote sense accuracy specification:

Add 3 ppm of voltage range + 11 µV per volt of HI lead drop plus 1 µV per volt of lead drop per Ω of corresponding sense lead resistance to voltage accuracy specifications.

Calculate the remote sense accuracy using the following formula:

$$\text{Accuracy} = \left(500\ \text{mV} * 0.02\,\% + 100\,\mu\text{V}\right) + \frac{600\ \text{mV} * 3\ \text{ppm} + 11\,\mu\text{V}}{1\,V \text{of lead drop}} * 3\,V + \frac{1\ \mu V}{V * \Omega} * 3\,V * 2\ \Omega + \frac{1\ \mu V}{V * \Omega} * 2.5\ V * 1.5\Omega$$

$$= 100\mu\text{V} + 100\mu\text{V} + 12.8\mu\text{V} * 3 + 6\mu\text{V} + 3.8\,\mu\text{V}$$

$$= 248.2\,\mu\text{V}$$

Therefore, the actual output is within 248.2 µV of 500 mV.

Example 3: Calculating Accuracy with Temperature Coefficient

Calculate the accuracy of 900 nA output in the 1 µA range. Assume the same conditions as in Example 1, with the following differences:

Ambient temperature	15 °C

Solution

Because the device internal temperature is within T_{cal} ±5 °C, the appropriate accuracy specification is the following value:

0.03% + 200 pA

Because the ambient temperature falls outside of 23 °C ±5 °C, use the following temperature coefficient per °C outside the 23 °C ±5 °C range:

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0.0006% + 4 pA

Calculate the accuracy using the following formula:

$$\text{TemperatureVariation} = \left(23\,°C - 5\,°C\right) - 15°C = 3\,°C$$

$$\text{Accuracy} = \left(500\ \text{nA} * 0.03\,\% + 200\,\text{pA}\right) + \frac{900\ \text{nA} * 0.0006\,\% + 4\,pA}{1\,°C} * 3\,°C$$

$$= 350\,\text{pA} + 28.2\,\text{pA}$$

$$= 378.2\,\text{pA}$$

Therefore, the actual output is within 378.2 pA of 900 nA.

Trigger Characteristics

Input triggers	
Types	Start, Source, Sequence Advance, Measure, Pulse
Sources (PXI trigger lines <0...7>)[28]	
Polarity	Configurable
Minimum pulse width	100 ns, nominal
Destinations[29] (PXI trigger lines <0...7>)[28]	
Polarity	Active high (not configurable)
Pulse width	>200 ns, typical
Output triggers (events)	
Types	Source Complete, Sequence Iteration Complete, Sequence Engine Done, Measure Complete, Pulse Complete, Ready for Pulse

[28] Pulse widths and logic levels are compliant with *PXI Express Hardware Specification Revision 1.0 ECN 1*.

[29] Input triggers can be re-exported.

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Destinations (PXI trigger lines <0...7>)[28]	
Polarity	Configurable
Pulse width	Configurable between 250 ns and 1.6 µs, nominal

Protection

Output channel protection	
Overcurrent or overvoltage	Automatic shutdown, output disconnect relay opens
Sink overload protection	Automatic shutdown, output disconnect relay opens
Overtemperature	Automatic shutdown, output disconnect relay opens
Safety interlock	Disable high voltage output, output disconnect relay opens

Isolation

Caution Do not connect to MAINs. Do not connect to signals or use for the measurements within CAT II, III, or IV.

Isolation voltage, channel-to-earth ground[30]	
Continuous	250 VDC, CAT I
Withstand	1,000 V_{RMS}

Note Measurement Categories CAT I and CAT O (Other) are equivalent. These test and measurement circuits are not intended for direct connection to the MAINs building installations of Measurement Categories CAT II, CAT III, or CAT IV.

Hazardous Voltage Take precautions to avoid electrical shock when operating this product at hazardous voltages.

Caution Isolation voltage ratings apply to the voltage measured between any channel pin and the chassis ground. When operating channels in series or floating on top of external voltage references, ensure that no terminal exceeds this rating.

[30] Verified with a 5-second dielectric withstand test.

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Guard Output Characteristics

Cable guard	
Output impedance	3 kΩ, nominal
Offset voltage	1 mV, typical

Calibration Interval

Recommended calibration interval	1 year

Power Requirement



Caution You can impair the protection provided by the PXIe-4135 if you use it in a manner not described in this document.

PXI Express power requirement	2.5 A from the 3.3 V rail 2.7 A from the 12 V rail

Physical Characteristics

Dimensions	3U, one-slot, PXI Express/CompactPCI Express module; 2.0 cm × 13.0 cm × 21.6 cm (0.8 in. × 5.1 in. × 8.5 in.), nominal
Weight	419 g (14.8 oz) , nominal
Front panel connectors	2 × 3 lug triaxial connectors, 1 × 4.08 mm (3 position) combicon
Safety interlock connector	3.55 mm (4 position)

Environment

Maximum altitude	2,000 m (800 mbar) (at 25 °C ambient temperature)
Pollution Degree	2

Indoor use only.

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Operating Environment

Ambient temperature range	0 °C to 55 °C (Tested in accordance with IEC 60068-2-1 and IEC 60068-2-2. Meets MIL-PRF-28800F Class 3 low temperature limit and MIL-PRF-28800F Class 2 high temperature limit.)
Relative humidity range	10% to 90%, noncondensing (Tested in accordance with IEC 60068-2-56.)[31]

Storage Environment

Ambient temperature range	-40 °C to 70 °C (Tested in accordance with IEC 60068-2-1 and IEC 60068-2-2. Meets MIL-PRF-28800F Class 3 limits.)
Relative humidity range	5% to 95%, noncondensing (Tested in accordance with IEC 60068-2-56.)

Shock and Vibration

Operating shock	30 g peak, half-sine, 11 ms pulse (Tested in accordance with IEC 60068-2-27. Meets MIL-PRF-28800F Class 2 limits.)
Random vibration	
Operating	5 Hz to 500 Hz, 0.3 g_{rms} (Tested in accordance with IEC 60068-2-64.)
Nonoperating	5 Hz to 500 Hz, 2.4 g_{rms} (Tested in accordance with IEC 60068-2-64. Test profile exceeds the requirements of MIL-PRF-28800F, Class 3.)

Compliance and Certifications

Hazardous Voltage This icon denotes a warning advising you to take precautions to avoid electrical shock.

[31] Accuracy specifications warranted for relative humidity between 10% and 70%, noncondensing up to 35 °C. Derate max relative humidity 3% per °C for ambient temperatures between 35 °C and 50 °C. From 50 °C to 55 °C, accuracy specifications warranted for relative humidity between 10% and 25%, noncondensing. See *Current Programming and Measurement Accuracy/Resolution* for humidity performance restrictions. When transitioning a device from a storage or operation environment with relative humidity outside of this range, device should be allowed to stabilize in the lower humidity environment for several hours before use.

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Safety

This product is designed to meet the requirements of the following electrical equipment safety standards for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA C22.2 No. 61010-1

Note For UL and other safety certifications, refer to the product label or the *Online Product Certification* section.

Electromagnetic Compatibility

This product meets the requirements of the following EMC standards for electrical equipment for measurement, control, and laboratory use:

- EN 61326-1 (IEC 61326-1): Class A emissions; Basic immunity
- EN 55011 (CISPR 11): Group 1, Class A emissions
- EN 55022 (CISPR 22): Class A emissions
- EN 55024 (CISPR 24): Immunity
- AS/NZS CISPR 11: Group 1, Class A emissions
- AS/NZS CISPR 22: Class A emissions
- FCC 47 CFR Part 15B: Class A emissions
- ICES-001: Class A emissions

Note In the United States (per FCC 47 CFR), Class A equipment is intended for use in commercial, light-industrial, and heavy-industrial locations. In Europe, Canada, Australia, and New Zealand (per CISPR 11), Class A equipment is intended for use only in heavy-industrial locations.

Note Group 1 equipment (per CISPR 11) is any industrial, scientific, or medical equipment that does not intentionally generate radio frequency energy for the treatment of material or inspection/analysis purposes.

Note For EMC declarations, certifications, and additional information, refer to the *Online Product Certification* section.

CE Compliance CE

This product meets the essential requirements of applicable European Directives, as follows:

- 2014/35/EU; Low-Voltage Directive (safety)
- 2014/30/EU; Electromagnetic Compatibility Directive (EMC)

Online Product Certification

Refer to the product Declaration of Conformity (DoC) for additional regulatory compliance information. To obtain product certifications and the DoC for this product, visit *ni.com/*

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certification, search by model number or product line, and click the appropriate link in the Certification column.

Environmental Management

NI is committed to designing and manufacturing products in an environmentally responsible manner. NI recognizes that eliminating certain hazardous substances from our products is beneficial to the environment and to NI customers.

For additional environmental information, refer to the *Minimize Our Environmental Impact* web page at *ni.com/environment*. This page contains the environmental regulations and directives with which NI complies, as well as other environmental information not included in this document.

Waste Electrical and Electronic Equipment (WEEE)



EU Customers At the end of the product life cycle, all NI products must be disposed of according to local laws and regulations. For more information about how to recycle NI products in your region, visit *ni.com/environment/weee*.

电子信息产品污染控制管理办法（中国 RoHS）



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