DEVICE SPECIFICATIONS

NI PXIe-4137

Single-Channel Precision System Source Measure Unit (SMU)

This document lists specifications for the NI PXIe-4137 (NI 4137).

The NI 4137 is a precision system source measure unit (SMU).

Specifications are subject to change without notice. For the most recent NI 4137 specifications, visit *ni.com/manuals*.

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

National Instruments defines the capabilities and performance of its Test & Measurement instruments as *Specifications*, *Typical Specifications*, and *Characteristic* or *Supplemental Specifications*. Data provided in this document are *Specifications* unless otherwise noted.

Specifications characterize the warranted performance of the instrument within the recommended calibration interval and under the stated operating conditions.

Typical Specifications are specifications met by the majority of the instruments within the recommended calibration interval and under the stated operating conditions. The performance of the instrument is not warranted.

Characteristic or *Supplemental Specifications* describe basic functions and attributes of the instrument established by design or during development and not evaluated during Verification or Adjustment. They provide information that is relevant for the adequate use of the instrument that is not included in the previous definitions.

Unless otherwise noted, specifications are valid under the following conditions:

- Ensure an ambient temperature of 23 °C ± 5 °C.[1]
- Ensure a calibration interval of 1 year.
- Allow 30 minutes warm-up time.
- Perform self-calibration within the last 24 hours.
- Set the **niDCPower Aperture Time** property or `NIDCPOWER_ATTR_APERTURE_TIME` attribute to 2 power-line cycles (PLCs).
- If the PXI Express chassis has multiple fan speed settings, set the fans to the highest setting.

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[1] For the definition of *ambient temperature*, refer to the *Maintain Forced-Air Cooling Note to Users* available at *ni.com/manuals*.

To access NI 4137 documentation, navigate to **Start»All Programs»National Instruments»NI-DCPower»Documentation**.

Contents

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.

Device Capabilities

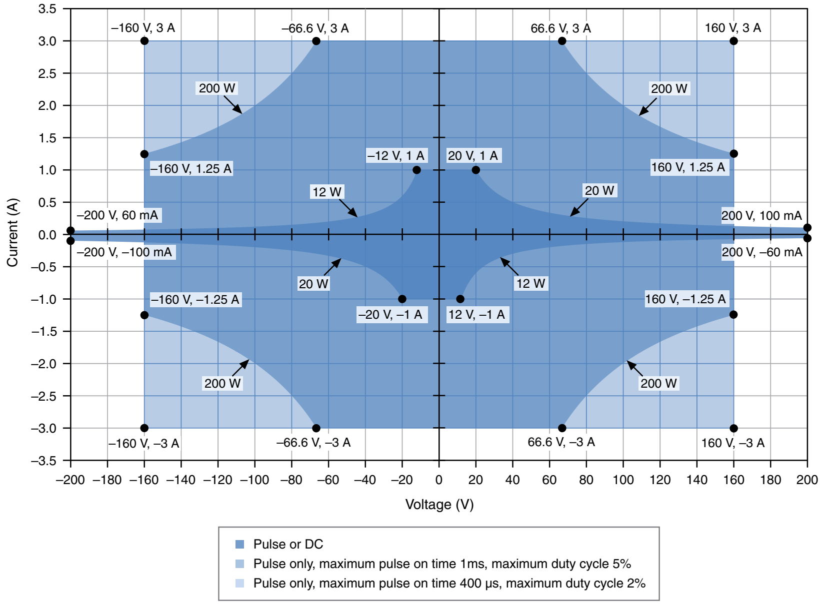
The following table and figure illustrate the voltage and the current source and sink ranges of the NI 4137.

Table 1. Current Source and Sink Ranges

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

[2] Voltages 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.

Figure 1. Quadrant Diagram[4]



DC sourcing power is limited to 20 W, regardless of output voltage.[5]

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 For information about configuring the NI 4137 for pulsing, refer to the *NI DC Power Supplies and SMUs Help*.

5 Power limit defined by voltage measured between HI and LO terminals.

6 T_{cal} is the internal device temperature recorded by the NI 4137 at the completion of the last self-calibration.

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)		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	

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)		Tempco ± (% of current + offset)/°C, 0 °C to 55 °C
			T_{cal} ± 5 °C[7]	T_{cal} ± 1 °C	
1 μA	100 fA	4 pA	0.03% + 100 pA	0.022% + 40 pA	0.0006% + 4 pA
10 μA	1 pA	30 pA	0.03% + 700 pA	0.022% + 300 pA	0.0006% + 22 pA

[7] T_{cal} is the internal device temperature recorded by the NI 4137 at the completion of the last self-calibration.

Table 3. Current Programming and Measurement Accuracy/Resolution (Continued)

Range	Resolution (noise limited)	Noise (0.1 Hz to 10 Hz, peak to peak), Typical	Accuracy (23 °C ± 5 °C) ± (% of current + offset)		Tempco ± (% of current + offset)/°C, 0 °C to 55 °C
			T_{cal} ± 5 °C[7]	T_{cal} ± 1 °C	
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[8]	1 µA	20 µA	0.08% + 900 µA	0.075% + 600 µA	0.0018% + 20 µA

Noise, Typical

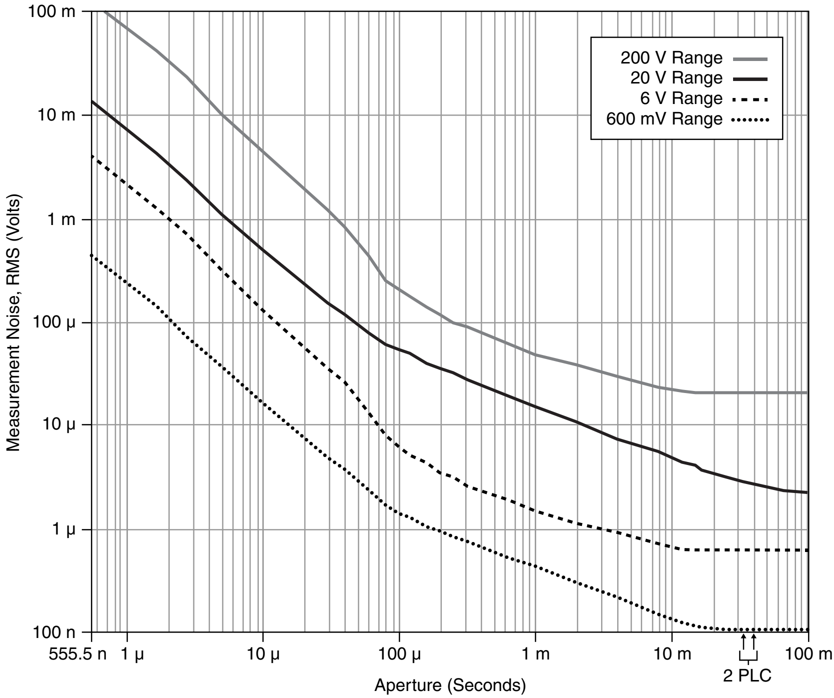
Wideband source noise	<20 mV peak-to-peak in 20 V range, device configured for normal transient response, 10 Hz to 20 MHz

The following figures illustrate noise as a function of measurement aperture for the NI 4137.

7 T_{cal} is the internal device temperature recorded by the NI 4137 at the completion of the last self-calibration.

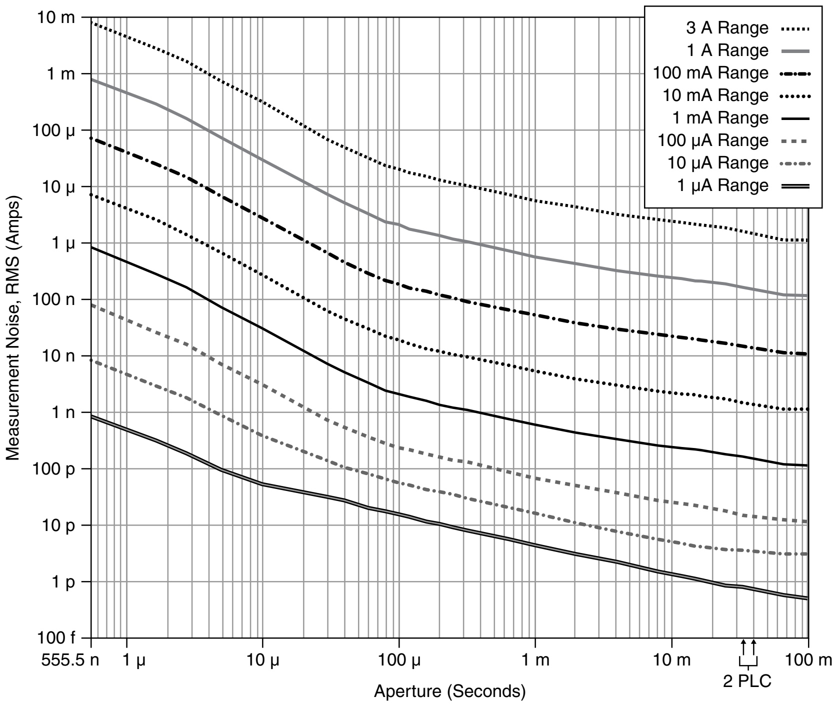
8 3 A range above 1 A is for pulsing only.

Figure 2. Voltage Measurement Noise vs. Measurement Aperture



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.

Figure 3. Current Measurement Noise vs. Measurement Aperture

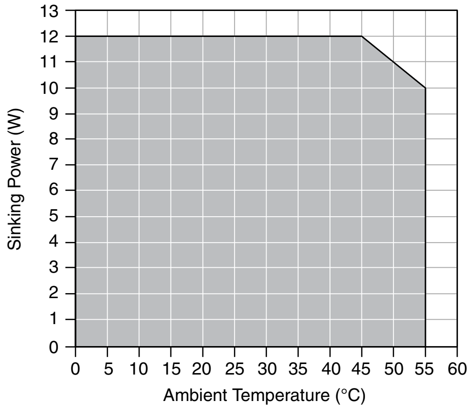


Note When the aperture time is set to 2 power-line cycles (PLCs), measurement noise differs slightly depending on whether the **niDCPower Power Line Frequency** property or `NIDCPOWER_ATTR_POWER_LINE_FREQUENCY` attribute is set to 50 Hz or 60 Hz.

Sinking Power vs. Ambient Temperature Derating

The following figure illustrates sinking power derating as a function of ambient temperature for the NI 4137.

Figure 4. Sinking Power vs. Ambient Temperature Derating



Output Resistance Programming Accuracy Characteristics

Table 4. Output Resistance Programming Accuracy Characteristics

Current Level/Limit Range	Programmable Resistance Range, Voltage Mode	Programmable Resistance Range, Current Mode	Accuracy ± (% of resistance setting), T_{cal} ± 5 °C[9]
1 µA	0 to ±5 MΩ	±5 MΩ to ±infinity	0.03%
10 µA	0 to ±500 kΩ	±500 kΩ 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[10]	0 to ±500 mΩ	±500 mΩ to ±infinity	

9 T_{cal} is the internal device temperature recorded by the NI 4137 at the completion of the last self-calibration.

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

Overvoltage Protection Characteristics

Accuracy[11] (% of OVP limit + offset)	0.1% + 200 mV
Temperature coefficient (% of OVP limit + offset)/°C	0.01% + 3 mV/°C
Measurement location	Local sense
Maximum OVP limit value	210 V
Minimum OVP limit value	2 V

Extended Range Pulsing Characteristics[12]

Maximum pulse	
Voltage	160 V
Current	3 A
On time[13]	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	<70 µs 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

11 Overvoltage protection accuracy is valid with an ambient temperature of 23 °C ± 5 °C and with Tcal ± 5 °C. Tcal is the internal device temperature recorded by the NI 4137 at the completion of the last self-calibration.

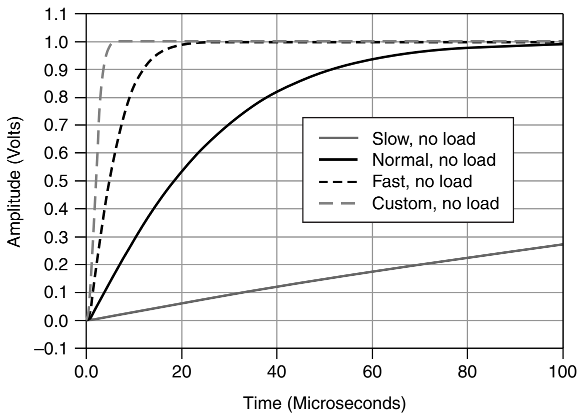
12 Extended range pulse currents fall outside DC range limits. In-range pulse currents fall within DC range limits. In-range pulses are not subject to extended range pulsing limitations.

13 *Pulse on time* is measured from the start of the leading edge to the start of the trailing edge.

Settling time[14]	
Voltage mode, 180 V step, unloaded[15]	<500 µs, typical
Voltage mode, 5 V step or smaller, unloaded[16]	<70 µs, typical
Current mode, full-scale step, 3 A to 100 µA ranges[17]	<50 µs, typical
Current mode, full-scale step, 10 µA range[17]	<150 µs, typical
Current mode, full-scale step, 1 µA range[17]	<300 µs, typical

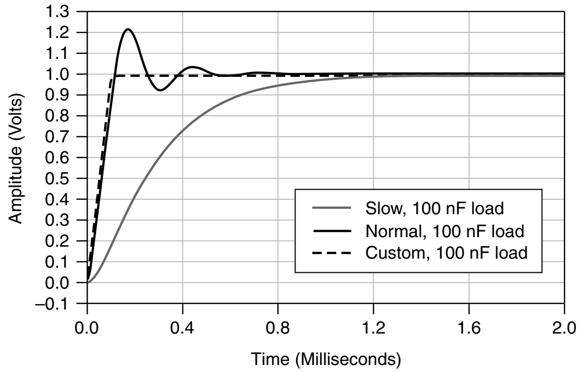
The following figures illustrate the effect of the transient response setting on the step response of the NI 4137 for different loads.

Figure 5. 1 mA Range No Load Step Response, Typical



[14] Measured as the time to settle to within 0.1% of step amplitude, device configured for fast transient response.
[15] Current limit set to ≥60 µA and ≥60% of the selected current limit range.
[16] Current limit set to ≥20 µA and ≥20% of selected current limit range.
[17] Voltage limit set to ≥2 V, resistive load set to 1 V/selected current range.

Figure 6. 1 mA Range, 100 nF Load Step Response, Typical



Load Regulation, Typical

Voltage	
Device configured for local sense	200 mV per A of output load change (measured between output channel terminals)
Device configured for remote sense	100 µV per A of output load change (measured between sense terminals)
Current, device configured for local or remote sense	Load regulation effect included in current accuracy specifications

Measurement and Update Timing Characteristics

Available sample rates[18]	(1.8 MS/s)/N where N = 1, 2, 3, … 2^{20}
Sample rate accuracy	Equal to PXIe_CLK100 accuracy
Maximum measure rate to host	1.8 MS/s per channel, continuous
Maximum source update rate[19]	100,000 updates/s

18 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.

19 As the source delay is adjusted, maximum source rates vary.

Input trigger to	
Source event delay	10 µs
Source event jitter	1 µs
Measure event jitter	1 µs
Pulse timing and accuracy	
Minimum pulse on time[20]	50 µs
Minimum pulse off time[21][22]	50 µs
Pulse on time or off time programming resolution	100 ns
Pulse on time or off time programming accuracy	±5 µs
Pulse on time or off time jitter	1 µs

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 ohm of corresponding sense lead resistance to voltage accuracy specifications
Maximum sense lead resistance	100 Ω, characteristic
Maximum lead drop per lead	3 V characteristic up to a maximum of 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.

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 voltage of up to the maximum voltage of the device 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

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

interlock terminal open the output voltage level/limit is limited to ±40 VDC, 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

Related Information

For more information about Safety Interlock operation, refer to the NI DC Power Supplies and SMUs Help.

Examples of Calculating Accuracy Specifications[23]

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 [24]
self-calibration	within the last 24 hours.

Solution

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

[24] T_{cal} is the internal device temperature recorded by the NI 4137 at the completion of the last self-calibration.

Since the device internal temperature is within $T_{cal} \pm 5$ °C and the ambient temperature is within 23 °C ± 5 °C, the appropriate accuracy specification is:

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

Solution

Since the device internal temperature is within $T_{cal} \pm 5$ °C and the ambient temperature is within 23 °C ± 5 °C, the appropriate accuracy specification is:

0.02% + 100 µV

Since the device is using remote sense, use the 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:

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

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

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

Therefore, the actual output will be 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

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

0.03% + 200 pA

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

0.0006% + 4 pA

Calculate the accuracy using the following formula:

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

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

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

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

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

Related Information

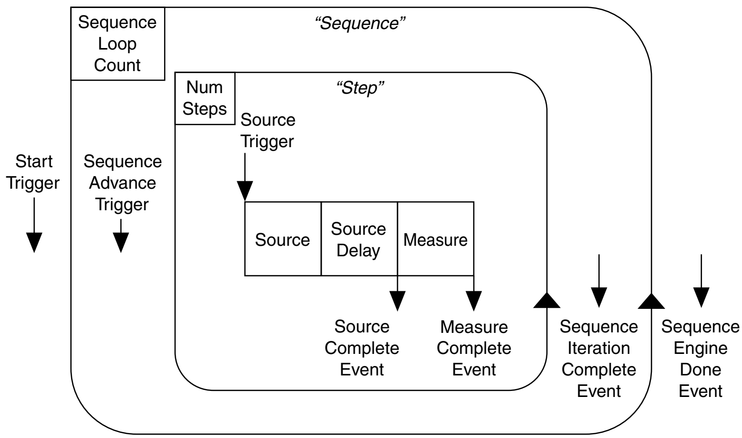
Voltage Programming and Measurement Accuracy/Resolution on page 5

Current Programming and Measurement Accuracy/Resolution on page 5

NI-DCPower Sequence Source Model

The following figure illustrates the programming flow in NI-DCPower using Sequence source mode with automatic measurements.

Figure 7. NI-DCPower Programming Flow



Related Information

NI DC Power Supplies and SMUs Help

Trigger Characteristics

Input triggers	
Types	Start, Source, Sequence Advance, Measure, Pulse

Sources (PXI trigger lines 0 to 7)[25]	
Polarity	Configurable
Minimum pulse width	100 ns
Destinations[26] (PXI trigger lines 0 to 7)[25]	
Polarity	Active high (not configurable)
Pulse width	>200 ns
Output triggers (events)	
Types	Source Complete, Sequence Iteration Complete, Sequence Engine Done, Measure Complete, Pulse Complete, Ready for Pulse
Destinations (PXI trigger lines 0 to 7)[25]	
Polarity	Configurable
Pulse width	Configurable between 250 ns and 1.6 µs

Protection Characteristics

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

Related Information

Safety Interlock on page 13

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

[26] Input triggers can be re-exported.

Isolation Characteristics

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	250 VDC, CAT I, verified by dielectric withstand test, 5 s, continuous

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.

Guard Output Characteristics

Cable guard	
Output impedance	3 kΩ
Offset voltage	1 mV

Accessories

Table 5. NI 4137 Accessories

Accessory	Manufacturer	Part Number
Additional Connector Kit for NI 4136 and NI 4137 SMUs	NI	784068-01

Related Information

Visit ni.com for more information about accessories.

Calibration Interval

Recommended calibration interval	1 year

Power Requirement Characteristics

Caution You can impair the protection provided by the NI 4137 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 and 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.)
Weight	419 g (14.8 oz)
Front panel connectors	5.08 mm (8 position)
Safety interlock connector	3.55 mm (4 position)

Related Information

NI DC Power Supplies and SMUs Help

NI 4137 Front Panel

Figure 8. Front Panel

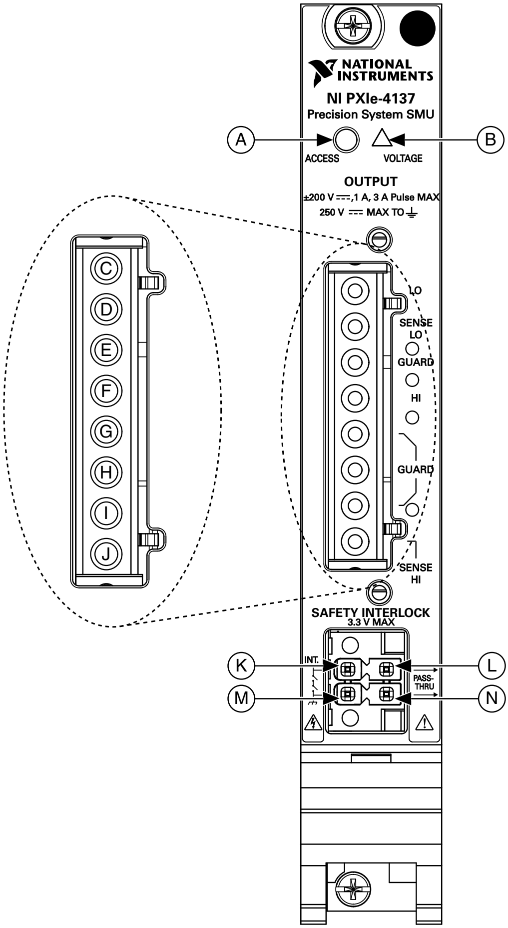


Table 6. Front Panel Connectors

	Description
A	Access Status LED
B	Voltage Status LED
C	Output LO

Table 6. Front Panel Connectors (Continued)

	Description
D	Sense LO
E	Guard
F	Output HI
G	Guard
H	Guard
I	Guard
J	Sense HI
K	Safety Interlock Input
L	Safety Interlock Pass Thru - Input
M	Safety Interlock Ground
N	Safety Interlock Pass Thru - Ground

Environment

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

Indoor use only.

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.)

Storage Environment

Ambient temperature range	-40 °C to 71 °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}
Nonoperating	5 Hz to 500 Hz, 2.4 g_{rms} (Tested in accordance with IEC 60068-2-64. Nonoperating test profile exceeds the requirements of MIL-PRF-28800F, Class 3.)

Compliance and Certifications

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 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/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）

中国客户 National Instruments 符合中国电子信息产品中限制使用某些有害物质指令(RoHS)。关于 National Instruments 中国 RoHS 合规性信息，请登录 `ni.com/environment/rohs_china`。(For information about China RoHS compliance, go to `ni.com/environment/rohs_china`.)

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