PXIe-4190

Specifications

Contents

PXIe-4190 Specifications

Notes on PXIe-4190 Variants

In this document, the 500 kHz and 2 MHz variants of the PXIe-4190 are referred to inclusively as the PXIe-4190. The information in this document applies to all variants of the PXIe-4190 unless otherwise specified.

To determine which version of the PXIe-4190 you have, locate the device name in one of the following places:

- On the device front panel, the PXIe-4190 (2 MHz) shows ***PXIe-4190 2MHz LCR Meter/SMU***. The PXIe-4190 (500 kHz) shows ***NI PXIe-4190 500kHz LCR Meter/SMU***.
- In MAX, the PXIe-4190 (2 MHz) appears as **NI PXIe-4190**. The PXIe-4190 (500 kHz) appears as **NI PXIe-4190 (500 kHz)**.

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 performance met by a majority of models.
- ***Nominal*** specifications describe an attribute that is based on design, conformance testing, or supplemental testing.

Specifications are ***Warranted*** unless otherwise noted.

Related reference:

- SMU Specifications
- LCR Specifications

- General Specifications

SMU Specifications

SMU Specifications Conditions

SMU mode specifications are valid only when the following conditions are met unless otherwise noted.

- Ambient temperature[1] of 23 °C ± 5 °C
- Temperature is within ±5 °C of last self-calibration (T_{cal})
- Relative humidity between 10% and 60%, noncondensing
- Chassis with slot cooling capacity ≥58 W
- Calibration interval of 1 year
- 30 minutes warm-up time
- Self-calibration performed within the last 24 hours
- NI-DCPower 23.3 or later installed
- Connections between force and sense leads are required[2]
- **niDCPower Aperture Time** property set to 2 power-line cycles (PLC)
- **niDCPower Cable Length** property set when using the lower two current ranges

> **Note** To avoid excessive relay wear, avoid setting **Output Connected** to `TRUE` with a non-zero voltage connected to the output.

PXIe-4190 Pinout

The following figure shows the terminals on the PXIe-4190 connector.

1. The ambient temperature of a PXI system is defined as the temperature at the chassis fan inlet (air intake).
2. For the PXIe-4190 revision D and earlier—niDCPower Output Enabled or niDCPower Output Connected properties must be set to FALSE when making connections between force and sense leads. Disconnecting the sense leads while both these properties are set to TRUE may result in output protection errors or long settling tails due to the feedback path for the control loop being open. If the PXIe-4190 is run open loop due to accidental sense lead disconnection, allow a minimum of 1 minute after establishing proper lead connections before making measurements.

Figure 1. PXIe-4190 Connector Pinout

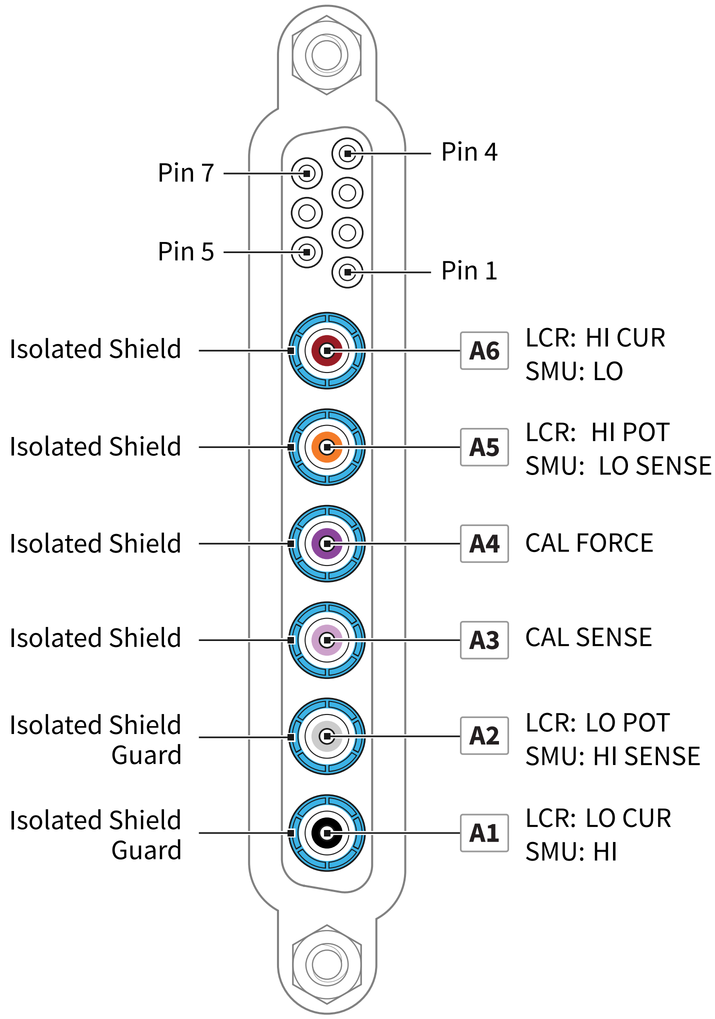


Table 1. Signal Descriptions

Contact	LCR Mode Functionality	SMU Mode Functionality
Pin 1 to Pin 7	General purpose input/output contacts	
A6 (Center Conductor)	HI CUR	LO
A6 (Outer Conductor)	Isolated Shield	
A5 (Center Conductor)	HI POT	Sense LO
A5 (Outer Conductor)	Isolated Shield	
A4 (Center Conductor)	CAL FORCE	
A4 (Outer Conductor)	Isolated Shield	
A3 (Center Conductor)	CAL SENSE	
A3 (Outer Conductor)	Isolated Shield	

Contact	LCR Mode Functionality	SMU Mode Functionality
A2 (Center Conductor)	LO POT	Sense HI
A2 (Outer Conductor)	Isolated Shield	GUARD
A1 (Center Conductor)	LO CUR	HI
A1 (Outer Conductor)	Isolated Shield	GUARD

SMU Instrument Capabilities

Table 2. DC Voltage Ranges

PXIe-4190 (2 MHz)	PXIe-4190 (500 kHz)
• 1 V • 10 V • 40 V	• 1 V • 10 V

Table 3. DC Current Ranges

PXIe-4190 (2 MHz)	PXIe-4190 (500 kHz)
• 1 nA • 100 nA • 1 μA • 10 μA • 100 μA • 1 mA • 10 mA • 100 mA	• 10 μA • 100 μA • 1 mA • 10 mA • 100 mA

Table 4. Available DC output power

	PXIe-4190 (2 MHz)	PXIe-4190 (500 kHz)
Sourcing	4 W	1 W
Sinking	4 W	1 W

Figure 2. PXIe-4190 (2 MHz) Quadrant Diagram

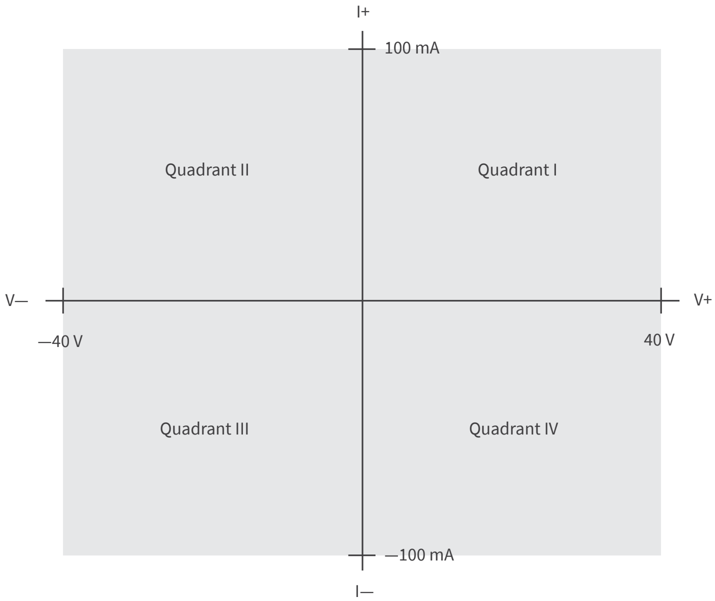
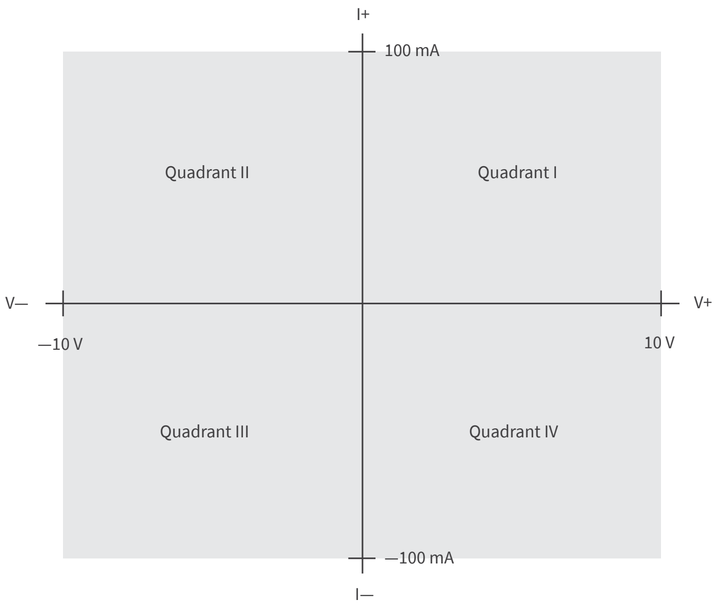


Figure 3. PXIe-4190 (500 kHz) Quadrant Diagram



SMU Voltage

Table 5. Voltage Programming and Measurement Accuracy/Resolution

Range	Resolution (Noise Limited)	Noise (0.1 Hz to 10 Hz, peak-to-peak, typical)	Accuracy ± (% of Voltage + Offset)		Tempco[†] ± (% of Voltage + Offset)/°C
			$T_{ambient}$ 23 °C ±5 °C, T_{cal}[*] ±5 °C		
			% of Voltage	Offset	$T_{ambient}$ 0 °C to 33 °C, T_{cal} ±5 °C
1 V	100 nV	2 µV	0.009%	160 µV	0.0002% + 1 µV
10 V	1 µV	10 µV	0.008%	1 mV	
40 V[‡]	4 µV	50 µV	0.009%	4.1 mV	

[*] T_{cal} is the internal device temperature recorded by the PXIe-4190 at the completion of the last self-calibration.

[†] Temperature coefficient applies beyond 23 °C ±5 °C ambient within ±5 °C T_{cal}.

[‡] PXIe-4190 (2 MHz) only

SMU Current

Table 6. Current Programming and Measurement Accuracy/Resolution

Range	Resolution (Noise Limited)	Noise (0.1 Hz to 10 Hz, peak-to-peak, typical)	Accuracy ± (% of Current + Offset)		Tempco[†] ± (% of Current + Offset)/°C
			$T_{ambient}$ 23 °C ±5 °C, T_{cal}[*] ±5 °C		
			% of Current	Offset[‡,§]	$T_{ambient}$ 0 °C to 33 °C, T_{cal} ±5 °C
1 nA[**,††]	1 fA	30 fA	0.14%	2 pA	0.0003% + 20 fA
1 nA[‡‡,††]		60 fA			

Range	Resolution (Noise Limited)	Noise (0.1 Hz to 10 Hz, peak-to-peak, typical)	Accuracy ± (% of Current + Offset)		Tempco[†] ± (% of Current + Offset)/°C
			$T_{ambient}$ 23 °C ±5 °C, T_{cal}[*] ±5 °C		$T_{ambient}$ 0 °C to 33 °C, T_{cal} ±5 °C
			% of Current	Offset[‡,§]	
100 nA[**,††]	10 fA	300 fA	0.091%	11 pA	
100 nA[‡‡,††]		700 fA			
1 µA[††]	100 fA	2 pA	0.032%	140 pA	
10 µA	1 pA	15 pA	0.026%	1 nA	
100 µA	10 pA	120 pA	0.024%	10 nA	
1 mA	100 pA	1.2 nA	0.023%	100 nA	
10 mA	1 nA	12 nA	0.022%	1 µA	
100 mA	10 nA	120 nA	0.028%	10 µA	

[*] T_{cal} is the internal device temperature recorded by the PXIe-4190 at the completion of the last self-calibration.

[†] Temperature coefficient applies beyond 23 °C ±5 °C ambient within ±5 °C T_{cal}.

[‡] Add 10 pA to current accuracy specifications when using DSUB-DSUB cable accessory (SHDB13W6-DB13W6-LL).

[§] Add 10 pA to current accuracy specifications when operating with $T_{ambient}$ >30 °C.

[**] Under the following additional conditions: with 10 PLC, and 11-point median filter.

[††] PXIe-4190 (2 MHz) only

[‡‡] Under default specification conditions.

SMU Noise

Wideband source noise	<20 mV peak-to-peak, typical[3]

Figure 4. Voltage RMS Noise versus Aperture Time, Nominal

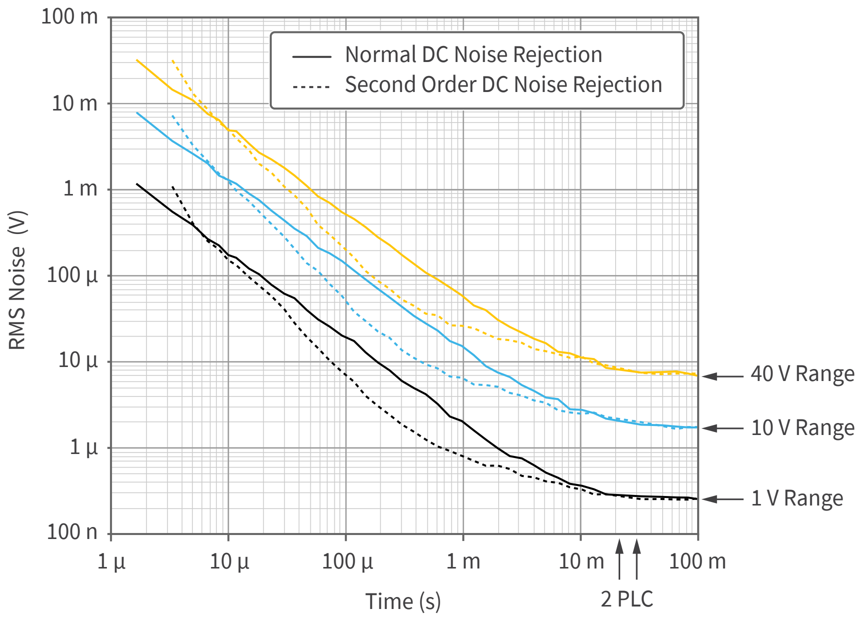
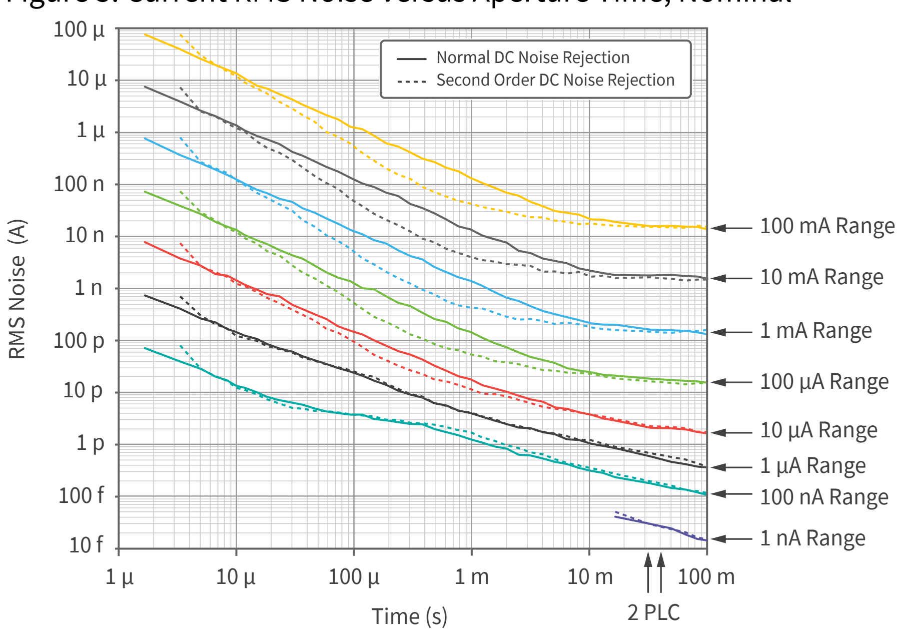


Figure 5. Current RMS Noise versus Aperture Time, Nominal



Note Use an aperture time of at least 1 PLC to minimize powerline noise

3. 10 Hz to 20 MHz bandwidth, PXIe-4190 configured for normal transient response.

> pickup in the 1 nA range.

SMU Load Regulation

Voltage	Error included in accuracy specifications
Current	Error included in accuracy specifications

SMU Transient Response and Settling Time

Table 7. Settling Time, Typical

Range	**Voltage Mode, ≤5 V Step, Unloaded***	**Current Mode, Full-Scale Step†**
100 mA to 10 µA	<200 µs	<200 µs
1 µA	<350 µs	<2 ms
100 nA	<2 ms	<8 ms
1 nA	<40 ms	<1,100 ms

Note: Measured as the time to settle to within 0.1% of step amplitude, PXIe-4190 configured for fast transient response, with 1 m cable.

* Current limit set to 100% of selected current range for 1 nA and 100 nA ranges, all other ranges set to 50% of selected current range.

† Voltage limit set to ≥2 V, resistive load set to 1 V/selected current range.

Table 8. Transient Response, Typical

Current Range	**Recovery Time***	**Voltage Dip**	**Time Constant†**
100 mA	<40 µs	<1.3 V	<10 µs
10 mA	<40 µs	<1.2 V	<10 µs

Current Range	Recovery Time*	Voltage Dip	Time Constant†
1 mA	<40 µs	<800 mV	<17 µs
100 µA	<65 µs	<500 mV	<35 µs
10 µA	<150 µs	<200 mV	<50 µs
1 µA	<450 µs	<35 mV	<340 µs
100 nA	—	<8 mV	<3 ms
1 nA	—	<800 µV	<300 ms

Note: Load current change from 10% to 90% of range, PXIe-4190 configured for fast transient response, with 1 m cable.

* ***Recovery Time*** defined as the time to recover within 10 mV after load current change.

† ***Time Constant*** defined as the time to recover within 63% of ***Voltage Dip*** after load current change.

SMU Remote Sense

Maximum sense lead resistance	200 Ω
Maximum lead drop per lead	1 V

SMU Guard Output Characteristics

Cable guard	
Output impedance	<100 mΩ, nominal
Offset voltage	1 mV, typical

SMU Measurement and Update Timing

Available sample rates[4]	(600 kS/s)/N, nominal

where

- N = 1, 2, 3, … 2^{24}
- S is samples

Sample rate accuracy	Equal to PXIe_CLK100 accuracy, nominal
Maximum measure rate to host	600 kS/s, nominal
Maximum source update rate, sequence mode	100,000 updates/s (10 µs/update), nominal

Input trigger to	
Source event delay	10 µs nominal
Source event jitter	2 µs peak-to-peak, nominal
Measure event jitter	2 µs peak-to-peak, nominal

4. When source-measuring, both the NI-DCPower Source Delay and Aperture Time properties affect the sampling rate. When taking a measure record, only the Aperture Time property affects the sampling rate.

LCR Specifications

LCR Specifications Conditions

LCR mode specifications are valid only when the following conditions are met unless otherwise noted.

- Ambient temperature[5] of 23 °C ± 10 °C
- Temperature is within ±5 °C of last self-calibration (T_{cal})
- Relative humidity between 10% and 60%, noncondensing
- Chassis with slot cooling capacity ≥58 W
- Calibration interval of 1 year
- 30 minutes warm-up time
- Self-calibration performed within the last 24 hours
- NI-DCPower 23.3 or later installed
- AC Stimulus Automatic Level Control (ALC) is `On`
- DC Bias Automatic Level Control (ALC) set to `On`
- Impedance range is within 30% of DUT impedance
- LCR Measurement Time is Long unless otherwise stated
- **Source delay** set to `Automatic`
- Open and short LCR compensation has been completed.
- Connections between force and sense leads are required[6]
- Four-terminal pair (4TP) connections to load[7]
- **niDCPower Cable Length** property set

> **Note** To avoid excessive relay wear, avoid setting **Output connected** to `TRUE` with a non-zero voltage connected to the output.

5. The ambient temperature of a PXI system is defined as the temperature at the chassis fan inlet (air intake).
6. For the PXIe-4190 revision D and earlier—niDCPower Output Enabled or niDCPower Output Connected properties must be set to FALSE when making connections between force and sense leads. Disconnecting the sense leads while both these properties are set to TRUE may result in output protection errors or long settling tails due to the feedback path for the control loop being open. If the PXIe-4190 is run open loop due to accidental sense lead disconnection, allow a minimum of 1 minute after establishing proper lead connections before making measurements.
7. Refer to the *PXIe-4190* ***Getting Started*** for more information on 4TP connections.

Related information:

- Compensation of LCR Measurements with NI-DCPower

LCR Instrument Capabilities

The PXIe-4190 is capable of measuring the following elements using AC stimulus frequencies from 40 Hz to 2 MHz:

- Capacitors—100 fF to 5 mF, with up to 100 aF sensitivity
- Inductors—Greater than 10 nH, with up to 10 pH sensitivity
- Resistors—100 mΩ to 1 GΩ, with up to 10 µΩ sensitivity

Maximum AC voltage	7.07 V RMS
Maximum AC current	70.7 mA RMS
Maximum DC bias voltage range	
PXIe-4190 (2 MHz)	±40 V, including peak AC stimulus
PXIe-4190 (500 kHz)	±10 V, including peak AC stimulus

Maximum DC bias current range	±100 mA, including peak AC stimulus

AC stimulus frequency range	
PXIe-4190 (2 MHz)	40 Hz to 2 MHz
PXIe-4190 (500 kHz)	40 Hz to 500 kHz

Measurement time settings	
Short	1 ms
Medium	10 ms
Long	100 ms
Custom	0 to 0.99999 s

Note Measurement times round up to the nearest positive integer number of cycles of the AC stimulus frequency.

Calculating Total LCR Measurement Time per Setpoint

Total Measurement Time per setpoint = LCR Source Delay + Total LCR Measurement Time

Calculating LCR Source Delay Time

- **LCR Source Delay Mode** = Automatic
  - In Automatic mode, the source delay is 20 cycles of the AC stimulus frequency with a minimum source delay of 1 ms.
  - $\text{LCR Source Delay} = \text{Maximum}\left(20 \times \frac{1}{f},\ 1\ \text{ms}\right)$
- **LCR Source Delay Mode** = Manual
  - LCR Source Delay time is as specified for the **Source Delay** property.

  Note Using a source delay smaller than the default value may not allow the output to sufficiently settle, resulting in measurement inaccuracy.
- Setpoint changes that result in a range change add an additional 600 µs of source

delay in either mode.

Calculating Total LCR Measurement Time

- Total LCR Measurement Time = N × (CoercedMeasurementTime + 10 µs)
  - ◦ **N**—Measurement count
  - **CoercedMeasurementTime**—
    - The measurement time coerces to a full sinewave cycle boundary regardless of mode.

      $\lceil x \rceil$ = Ceiling function
    - $\text{CoercedMeasurementTime} = \dfrac{\lceil \text{LCR Measurement Time} \times f \rceil}{f}$

      Where **LCR Measurement Time** =
      Short (1 ms)/Medium (10 ms))/Long (100 ms)/Custom

      > **Note** LCR Custom Measurement Time = 0 is a special case that gives 1 cycle for any frequency.

LCR Measurements

- **Z**—Impedance
- **Y**—Admittance
- **Ls**—Inductance using series-equivalent circuit model
- **Cs**—Capacitance using series-equivalent circuit model
- **Rs**—Resistance using series-equivalent circuit model
- **Lp**—Inductance using parallel-equivalent circuit model
- **Cp**—Capacitance using parallel-equivalent circuit model
- **Rp**—Resistance using parallel-equivalent circuit model
- **D**—Dissipation factor
- **Q**—Quality factor
- **V DC**—DC voltage measurement
- **I DC**—DC current measurement
- **AC voltage**—AC voltage magnitude and phase angle
- **AC current**—AC current magnitude and phase angle

LCR AC Stimulus

Voltage stimulus		
Maximum		7.07 V RMS
Minimum		7.07 mV RMS
Resolution		<1 µV RMS
Maximum current		70.7 mA RMS
Accuracy (ALC on)		
	≤10 kHz	±0.4%
	>10 kHz	±4%

Current stimulus		
Maximum		70.7 mA RMS
Minimum		707 nA RMS
Resolution		<100 pA RMS
Maximum voltage		7.07 V RMS
Accuracy (ALC on)		
	≤10 kHz	±0.5%
	>10 kHz	±6%

LCR DC Bias

Voltage DC bias - PXIe-4190 (2 MHz)	
Maximum	±40 V, including peak AC stimulus
Resolution	<10 µV

Accuracy	0.02% + 5 mV
Voltage DC bias - PXIe-4190 (500 kHz)	
Maximum	±10 V, including peak AC stimulus
Resolution	<10 µV
Accuracy	0.02% + 5 mV
Current DC bias	
Maximum	±100 mA, including peak AC stimulus
Resolution	<10 nA
Accuracy	0.04% + 10 µA

LCR Frequency

Accuracy	Equal to PXIe_CLK100 accuracy, nominal
Frequency resolution	1 mHz

LCR Measurement Accuracy

This topic shows the illustrated LCR measurement accuracy for capacitive DUTs.

The following figure shows capacitor impedance magnitude versus test frequency to help quickly identify the appropriate impedance range for your measurements. Additionally, several important DUT test points across frequency are highlighted, with the corresponding Absolute Measurement Accuracy and AC Stimulus range shown in Table 9. Specifications for Representative DUT Test Points.

Complete absolute accuracy specifications are described beginning in Table 11. Absolute Impedance Magnitude Accuracy, 708 mV RMS to 7.07 V RMS AC Stimulus Voltage.

Figure 6. Capacitor Impedance versus Frequency, with Representative Test Points Identified

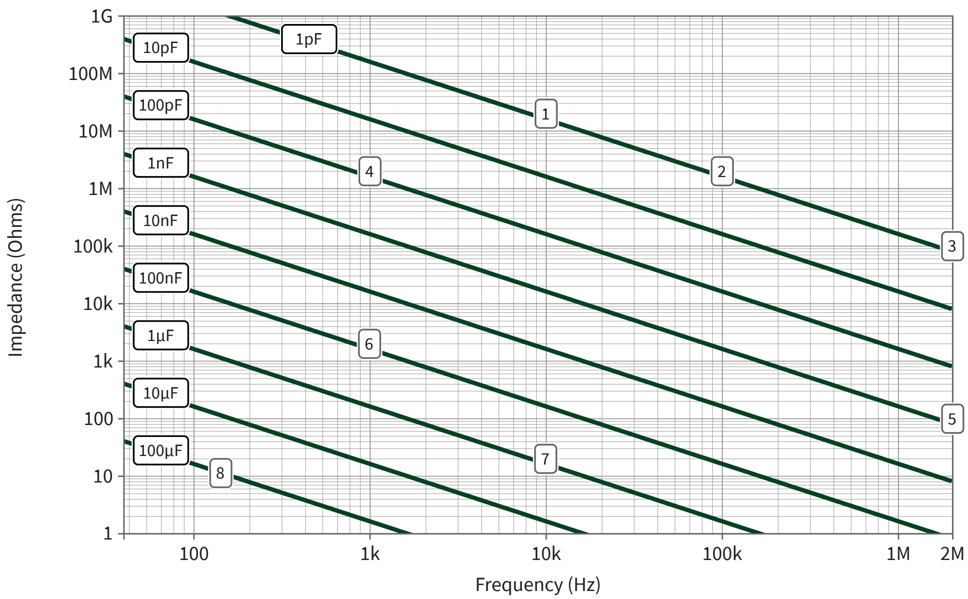


Table 9. Specifications for Representative DUT Test Points

Test Point	Capacitor Value	AC Stimulus Frequency	AC Stimulus Level	Z_C at AC Stimulus Frequency	Measurement Accuracy	
					Magnitude (Capacitance)	Phase (Dissipation Factor)
1	1 pF	10 kHz	708 mV RMS to 7.07 V RMS	15.9 MΩ	0.15% (1.5 fF)	0.08° (0.0014)
2	1 pF	100 kHz	708 mV RMS to 7.07 V RMS	1.59 MΩ	0.30% (3 fF)	0.19° (0.0033)
3	1 pF	2 MHz	708 mV RMS	79.6 kΩ	0.60% (6 fF)	0.26°

Test Point	Capacitor Value	AC Stimulus Frequency	AC Stimulus Level	Z_C at AC Stimulus Frequency	Measurement Accuracy	
					Magnitude (Capacitance)	Phase (Dissipation Factor)
			to 5 V RMS			(0.0045)
4	100 pF	1 kHz	708 mV RMS to 7.07 V RMS	1.59 MΩ	0.06% (60 fF)	0.03° (0.0005)
5	1 nF	2 MHz	150 mV RMS to 707 mV RMS	79.6 Ω	0.50% (50 pF)	0.18° (0.0031)
6	100 nF	1 kHz	150 mV RMS to 707 mV RMS	1.59 kΩ	0.05% (50 pF)	0.02° (0.00035)
7	1 µF	10 kHz	150 mV RMS to 707 mV RMS	15.9 Ω	0.08% (800 pF)	0.22° (0.0038)
8	100 µF	120 Hz	50 mV RMS to 150 mV RMS	13.3 Ω	0.08% (80 nF)	0.04° (0.0007)

Note Equations to solve for capacitor impedance, inductor impedance, and dissipation factor are shown in Example 1.

Table 10. Calculated Accuracy for Capacitive DUTs (Cp, Cs) for Common MLCC AC Stimulus Frequencies from Absolute Impedance Magnitude Accuracy and Absolute Impedance Phase Accuracy Tables

Capacitor Value	AC Stimulus Voltage	AC Stimulus Frequency	Capacitance Magnitude Accuracy	Phase Accuracy	Df Accuracy
13.3 pF < C ≤ 132.6 pF	1.0 V RMS	120 Hz	±0.15%	±0.08°	±0.001396
132.6 pF < C ≤ 1.3 nF	1.0 V RMS	120 Hz	±0.06%	±0.03°	±0.000524
1.3 nF < C ≤	1.0 V RMS	120 Hz	±0.06%	±0.02°	±0.000349

Capacitor Value	AC Stimulus Voltage	AC Stimulus Frequency	Capacitance Magnitude Accuracy	Phase Accuracy	Df Accuracy
13.3 nF					
13.3 nF < C ≤ 132.6 nF	1.0 V RMS	120 Hz	±0.05%	±0.02°	±0.000349
132.6 nF < C ≤ 1.3 µF	1.0 V RMS	120 Hz	±0.06%	±0.02°	±0.000349
1.3 µF < C ≤ 93.8 µF	1.0 V RMS	120 Hz	±0.08%	±0.03°	±0.000524
93.8 µF < C ≤ 132.6 µF	0.5 V RMS	120 Hz	±0.08%	±0.03°	±0.000524
1.6 pF < C ≤ 15.9 pF	1.0 V RMS	1 kHz	±0.15%	±0.08°	±0.001396
15.9 pF < C ≤ 159.2 pF	1.0 V RMS	1 kHz	±0.06%	±0.03°	±0.000524
159.2 pF < C ≤ 1.6 nF	1.0 V RMS	1 kHz	±0.06%	±0.02°	±0.000349
1.6 nF < C ≤ 15.9 nF	1.0 V RMS	1 kHz	±0.05%	±0.02°	±0.000349
15.9 nF < C ≤ 159.2 nF	1.0 V RMS	1 kHz	±0.06%	±0.02°	±0.000349
159.2 nF < C ≤ 11.3 µF	1.0 V RMS	1 kHz	±0.08%	±0.03°	±0.000524
11.3 µF < C ≤ 15.9 µF	0.5 V RMS	1 kHz	±0.08%	±0.03°	±0.000524
624 fF < C ≤ 1.6 pF	1.0 V RMS	1 MHz	±0.30%	±0.16°	±0.002793
1.6 pF < C ≤ 15.9 pF	1.0 V RMS	1 MHz	±0.30%	±0.13°	±0.002269
15.9 pF < C ≤ 159.2 pF	1.0 V RMS	1 MHz	±0.20%	±0.12°	±0.002094

Capacitor Value	AC Stimulus Voltage	AC Stimulus Frequency	Capacitance Magnitude Accuracy	Phase Accuracy	Df Accuracy
159.2 pF < C ≤ 530.5 pF	1.0 V RMS	1 MHz	±0.20%	±0.12°	±0.002094
530.5 pF < C ≤ 11.3 nF	1.0 V RMS	1 MHz	±0.20%	±0.11°	±0.001920
11.3 nF < C ≤ 15.9 nF	0.5 V RMS	1 MHz	±0.20%	±0.13°	±0.002269

LCR Magnitude and Phase Accuracy

Table 11. Absolute Impedance Magnitude Accuracy, 708 mV RMS to 7.07 V RMS AC Stimulus Voltage

Impedance Range	AC Stimulus Frequency						
	40 Hz to 100 Hz	100 Hz to 1 kHz	1 kHz to 10 kHz	10 kHz to 200 kHz	200 kHz to 500 kHz	500 kHz to 1 MHz*	1 MHz to 2 MHz*
100 MΩ to 1 GΩ	1.00%, typical	1.00%	—	—	—	—	—
10 MΩ to 100 MΩ	0.15%, typical	0.15%	0.15%	—	—	—	—
1 MΩ to 10 MΩ	0.06%, typical	0.06%	0.15%	0.30%	—	—	—
100 kΩ to 1 MΩ	0.05%	0.06%	0.08%	0.30%	0.30%†	0.30%‡	0.60%§
10 kΩ to 100 kΩ	0.05%	0.05%	0.08%	0.30%	0.30%	0.30%	0.60%
1 kΩ to 10 kΩ	0.05%	0.06%	0.08%	0.20%	0.20%	0.20%	0.50%
300 Ω to 1 kΩ	0.08%	0.08%	0.08%	0.15%	0.15%	0.20%	0.50%
10 Ω to 300 Ω	0.08%	0.08%	0.20%	0.20%	0.20%	0.20%	0.50%

Impedance Range	AC Stimulus Frequency						
	40 Hz to 100 Hz	100 Hz to 1 kHz	1 kHz to 10 kHz	10 kHz to 200 kHz	200 kHz to 500 kHz	500 kHz to 1 MHz*	1 MHz to 2 MHz*

* PXIe-4190 (2 MHz) only

† Up to 640 kΩ impedance range.

‡ Up to 255 kΩ impedance range.

§ Up to 130 kΩ impedance range.

Note: Impedances <10 Ω require a reduced AC stimulus. Refer to the following table for more information.

Note: When on boundary, use lower adjacent value.

Note: Add the following derating factor to LCR magnitude when AC stimulus level is >5 V RMS and >1 MHz:

$$\text{Additional magnitude error (\%)} = \left(\frac{f}{1\text{ MHz}}\right)^2 \times \left(V_{\text{stim}} - 5\text{ V}\right)^2 \times 0.025\%$$

Table 12. Absolute Impedance Magnitude Accuracy, 150 mV RMS to 707 mV RMS AC Stimulus Voltage

Impedance Range	AC Stimulus Frequency						
	40 Hz to 100 Hz	100 Hz to 1 kHz	1 kHz to 10 kHz	10 kHz to 200 kHz	200 kHz to 500 kHz	500 kHz to 1 MHz*	1 MHz to 2 MHz*
10 MΩ to 100 MΩ	0.20%, typical	0.40%	1.10%	—	—	—	—
1 MΩ to 10 MΩ	0.06%, typical	0.06%	0.20%	0.90%	—	—	—
100 kΩ to 1 MΩ	0.05%	0.06%	0.08%	0.90%	0.60%†	0.60%‡	0.60%§
10 kΩ to 100 kΩ	0.05%	0.05%	0.08%	0.30%	0.30%	0.30%	0.50%

Impedance Range	AC Stimulus Frequency						
	40 Hz to 100 Hz	100 Hz to 1 kHz	1 kHz to 10 kHz	10 kHz to 200 kHz	200 kHz to 500 kHz	500 kHz to 1 MHz*	1 MHz to 2 MHz*
1 kΩ to 10 kΩ	0.05%	0.05%	0.08%	0.20%	0.20%	0.20%	0.50%
300 Ω to 1 kΩ	0.08%	0.08%	0.08%	0.15%	0.15%	0.20%	0.50%
10 Ω to 300 Ω	0.08%	0.08%	0.08%	0.20%	0.20%	0.20%	0.50%
<10 Ω**	0.08% + 1 mΩ	0.08% + 1 mΩ	0.08% + 1 mΩ	0.90% + 1mΩ	0.90% + 1 mΩ	1.20% + 1 mΩ††	2.00% + 2 mΩ††

* PXIe-4190 (2 MHz) only

† Up to 640 kΩ impedance range.

‡ Up to 255 kΩ impedance range.

§ Up to 130 kΩ impedance range.

** Typical, offset relative to short compensation.

†† Refer to ***AC Stimulus Current Short Offset Multiplier*** table for offset multiplier.

Note: When on boundary, use lower adjacent value.

Table 13. AC Stimulus Current Short Offset Multiplier

AC Stimulus Current	Short Offset Multiplier
<7.07 mA	5
7.08 mA to 20 mA	1
>20 mA	2

Table 14. Absolute Impedance Magnitude Accuracy Multiplier for AC Stimuli Below 150 mV RMS

Impedance Range	AC Stimulus Voltage	
	50 mV RMS to 150 mV RMS	7.08 mV RMS to 50 mV RMS, typical
<10 Ω	1	1
10 Ω to 300 Ω	2	5
300 Ω to 10 MΩ	2	11
10 MΩ to 100 MΩ	3	—

Note: Absolute accuracy is the ***Absolute Impedance Magnitude Accuracy, 150 mV RMS to 707 mV RMS AC Stimulus Voltage*** table value times the respective multiplier.

Table 15. Absolute Impedance Phase Accuracy, 708 mV RMS to 7.07 V RMS AC Stimulus Voltage

Impedance Range	AC Stimulus Frequency						
	40 Hz to 100 Hz	100 Hz to 1 kHz	1 kHz to 10 kHz	>10 kHz to 200 kHz	200 kHz to 500 kHz	500 kHz to 1 MHz*	1 MHz to 2 MHz*
100 MΩ to 1 GΩ	0.55 °, typical	0.55 °	—	—	—	—	—
10 MΩ to 100 MΩ	0.19 °, typical	0.08 °	0.25 °	—	—	—	—
1 MΩ to 10 MΩ	0.02 °, typical	0.03 °	0.21 °	0.19 °	—	—	—
100 kΩ to 1 MΩ	0.01 °	0.02 °	0.19 °	0.19 °	0.14 °†	0.16 °‡	0.26 °§
10 kΩ to 100 kΩ	0.01 °	0.02 °	0.10 °	0.11 °	0.12 °	0.13 °	0.26 °
1 kΩ to 10 kΩ	0.01 °	0.02 °	0.09 °	0.10 °	0.10 °	0.12 °	0.31 °
300 Ω to 1 kΩ	0.01 °	0.03 °	0.12 °	0.08 °	0.13 °	0.12 °	0.34 °
10 Ω to 300 Ω	0.01 °	0.03 °	0.13 °	0.08 °	0.09 °	0.11 °	0.15 °

Impedance Range	AC Stimulus Frequency						
	40 Hz to 100 Hz	100 Hz to 1 kHz	1 kHz to 10 kHz	>10 kHz to 200 kHz	200 kHz to 500 kHz	500 kHz to 1 MHz*	1 MHz to 2 MHz*

* PXIe-4190 (2 MHz) only

† Up to 640 kΩ impedance range.

‡ Up to 255 kΩ impedance range.

§ Up to 130 kΩ impedance range.

Note: Impedances <10 Ω require a reduced AC stimulus. Refer to the following table for more information.

Note: When on boundary, use lower adjacent value.

Table 16. Absolute Impedance Phase Accuracy, 150 mV RMS to 707 mV RMS AC Stimulus Voltage

Impedance Range	AC Stimulus Frequency						
	40 Hz to 100 Hz	100 Hz to 1 kHz	1 kHz to 10 kHz	>10 kHz to 200 kHz	200 kHz to 500 kHz	500 kHz to 1 MHz*	1 MHz to 2 MHz*
10 MΩ to 100 MΩ	0.14 °, typical	0.30 °	0.50 °	—	—	—	—
1 MΩ to 10 MΩ	0.03 °, typical	0.03 °	0.14 °	0.45 °	—	—	—
100 kΩ to 1 MΩ	0.02 °	0.03 °	0.14 °	0.45 °	0.22 °†	0.22 °‡	0.34 °§
10 kΩ to 100 kΩ	0.01 °	0.02 °	0.07 °	0.15 °	0.14 °	0.14 °	0.34 °
1 kΩ to 10 kΩ	0.01 °	0.02 °	0.07 °	0.15 °	0.09 °	0.11 °	0.20 °
300 Ω to 1 kΩ	0.01 °	0.02 °	0.07 °	0.08 °	0.09 °	0.12 °	0.34 °
10 Ω to 300 Ω	0.01 °	0.04 °	0.22 °	0.08 °	0.10 °	0.13 °	0.18 °

Impedance Range	AC Stimulus Frequency						
	40 Hz to 100 Hz	100 Hz to 1 kHz	1 kHz to 10 kHz	>10 kHz to 200 kHz	200 kHz to 500 kHz	500 kHz to 1 MHz*	1 MHz to 2 MHz*
<10 Ω, typical	0.01 °	0.04 °	0.08 °	0.03 °	0.07 °	0.15 °	0.20 °

* PXIe-4190 (2 MHz) only

† Up to 640 kΩ impedance range.

‡ Up to 255 kΩ impedance range.

§ Up to 130 kΩ impedance range.

Note: When on boundary, use lower adjacent value.

Table 17. Absolute Impedance Phase Accuracy Multiplier for AC Stimuli Below 150 mV RMS

Impedance Range	AC Stimulus Voltage	
	50 mV RMS to 150 mV RMS	7.08 mV RMS to 50 mV RMS, typical
<10 Ω	1	4
10 Ω to 300 Ω	2	20
300 Ω to 1 kΩ	2	70
1 kΩ to 10 kΩ	2	25
>10 kΩ to 100 kΩ	2	25
100 kΩ to 1 MΩ	2	10
1 MΩ to 10 MΩ	2	8
10 MΩ to 100 MΩ	3	8

Note: Absolute accuracy is the ***Absolute Impedance Phase Accuracy, 150 mV RMS to 707 mV RMS AC Stimulus Voltage*** table value times the respective multiplier.

LCR Noise

Figure 7. Impedance Magnitude Measurement Noise versus Measurement Time, 1 kΩ, Nominal

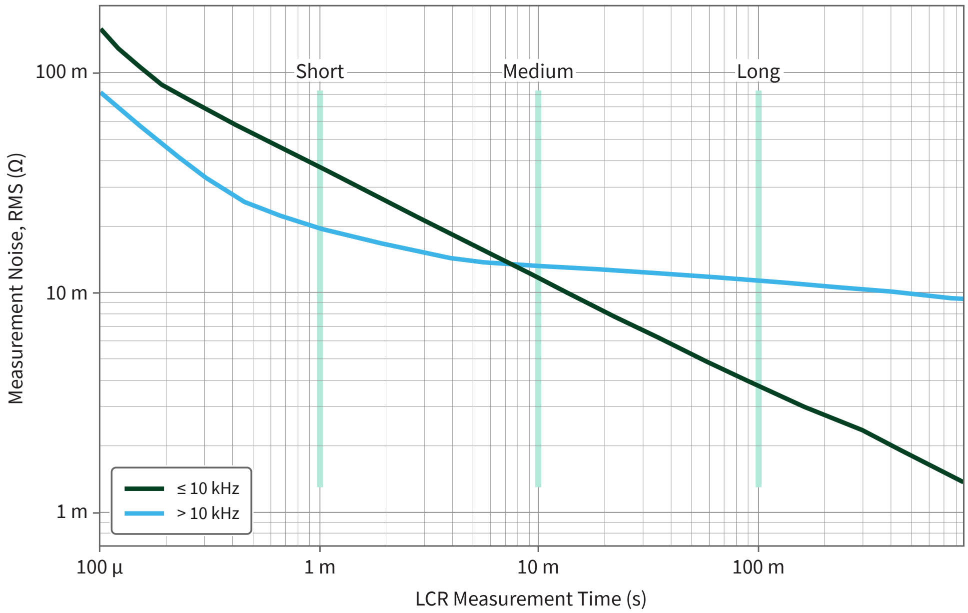


Figure 8. Impedance Phase Measurement Noise versus Measurement Time, 1 kΩ, Nominal

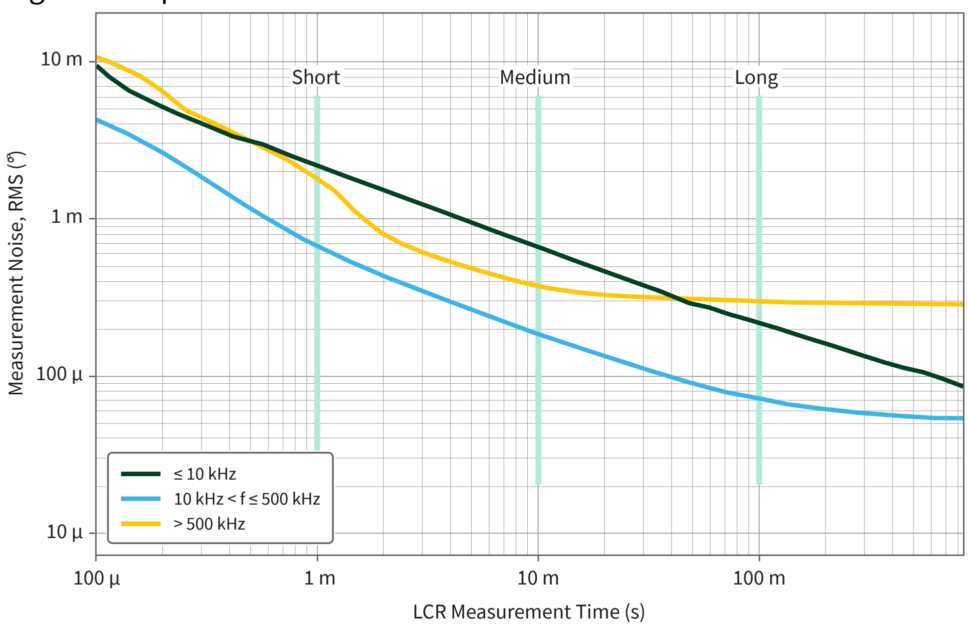


Table 18. Specification Derating for Short and Medium Measurement Time, Typical

Use the following table to multiply the respective magnitude and phase accuracy specification value by the derating factor for the applicable measurement time.

Measurement Time	Derating Factor
Medium	$\mathrm{Maximum}\left(1, \log\left(\frac{\lvert Z\rvert}{V_{acStimulus} \times 10^{6}}\right)\right)$
Short	$\mathrm{Maximum}\left(1.5, \log\left(\frac{\lvert Z\rvert}{V_{acStimulus} \times 5 \times 10^{4}}\right)\right)$

Note: Measurement time derating is a function of impedance magnitude and AC stimulus voltage level, and is independent of frequency. Specifications are determined by comparing differences in the standard deviation for different measurement times.

Figure 9. Capacitance versus Frequency, 1 pF, 1 V RMS AC Stimulus, Long Measurement Time, Measured Data for 20 Modules

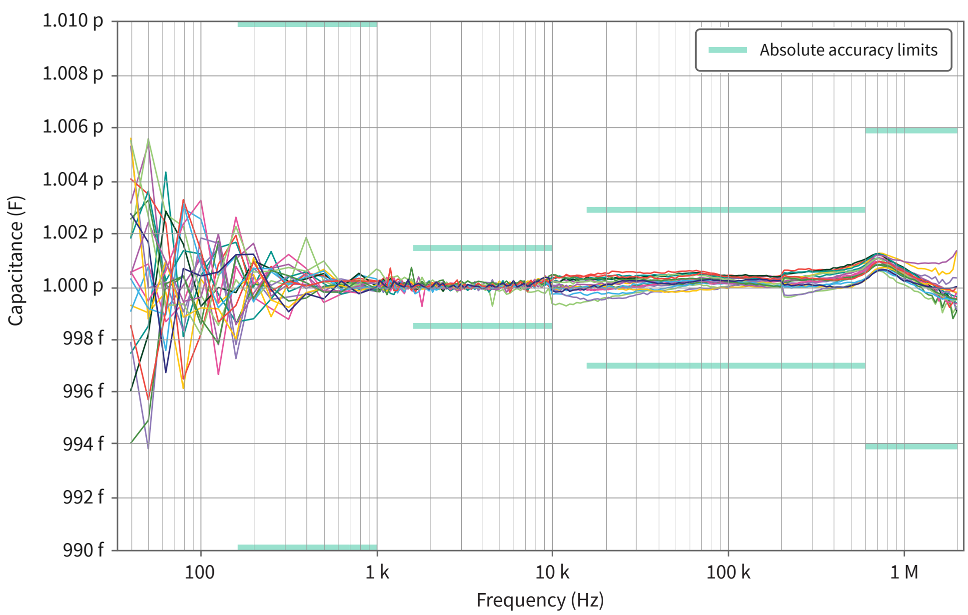


Figure 10. Dissipation Factor versus Frequency, 1 pF, 1 V RMS AC Stimulus, Long Measurement Time,

Measured Data for 20 Modules

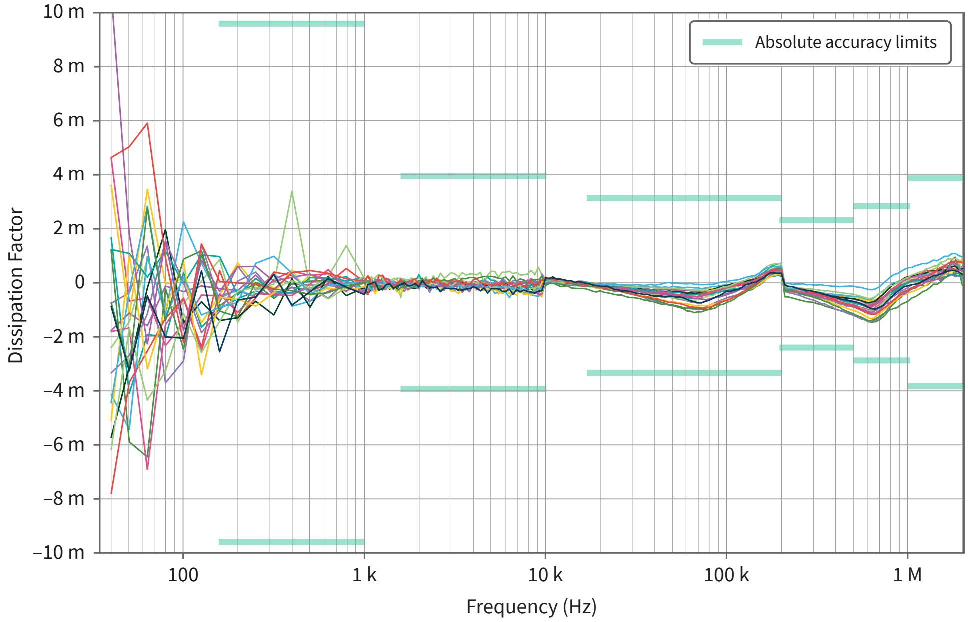


Figure 11. Capacitance versus Frequency, 100 pF, 1 V RMS AC Stimulus, Long Measurement Time, Measured Data for 20 Modules

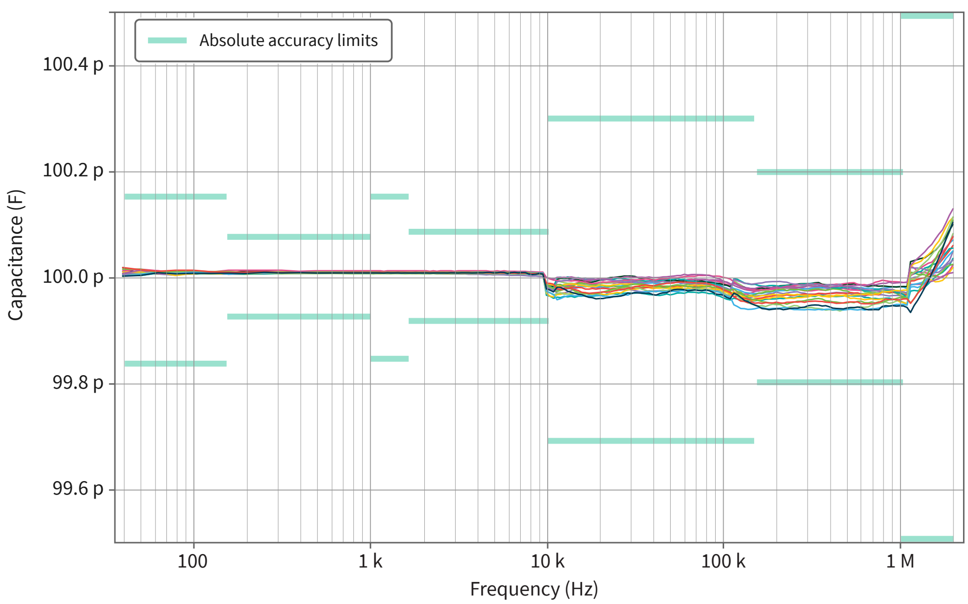
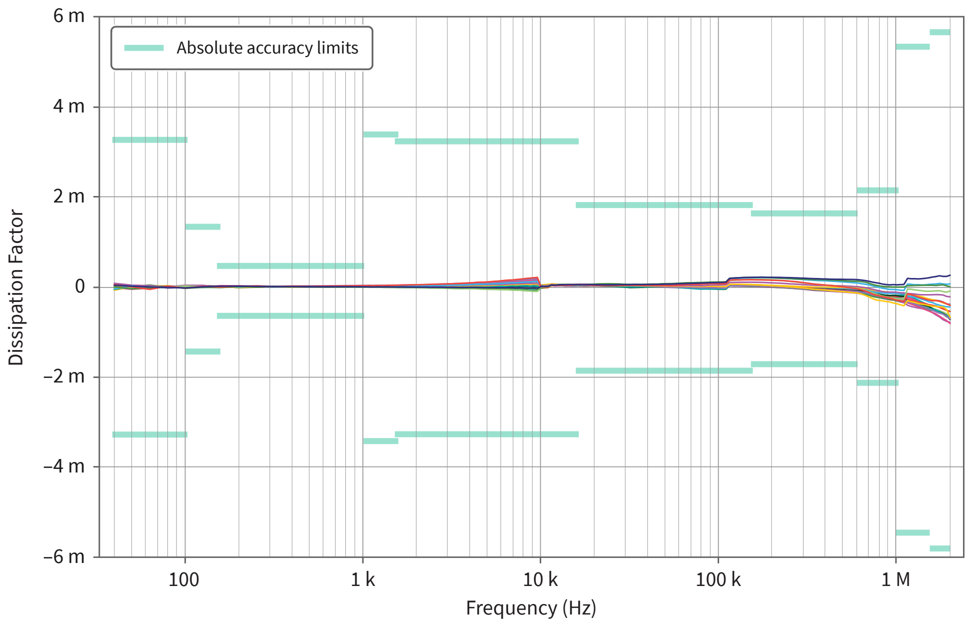


Figure 12. Dissipation Factor versus Frequency, 100 pF, 1 V RMS AC Stimulus, Long Measurement

Time, Measured Data for 20 Modules



LCR Accuracy Derating with DC Bias

Above 500 kHz with DC Bias enabled, add the additional error term to the stated magnitude accuracy specification:

$$\text{Additional magnitude error (\%)} = \frac{f}{500\text{ kHz}} \times \left| V_{\text{DCBias}} \right| \times 0.0015\%\text{, typical}$$

Above 500 kHz with DC Bias enabled, add the additional error term to the stated phase accuracy specification:

$$\text{Additional phase error (°)} = \frac{f}{500\text{ kHz}} \times \left| V_{\text{DCBias}} \right| \times 0.0005°\text{, typical}$$

LCR DC Bias Settling Time for Large Capacitors

Set DC Bias ALC to `Off` when measuring capacitors over 1 uF to minimize settling time.

Figure 13. DC Bias Settling Time (40 V Step Settled to 10 mV)

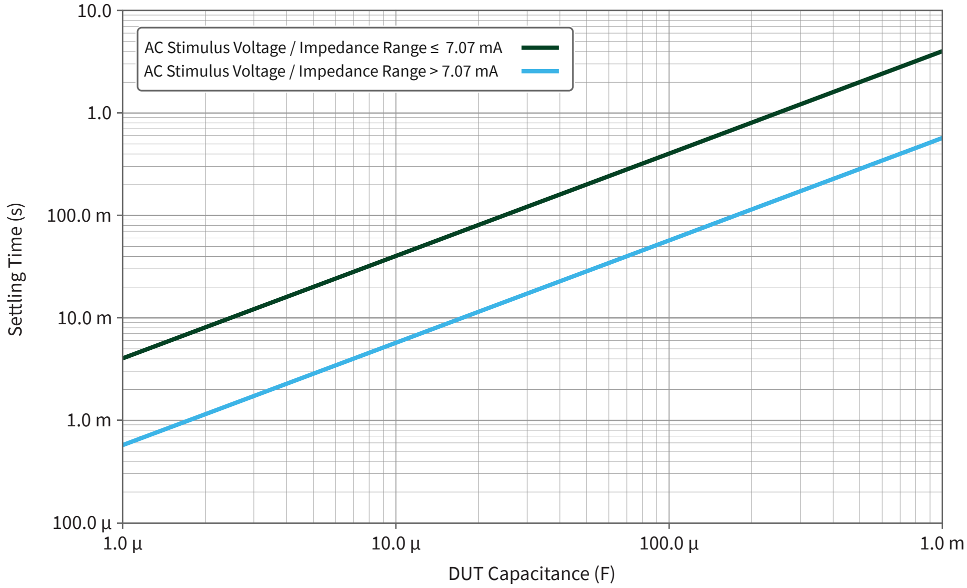


Table 19. DC Bias Settling Time Required in Addition to LCR Source Delay for Large Capacitors

Bias	Settling Time
AC Stimulus Voltage / Impedance Range ≤ 7.07 mA	Add 3 ms per µF of DUT capacitance
AC Stimulus Voltage / Impedance Range > 7.07 mA	Add 600 µs per µF of DUT capacitance

Note: When applying a bias voltage to capacitors over 1 mF, the bias voltage steps should be no larger than 40 V x 1 mF/C to avoid tripping overcurrent protection.

Note: For AC Stimulus Voltage / Impedance Range ≤7.07mA, limit DC bias steps to ≤5 V each, up to 40 V total.

LCR Cable Accuracy Derating

Table 20. Cable Accuracy Derating

Cable	Description	NI Part Number			
		0.5 m	1 m	2 m*	4 m*
SHDB13W6-4BNCM-LL	DSUB to Male BNC	—	788280-01	788280-02	788280-04
SHDB13W6-4BNCF-LL	DSUB to	789536-0R5	789536-01	789536-02	—

Cable	Description	NI Part Number			
		0.5 m	1 m	2 m*	4 m*
	Female BNC				
SHDB13W6-DB13W6-LL	DSUB to DSUB	—	788279-01	788279-02	788279-04
SHDB13W6-4TriaxM-LL	DSUB to Male Triaxial	—	788281-01	788281-02	788281-04
* LCR specifications are typical					

For cable lengths >1 m, LCR measurement magnitude specifications are typical with the following additional derating. Add the following term to the absolute accuracy, where

- **L**—is the cable length in meters

Additional magnitude error (%) = $\frac{f \times L}{8 \times 10^6}$

For cable lengths >1 m, LCR measurement phase specifications are typical with the following additional derating. Refer to the following table and add the term that corresponds to your measurement frequency and AC stimulus amplitude to the absolute accuracy, where

- **L**—is the cable length in meters
- **|Z|**—is impedance magnitude

Table 21. Additional Phase Error (°)

	≤707 mV RMS	>707 mV RMS
≤10 kHz	$\frac{L \times \lvert Z \rvert}{5 \times 10^7}$	$\frac{L \times \lvert Z \rvert}{5 \times 10^8}$
>10 kHz	$\frac{L \times \lvert Z \rvert}{1 \times 10^8}$	$\frac{L \times \lvert Z \rvert}{1 \times 10^9}$

Determining LCR Measurement Impedance Range

The impedance range can be calculated and programmed in several ways. The following methods allow you to set the impedance range directly.

Calculating Impedance Range Manually

Use the following formulas to determine the expected impedance based on the load.

The impedance of an ideal capacitor is

$$\left|Z_C\right| = \frac{1}{2\pi fC} = \frac{0.159}{fC}$$

where

- **Z_C**—Capacitor impedance (Ω)
- **f**—AC stimulus frequency (Hz)
- **C**—Nominal capacitance value (F)

The impedance of an ideal inductor is

$$\left|Z_L\right| = 2\pi fL = 6.283 \times f \times L$$

- **Z_L**—Inductor impedance (Ω)
- **f**—AC stimulus frequency (Hz)
- **L**—Nominal inductance value (H)

Setting LCR Impedance Range Source Programmatically

By setting **LCR Impedance Range Source** to **LCR Load Configuration**, the range can be determined automatically based on the AC stimulus frequency, and the load settings ***LCR Load Resistance***, ***LCR Load Inductance***, and ***LCR Load Capacitance***.

Note The PXIe-4190 LCR impedance ranges do not directly correspond to the underlying hardware ranges. When a measurement is configured, NI-DCPower will determine the best hardware range based on the requested impedance range, frequency, AC stimulus level, and bias settings. To determine the active hardware ranges for the configured measurement—or to set them manually—NI-DCPower provides these settings:

- LCR Voltage Range

- LCR Current Range
- LCR DC Bias Voltage Range
- LCR DC Bias Current Range

The LCR Voltage Range and LCR Current Range are expressed as RMS values but are equivalent to the corresponding SMU mode ranges when converted to peak value.

Translating LCR Specifications to Other Impedance Parameters

Accuracy for additional impedance parameters can be derived from the absolute impedance magnitude and phase specifications. For some calculations, the actual DUT impedance must also be known—in these cases, the measured value can be used as an approximation with typically negligible impact on the result.

- **Δx_{Spec}**—Specified accuracy for a parameter x (for example, $\Delta|Z|_{Spec}$ is the magnitude accuracy specification)
- **x_{DUT}**—The actual value of parameter x for a DUT
- **|Z|**—Impedance magnitude. $\Delta|Z|_{Spec}$ corresponds to the numbers listed in the magnitude accuracy tables (in percent).
- **θ**—Impedance phase angle. $\Delta\theta_{Spec}$ corresponds to the numbers listed in the phase accuracy tables (in degrees).
- **δ**—Phase angle between the impedance vector and the reactive axis.
  $\Delta\delta_{Spec} = \Delta\theta_{Spec}(°)$
- **D**—Dissipation factor.

  $$D = \tan\left(\delta\right) = \frac{R}{|X|}$$

  $$\Delta D_{Spec} = \pm\tan\left(\Delta\theta_{Spec}\right)$$

  (when $D_{DUT} < 0.1$).

- **Q**—Quality factor,
  $Q = \frac{1}{D}$

  To determine the specified range of possible Q values, calculate

$$\frac{1}{D_{DUT} \pm \Delta D_{Spec}}$$

(when $D_{DUT} < 0.1$).

- **C**—Capacitance, series (C_S) or parallel (C_P) equivalent model.

  When D_{DUT} is sufficiently small (<0.1), $\Delta C_{Spec} \cong \Delta|Z|_{Spec}$ (%).

  For a general solution, determine accuracy using the AC stimulus frequency and reactance specification:

  $$\Delta C_{Spec} = \pm \frac{1}{2\pi f \times \Delta X_{Spec}}(F)$$

- **L**—Inductance, series (L_S) or parallel (L_P) equivalent model.

When D_{DUT} is sufficiently small (<0.1), $\Delta L_{Spec} \cong \Delta|Z|_{Spec}$ (%).

For a general solution, determine accuracy using the AC stimulus frequency and reactance specification:

$$\Delta L_{Spec} = \pm \left(2\pi f \times \Delta X_{Spec}\right)(H)$$

- **R**—Resistance, the real component of complex impedance.

  For typical non-reactive resistance measurements ($D_{DUT} > 10$), $\Delta R_{Spec} \cong \Delta|Z|_{Spec}$ (%).

  To determine accuracy for an arbitrary impedance, first find the maximum and minimum values, R_{Max} and R_{Min}, from four calculations:

  $$\left(|Z|_{DUT} \pm \Delta|Z|_{Spec}\right) \times \cos\left(\theta_{DUT} \pm \Delta\theta_{Spec}\right),$$

  then

  $$\Delta R_{Spec} = \pm \frac{R_{Max} - R_{Min}}{2}(\Omega)$$

- **X**—Reactance, the imaginary component of complex impedance.

For typical L/C measurements ($D_{DUT} < 0.1$), $\Delta X_{Spec} \cong \Delta|Z|_{Spec}$ (%).

To determine accuracy for an arbitrary impedance, first find the maximum and minimum values, R_{Max} and R_{Min}, from four calculations:

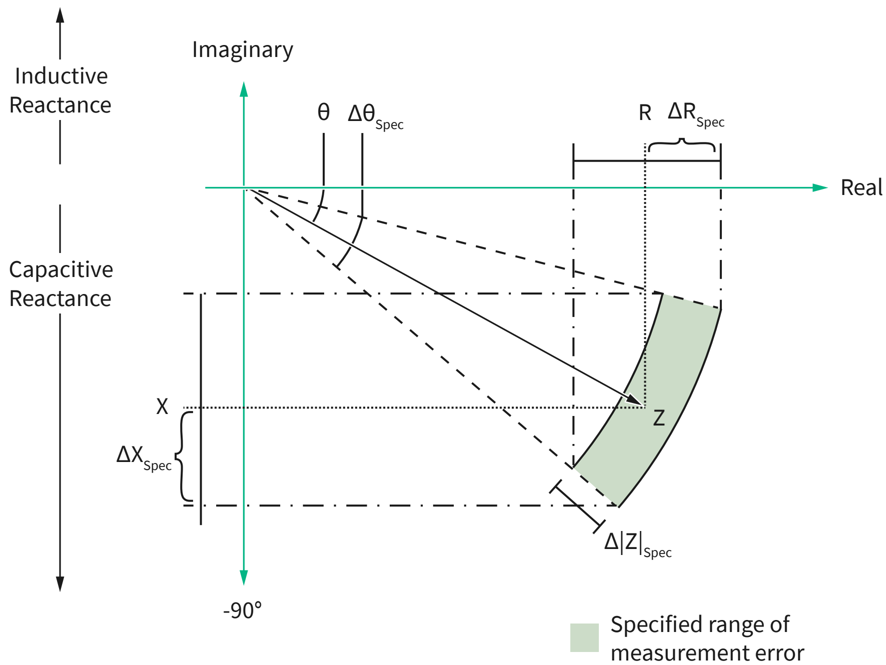
$$\left(|Z|_{DUT} \pm \Delta|Z|_{Spec}\right) \times \sin\left(\theta_{DUT} \pm \Delta\theta_{Spec}\right),$$

then

$$\Delta X_{Spec} = \pm \frac{X_{Max} - X_{Min}}{2}(\Omega)$$

The following figure shows the relationship between these parameters when an example vector Z is plotted on the complex impedance plane.

Figure 14. Impedance Specification Representation on a Complex Impedance Plane



> **Note** When computing tan(PhaseInDegrees) using tan(Radians), note that Degrees $\times \frac{\pi}{180}$ = Radians

Example 1: Calculating Specifications for Capacitance Measurement

For a capacitor measurement under the stated conditions, complete the following steps to determine and interpret the absolute measurement accuracy.

DUT Actual Capacitance (C_{DUT})	10 pF
DUT Actual Dissipation (D_{DUT})	0.005
AC Stimulus Frequency (f)	1 MHz
AC Stimulus Voltage (V_{stim})	1 V RMS
DC Bias Voltage (V DC)	10 V
Measurement time	Short
Cable length	1 m

1. Calculate ideal capacitor impedance as $Z_{DUT} = \frac{1}{2\pi fC} = \frac{1}{2 \times \pi \times 1\text{ MHz} \times 10\text{ pF}} = 15.915\text{k}\Omega$
2. Based on the 1 V RMS AC stimulus, the applicable magnitude and phase specs are found in Table 11. Absolute Impedance Magnitude Accuracy, 708 mV RMS to 7.07 V RMS AC Stimulus Voltage and Table 15. Absolute Impedance Phase Accuracy, 708 mV RMS to 7.07 V RMS AC Stimulus Voltage, respectively.
   - From the calculated impedance, Z_{DUT}, the relevant impedance range is 10 kΩ – 100 kΩ.
   - 1 MHz is on the boundary between the 500 kHz to 1 MHz and 1 MHz to 2 MHz frequency ranges, so choose the smaller of the adjacent values.
   - The resulting specifications are 0.3% magnitude accuracy and 0.13° phase accuracy.
3. Base specifications apply to long measurement time. For short measurement time, apply the derating factor:

$$\mathrm{Max}\left(1.5, \log\left(\frac{|Z|}{V_{\mathrm{stim}} \times 5 \times 10^4}\right)\right) = \mathrm{Max}\left(1.5, \log\left(\frac{15.915\ \mathrm{k\Omega}}{1\ \mathrm{V} \times 5 \times 10^4}\right)\right) = \mathrm{Max}(1.5, 0.5) = 1.5$$

   - The derated magnitude specification is then 1.5 * 0.3% = 0.45%
   - The derated phase specification is then 1.5 * 0.13° = 0.195°
4. Because DC bias is enabled and f >500 kHz, the additional error terms from LCR Accuracy Derating with DC Bias apply:
   - The additional magnitude error is calculated as
     $$\frac{f \times V_{\mathrm{DC}} \times 0.0015\%}{500\ \mathrm{kHz}} = \frac{1\ \mathrm{MHz} \times 10\ \mathrm{V} \times 0.0015\%}{500\ \mathrm{kHz}} = 0.03\%$$
   - The additional phase error is calculated as
     $$\frac{f \times V_{\mathrm{DC}} \times 0.005°}{500\ \mathrm{kHz}} = \frac{1\ \mathrm{MHz} \times 10\ \mathrm{V} \times 0.0005°}{500\ \mathrm{kHz}} = 0.01°$$
5. From the previous steps, the final accuracy specifications under these measurement conditions:
   - Magnitude accuracy, ΔZ_{Spec} = 0.45% + 0.03% = 0.48%
   - Phase accuracy, $\Delta\theta_{Spec}$ = 0.195° + 0.01° = 0.205°

These specifications can then be used to derive accuracies for other parameters.

- Dissipation factor accuracy, $\Delta D_{Spec} = \pm\tan(\Delta\theta_{Spec}) = \pm 0.0036$
   - Specified range is $D_{DUT} \pm \Delta D_{Spec}$ = 0.0013 to 0.0087
- Quality factor specified range is
  $$\frac{1}{D_{\mathrm{DUT}} \pm \Delta D_{\mathrm{Spec}}} = 115 \text{ to } 769$$
- Impedance phase has an accuracy of $\Delta\theta_{Spec}$ = 0.205° and can be expressed as
   - Loss angle, $\delta_{DUT} = \arctan(D_{DUT}) = \arctan(0.005) = 0.286° \pm 0.205°$
   - Impedance phase angle, $\theta_{DUT} = \delta - 90° = 0.286° - 90° = -89.714° \pm 0.205°$
- Resistance accuracy, ΔR_{Spec}, can be calculated by
   - Finding the maximum and minimum values, R_{Max} and R_{Min}, from four calculations:
     $$\left(Z_{\mathrm{DUT}} \pm \Delta Z_{\mathrm{Spec}}\right) \times \cos\left(\theta_{\mathrm{DUT}} \pm \Delta\theta_{\mathrm{Spec}}\right)$$
     $$= \left(15.915\ \mathrm{k\Omega} \pm 0.48\%\right) \times \cos\left(-89.714° \pm 0.205°\right)$$
     $$= \left[15.991\ \mathrm{k\Omega} \times \cos\left(-89.919°\right),\ 15.991\ \mathrm{k\Omega} \times \cos\left(-89.509°\right),\ 15.839\ \mathrm{k\Omega} \times \cos\left(-89.919°\right),\ 15.839\ \mathrm{k\Omega} \times \cos\left(-89.509°\right)\right]$$
     $$= \left[22.6\Omega,\ 137\Omega,\ 22.4\Omega,\ 135.7\Omega\right]$$
   - Selecting the maximum and minimum values, R_{Max} = 137 Ω, R_{Min} = 22.4 Ω

- $\Delta R_{Spec} = \frac{R_{Max} - R_{Min}}{2} = \frac{137\Omega - 22.4\Omega}{2} = \pm 57.3\Omega$

- Reactance accuracy, ΔX_{Spec}, can be calculated by
  - Since D_{DUT} is small, $\Delta X_{Spec} \cong \Delta|Z|_{Spec}$
  - Using this simplified approximation, ΔX_{Spec} = 0.48% * 15.915 kΩ = ± 76.4 Ω
  - For example, to compare the explicitly calculated specification, first find the maximum and minimum values, X_{Max} and X_{Min}, from the four calculations:

$$\left(Z_{DUT} \pm \Delta Z_{Spec}\right) \times \sin\left(\theta_{DUT} \pm \Delta\theta_{Spec}\right)$$

$$= \left(15.915\ \mathrm{k\Omega} \pm 0.48\%\right) \times \sin\left(-89.714° \pm 0.205°\right)$$

$$= \left[15.991\ \mathrm{k\Omega} \times \sin\left(-89.919°\right),\ 15.991\ \mathrm{k\Omega} \times \sin\left(-89.509°\right),\ 15.839\ \mathrm{k\Omega} \times \sin\left(-89.919°\right),\ 15.839\ \mathrm{k\Omega} \times \sin\left(-89.509°\right)\right]$$

$$= \left[-15.991\ \mathrm{k\Omega},\ -15.990\ \mathrm{k\Omega},\ -15.839\ \mathrm{k\Omega},\ -15.838\ \mathrm{k\Omega}\right]$$

  - Selecting the maximum and minimum values, X_{Max} = -15.838 kΩ, X_{Min} = -15.991 kΩ
  - $\Delta X_{Spec} = \frac{X_{Max} - X_{Min}}{2} = \frac{-15.838\ \mathrm{k\Omega} - -15.991\ \mathrm{k\Omega}}{2} = \pm 76.5\Omega$

General Specifications

Isolation

Isolation voltage, any pin to earth ground	40 V DC, Measurement Category I, functional

Note Pins are functionally isolated from chassis ground to prevent ground loops, but do not meet IEC 61010-1 for safety isolation.

Note The PXIe-4190 contains an internal switch controlled by the **niDCPower Isolation State** property that can connect the GUARD terminal to chassis ground and prevent the module output from floating. Isolation ratings only apply when this property/attribute is set to **Isolated**.

Protection

Absolute maximum voltage	
Output HI/Output LO/Sense HI/Sense LO to Output HI/Output LO/Sense HI/Sense LO	±42 V
Output HI/Sense HI to GUARD/Isolated Shield	± 6 V
GUARD/Isolated Shield to Chassis GND	±42 V
Absolute maximum current	
All terminals	±300 mA

Output channel protection		
Output HI to GUARD/Isolated Shield		
	Overvoltage	Automatic output disable
Output LO to all terminals		
	Overcurrent	Automatic output disable
Sense HI/Sense LO to all terminals		
	Overcurrent	Current limiter protects inputs up to absolute maximum voltage specification
Overtemperature		Automatic output disable

Physical Characteristics

Dimensions	3U, one-slot, PXI Express/CompactPCI Express module 2.0 cm x 13.0 cm x 21.6 cm (0.8 in. x 5.1 in. x 8.5 in.)

Weight	481 g (17.1 oz)
Front panel connectors	Mixed layout DSUB, 13W6 contact arrangement (6 coaxial 50 Ω, 7-signal), female

Triggers

Input triggers		
Types		Start, Source, Sequence Advance, Measure
Sources (PXI trigger lines 0 to 7)		
	Polarity	Active high (not configurable)
	Minimum pulse width	100 ns
Destinations[8] (PXI trigger lines 0 to 7)		
	Polarity	Active high (not configurable)
	Minimum pulse width	200 ns

Output triggers (events)		
Types		Source Complete, Sequence Iteration Complete, Sequence Engine Done, Measure Complete
Destinations (PXI trigger lines 0 to 7)[9]		
	Polarity	Active high (not configurable)
	Pulse width	230 ns

8. Input triggers can come from any source (PXI trigger or software trigger) and be exported to any PXI trigger line. This allows for easier multi-board synchronization regardless of the trigger source.
9. Pulse widths and logic levels are compliant with ***PXI Express Hardware Specification Revision 1.0 ECN 1***.

Calibration Interval

Recommended calibration interval	1 year

Power Requirements

+3.3 V	1.0 A
+12 V	2.7 A

Environmental Characteristics

Temperature	
Operating	0 °C to 55 °C [10]
Storage	-40 °C to 71 °C

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

Humidity	
Operating	10% RH to 90% RH, noncondensing [11]

10. Not all chassis can achieve this ambient temperature range. Refer to PXI chassis specifications to determine the ambient temperature ranges your chassis can achieve.
11. Accuracy specifications are only warranted for operating environments with temperatures below 30 °C and relative humidity levels below 60%. When transitioning the product from a storage or operating environment with relative humidity above 60%, you should allow the product to stabilize in the lower humidity environment for several hours before using it.

Storage	5% RH to 95% RH, noncondensing

Shock and Vibration	
Operating vibration	5 Hz to 500 Hz, 0.3 g RMS
Non-operating vibration	5 Hz to 500 Hz, 2.4 g RMS
Operating shock	30 g, half-sine, 11 ms pulse