

## SPECIFICATIONS

# PXIe-4139

## PXIe, $\pm 60$ V, $\pm 3$ A (DC)/ $\pm 10$ A (Pulsed) Precision System PXI Source Measure Unit

These specifications apply to the PXIe-4139.



**Note** In this document, the PXIe-4139 (40W) and PXIe-4139 (20W) are referred to inclusively as the PXIe-4139. The information in this document applies to all versions of the PXIe-4139 unless otherwise specified. To determine which version of the module you have, locate the device name in one of the following places:

- **In MAX**—The PXIe-4139 (40W) shows *NI PXIe-4139 (40W)*, and the PXIe-4139 (20W) shows as *NI PXIe-4139*.
- **Device front panel**—The PXIe-4139 (40W) shows *PXIe-4139 40W System SMU*, and the PXIe-4139 (20W) shows *NI PXIe-4139 Precision System SMU* on the front panel.

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## Definitions

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*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.
- *Measured* specifications describe the measured performance of a representative model.

Specifications are *Warranted* unless otherwise noted.

## Conditions

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Specifications are valid under the following conditions unless otherwise noted.

- Ambient temperature<sup>1</sup> of 23 °C ± 5 °C
- Chassis with slot cooling capacity ≥38 W<sup>2</sup>
  - For chassis with slot cooling capacity = 38 W, fan speed set to HIGH
- Calibration interval of 1 year
- 30 minutes warm-up time
- Self-calibration performed within the last 24 hours
- **NI-DCPower Aperture Time** is set to 2 power-line cycles (PLC)

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<sup>1</sup> The ambient temperature of a PXI system is defined as the temperature at the chassis fan inlet (air intake).

<sup>2</sup> For increased capability, NI recommends installing the PXIe-4139 (40W) in a chassis with slot cooling capacity ≥58 W.

# Cleaning Statement

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**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

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The following table and figures illustrate the voltage and the current source and sink ranges of the PXIe-4139.

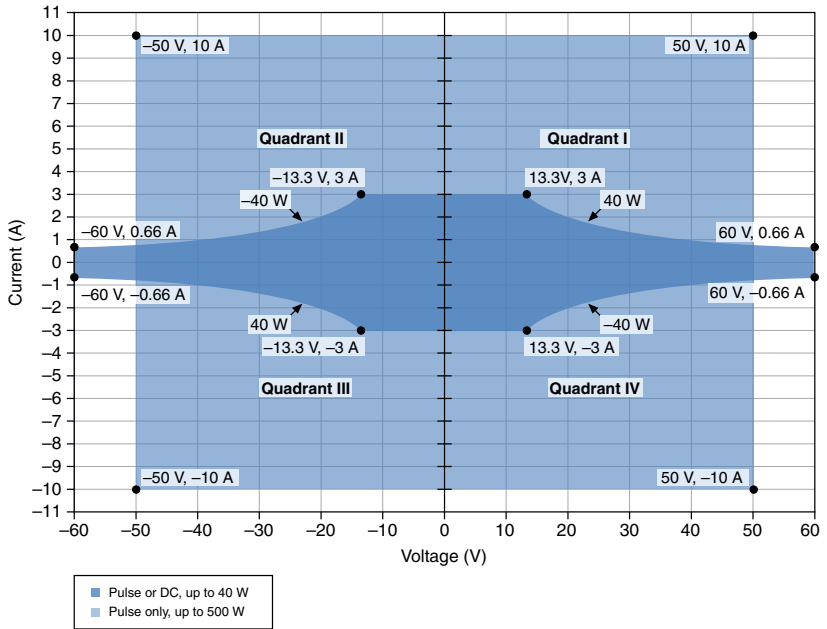
**Table 1.** Current Source and Sink Ranges

DC voltage ranges	DC current source and sink ranges
600 mV	1 $\mu$ A
6 V	10 $\mu$ A
60 V <sup>3</sup>	100 $\mu$ A
	1 mA
	10 mA
	100 mA
	1 A
	3 A
	10 A, pulse only

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<sup>3</sup> The PXIe-4139 does not support configurations involving voltage  $> |42.4 \text{ V}|$  when **Sequence Step Delta Time Enabled** is set to True.

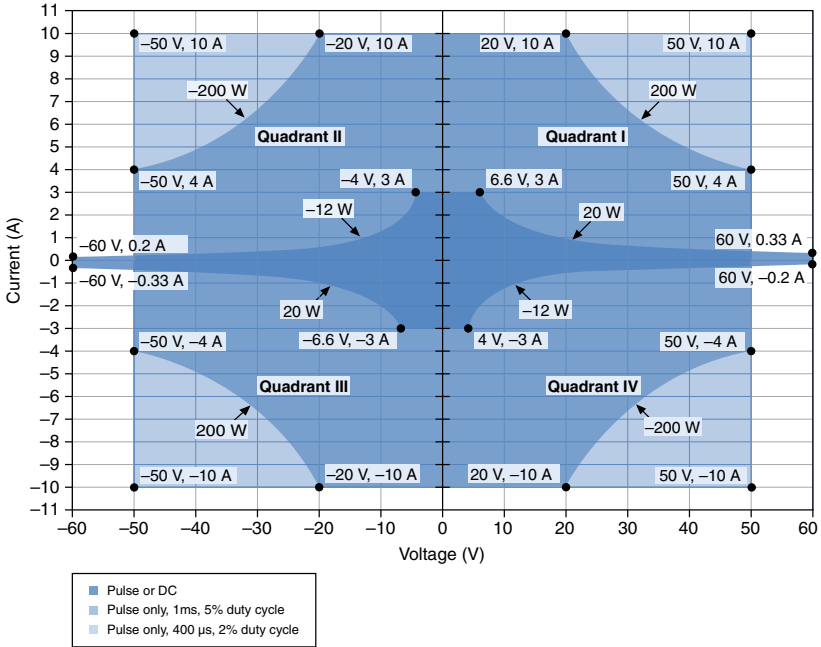
**Figure 1. Quadrant Diagram for PXIe-4139 (40W)**



For additional information related to the Pulse Voltage or Pulse Current settings of the **Output Function**, for the PXIe-4139 (40W), including pulse on time and duty cycle limits for a particular operating point, refer to [Pulsed Operation](#) on page 11.

For supplementary examples, refer to [Examples of Determining Extended Range Pulse Parameters and Optimizing Slew Rate using NI SourceAdapt](#) on page 23.

**Figure 2. Quadrant Diagram for PXIe-4139 (20W)**



DC sourcing power and sinking power are limited to the values in the following table, regardless of output voltage.<sup>4</sup>

**Table 2. DC Sourcing & Sinking Power**

Model Variant	Chassis Type	DC Sourcing Power	DC Sinking Power
PXIe-4139 (40W)	≥58 W Slot Cooling Capacity	40 W	40 W
	<58 W Slot Cooling Capacity	20 W	12 W
PXIe-4139 (20W)	≥58 W Slot Cooling Capacity	20 W	12 W
	<58 W Slot Cooling Capacity	20 W	12 W

<sup>4</sup> Power limit defined by voltage measured between HI and LO terminals.



**Caution** Limit DC power sinking to 12 W where applicable as indicated in the above table. For 38W cooling slots,

- 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.

### Related Information

[Sinking Power vs. Ambient Temperature Derating](#) on page 9

[Extended Range Pulsing for PXIe-4139 \(40W\)\(1\)](#) on page 12

[Extended Range Pulsing for PXIe-4139 \(20W\)\(1\)](#) on page 16

## Voltage

**Table 3.** 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) <sup>5, 6</sup>		Tempco ± (% of voltage + offset)/°C, 0 °C to 55 °C
			T <sub>cal</sub> ± 5 °C	T <sub>cal</sub> ± 1 °C	
600 mV	100 nV	2 µV	0.02% + 50 µV	0.016% + 30 µV	0.0005% + 1 µV
6 V	1 µV	6 µV	0.02% + 300 µV	0.016% + 90 µV	
60 V	10 µV	60 µV	0.02% + 3 mV	0.016% + 900 µV	

### Related Information

[Load Regulation](#) on page 18

[Remote Sense](#) on page 20

[Noise](#) on page 8

<sup>5</sup> Accuracy is specified for no load output configurations. Refer to *Load Regulation* and *Remote Sense* sections for additional accuracy derating and conditions.

<sup>6</sup> T<sub>cal</sub> is the internal device temperature recorded by the PXIe-4139 at the completion of the last self-calibration.

# Current

**Table 4.** 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) <sup>7</sup>		Tempco ± (% of current + offset)/°C, 0 °C to 55 °C
			T <sub>cal</sub> ± 5 °C	T <sub>cal</sub> ± 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
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	0.03% + 60 μA	0.027% + 20 μA	0.0006% + 2 μA
3 A	1 μA	20 μA	0.083% + 900 μA	0.083% + 600 μA	0.002% + 20 μA
10 A, pulsing only, typical					

<sup>7</sup> T<sub>cal</sub> is the internal device temperature recorded by the PXIe-4139 at the completion of the last self-calibration.

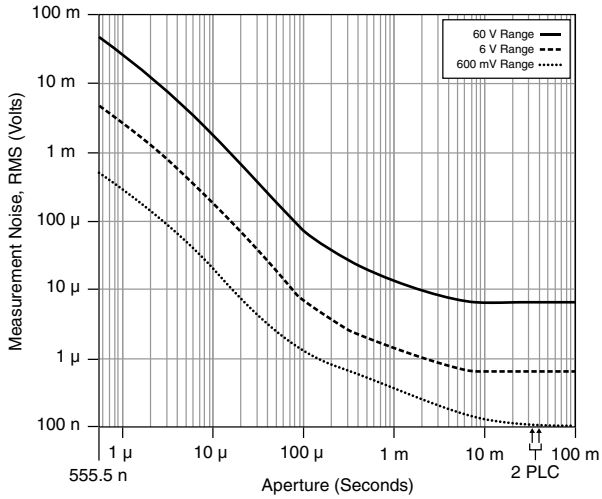
# Noise

Wideband source noise

<20 mV peak-to-peak in 60 V range, device configured for normal transient response, 10 Hz to 20 MHz, typical

The following figures illustrate measurement noise as a function of measurement aperture for the PXIe-4139.

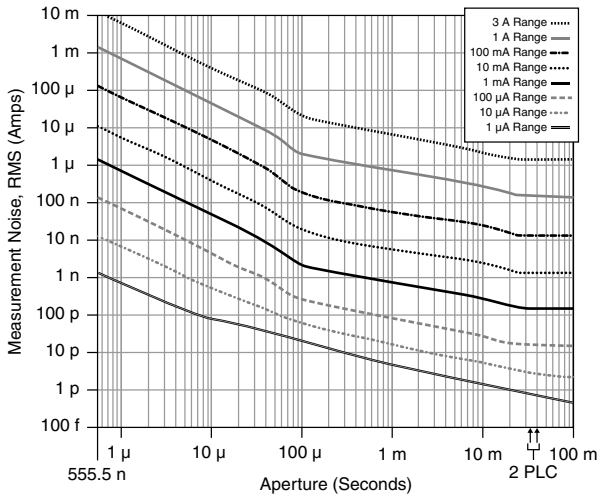
**Figure 3. Voltage Measurement Noise vs. Measurement Aperture, Nominal**



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



**Figure 4.** Current Measurement Noise vs. Measurement Aperture, Nominal

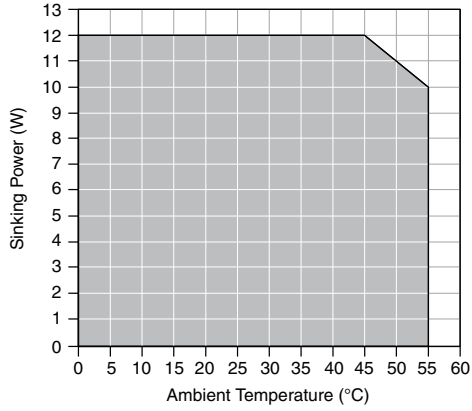


**Note** When the aperture time is set to 2 power-line cycles (PLCs), measurement noise differs slightly depending on whether the **Power Line Frequency** is set to 50 Hz or 60 Hz.

## Sinking Power vs. Ambient Temperature Derating

The following figure illustrates sinking power derating as a function of ambient temperature. This applies to the PXIe-4139 (20W) when used with any chassis and only applies to the PXIe-4139 (40W) when used with a chassis with slot cooling capacity <58 W.

**Figure 5. Sinking Power vs. Ambient Temperature Derating**



**Note** When using the PXIe-4139 (40W) with a chassis with slot cooling capacity  $\geq 58$  W, ambient temperature derating does not apply.

# Output Resistance Programming Accuracy

**Table 5.** Output Resistance Programming Accuracy

Current Level/Limit Range	Programmable Resistance Range, Voltage Mode	Programmable Resistance Range, Current Mode	Accuracy ± (% of resistance setting), $T_{cal} \pm 5\text{ }^{\circ}\text{C}$ <sup>8</sup>
1 $\mu\text{A}$	0 to $\pm 5\text{ M}\Omega$	$\pm 5\text{ M}\Omega$ to $\pm\text{infinity}$	0.03%
10 $\mu\text{A}$	0 to $\pm 500\text{ k}\Omega$	$\pm 500\text{ k}\Omega$ to $\pm\text{infinity}$	
100 $\mu\text{A}$	0 to $\pm 50\text{ k}\Omega$	$\pm 50\text{ k}\Omega$ to $\pm\text{infinity}$	
1 mA	0 to $\pm 5\text{ k}\Omega$	$\pm 5\text{ k}\Omega$ to $\pm\text{infinity}$	
10 mA	0 to $\pm 500\text{ }\Omega$	$\pm 500\text{ }\Omega$ to $\pm\text{infinity}$	
100 mA	0 to $\pm 50\text{ }\Omega$	$\pm 50\text{ }\Omega$ to $\pm\text{infinity}$	
1 A	0 to $\pm 5\text{ }\Omega$	$\pm 5\text{ }\Omega$ to $\pm\text{infinity}$	
3 A	0 to $\pm 500\text{ m}\Omega$	$\pm 500\text{ m}\Omega$ to $\pm\text{infinity}$	
10 A , pulsing only			

## Pulsed Operation

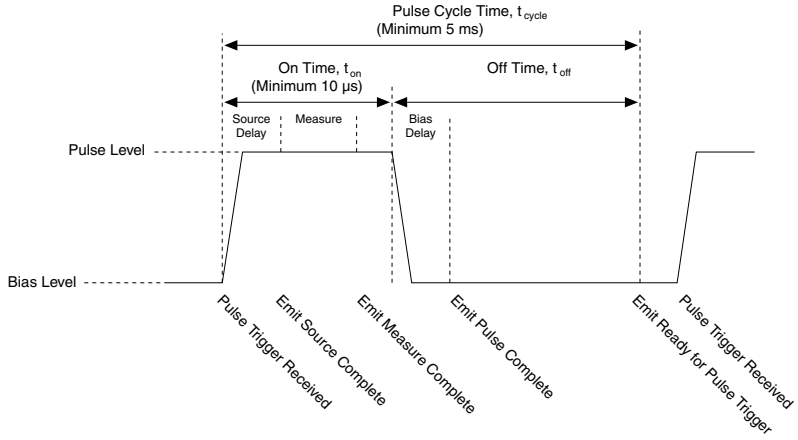
Dynamic load, minimum pulse cycle time<sup>9</sup>      25  $\mu\text{s}/\text{W}$

The following figure visually explains the terms used in the extended range pulsing sections.

<sup>8</sup>  $T_{cal}$  is the internal device temperature recorded by the PXIe-4139 at the completion of the last self-calibration.

<sup>9</sup> For example, given a continuous pulsing load, if the largest dynamic step in power that the load sources/sinks is from 5 W to 15 W, then the maximum SMU power step is 10 W. Thus, the minimum dynamic load pulse cycle time is 250  $\mu\text{s}$ .

**Figure 6. Definition of Pulsing Terminology**

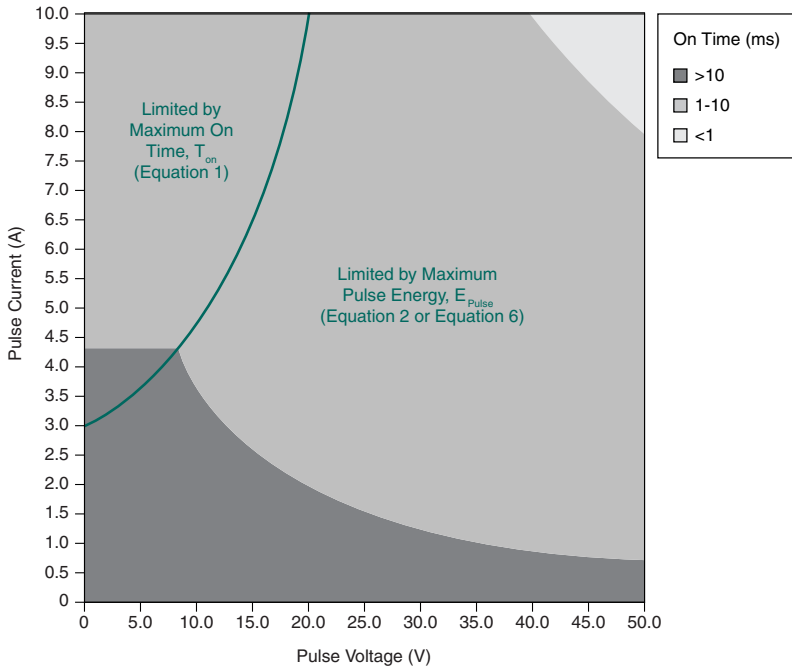


## Extended Range Pulsing for PXIe-4139 (40W)<sup>10</sup>

The following figures illustrate the maximum pulse on time and duty cycle for the PXIe-4139 (40W) in a  $\geq 58$  W cooling slot, for a desired pulse voltage and pulse current given zero bias voltage and current. The shaded areas allow for a quick approximation of output limitations and limiting parameters. Actual limits are described by equations in [Table 6](#), on page 14.

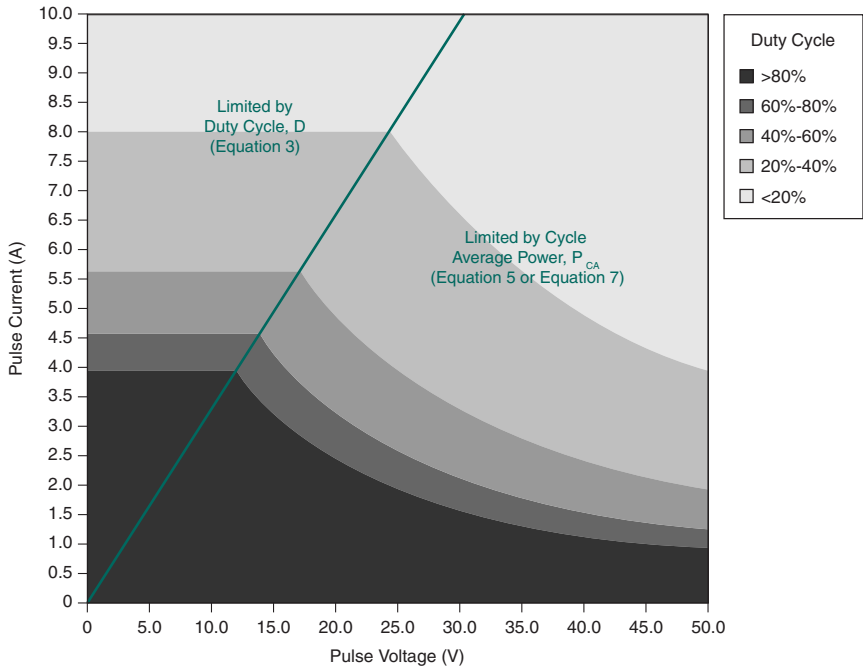
<sup>10</sup> Extended range pulses fall outside DC range limits for either current or power. In-range pulses fall within DC range limits and are not subject to extended range pulsing limitations. Extended range pulsing is enabled by setting the **Output Function** to Pulse Voltage or Pulse Current.

**Figure 7. Pulse On-time vs Pulse Current and Pulse Voltage**



**Note** Equations to solve for maximum pulse on time,  $t_{onMax}$ , are shown in [Table 6](#) on page 14. Additionally, Equation 6 solves for pulse on time,  $t_{on}$ , in terms of maximum pulse energy in [Example 1: Determining Extended Range Pulse On Time and Duty Cycle Parameters for the PXIe-4139 \(40W\)](#) on page 23.

**Figure 8. Duty Cycle vs Pulse Current and Pulse Voltage**



**Note** Equations to solve for maximum duty cycle,  $D_{Max}$ , are shown in [Table 6](#), on page 14. Additionally, Equation 7 solves for pulse off time,  $t_{off}$ , in terms of maximum pulse energy in [Example 1: Determining Extended Range Pulse On Time and Duty Cycle Parameters for the PXIe-4139 \(40W\)](#) on page 23.

**Bias level limits**

Maximum voltage, $V_{bias}$	60 V
Maximum current, $I_{bias}$	3 A

**Table 6. PXIe-4139 (40W) Pulse Level Limits**

Specification	Value	Equation
Maximum voltage, $V_{pulseMax}$	50 V	—
Maximum current, $I_{pulseMax}$	10 A	—

**Table 6. PXIe-4139 (40W) Pulse Level Limits (Continued)**

Specification		Value	Equation
Maximum on time, $t_{onMax}^{11}$	If $I_{pulse} > 3\text{ A}$	Calculate using the equation or refer to <a href="#">Figure 7</a> . on page 13 to estimate the value.	$t_{onMax} = 2\text{ ms} * \frac{7\text{ A}}{ I_{pulse}  - 3\text{ A}}$ <p>, where <math>t_{onMax}</math> is <math>\leq 167\text{ s}</math></p> <p>(Equation 1)</p>
	If $I_{pulse} \leq 3\text{ A}$	$t_{onMax} = 167\text{ s}$	—
Maximum pulse energy, $E_{pulseMax}^{12}$		0.4 J	$E_{pulse} =  V_{pulse} * I_{pulse} * t_{on} $ <p>, where <math>E_{pulse} &lt; E_{pulseMax}</math></p> <p>(Equation 2)</p>
Maximum duty cycle, $D_{Max}^{13}$		Calculate using the equation or refer to <a href="#">Figure 8</a> . on page 14 to estimate the value.	$D_{Max} = \frac{(3.68\text{ A})^2 -  I_{bias} ^2}{ I_{pulse} ^2 -  I_{bias} ^2} * 100\%$ <p>(Equation 3)</p>

<sup>11</sup> *Pulse on time* is measured from the start of the leading edge to the start of the trailing edge. See [Figure 6](#). on page 12.

<sup>12</sup> Refer to [Figure 7](#). on page 13 to estimate the value and determine the limiting equation.

<sup>13</sup> Refer to [Figure 8](#). on page 14 to estimate the value and determine the limiting equation. If  $D \geq 100\%$ , consider switching **Output Function** from Pulse mode to DC mode.

**Table 6. PXIe-4139 (40W) Pulse Level Limits (Continued)**

Specification		Value	Equation
Minimum pulse cycle time, $t_{\text{cycleMin}}$		5 ms	$t_{\text{cycle}} = t_{\text{on}} + t_{\text{off}}$ <p>, where <math>t_{\text{cycle}} &gt; t_{\text{cycleMin}}</math></p> <p>(Equation 4)</p>
Maximum cycle average power, $P_{\text{CAMax}}^{14}$	$\geq 58$ W Slot Cooling Capacity Chassis	40 W	$P_{\text{CA}} = \frac{ V_{\text{pulse}} * I_{\text{pulse}} * t_{\text{on}}  +  V_{\text{bias}} * I_{\text{bias}} * t_{\text{off}} }{t_{\text{on}} + t_{\text{off}}}$ <p>, where <math>P_{\text{CA}} &lt; P_{\text{CAMax}}</math></p> <p>(Equation 5)</p>
	$< 58$ W Slot Cooling Capacity Chassis	10 W	



**Note** Software will not allow settings that violate these limiting equations and will generate an error.

## Extended Range Pulsing for PXIe-4139 (20W)<sup>15</sup>

### Bias level limits

Maximum voltage	60 V
Maximum current	3 A

### Pulse level limits

Maximum voltage	50 V
Maximum current	10 A
Maximum on time <sup>16</sup>	1 ms
Minimum pulse cycle time	5 ms
Energy	0.2 J

<sup>14</sup> Refer to [Figure 8](#), on page 14 to estimate the value and determine the limiting equation.

<sup>15</sup> Extended range pulses fall outside DC range limits for either current or power. In-range pulses fall within DC range limits and are not subject to extended range pulsing limitations. Extended range pulsing is enabled by configuring the **Output Function** to Pulse Voltage or Pulse Current.

<sup>16</sup> *Pulse on time* is measured from the start of the leading edge to the start of the trailing edge. See [Figure 6](#), on page 12.



Maximum cycle average power	10 W
Maximum duty cycle	5%

## Transient Response and Settling Time

Transient response	<70 $\mu\text{s}$ 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, typical
Maximum slew rate <sup>17, 18</sup>	0.7 A/ $\mu\text{s}$
Settling time <sup>19</sup>	
Voltage mode, 50 V step, unloaded <sup>20</sup>	<200 $\mu\text{s}$ , typical
Voltage mode, 5 V step or smaller, unloaded <sup>21</sup>	<70 $\mu\text{s}$ , typical
Current mode, full-scale step, 10 A to 100 $\mu\text{A}$ ranges <sup>22</sup>	<50 $\mu\text{s}$ , typical
Current mode, full-scale step, 10 $\mu\text{A}$ range <sup>22</sup>	<150 $\mu\text{s}$ , typical
Current mode, full-scale step, 1 $\mu\text{A}$ range <sup>22</sup>	<300 $\mu\text{s}$ , typical

The following figures illustrate the effect of the transient response setting on the step response of the PXIe-4139 for different loads.

<sup>17</sup> Optimize transient response, overshoot, and slew rate with NI SourceAdapt by adjusting the **Transient Response**.

<sup>18</sup> To improve the slew rate, see *Examples of Determining Extended Range Pulse Parameters and Optimizing Slew Rate using NI SourceAdapt* on page 23.

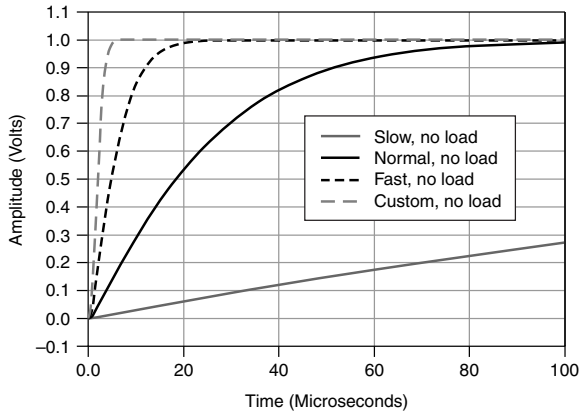
<sup>19</sup> Measured as the time to settle to within 0.1% of step amplitude, device configured for fast transient response.

<sup>20</sup> Current limit set to  $\geq 50 \mu\text{A}$  and  $\geq 50\%$  of the selected current limit range.

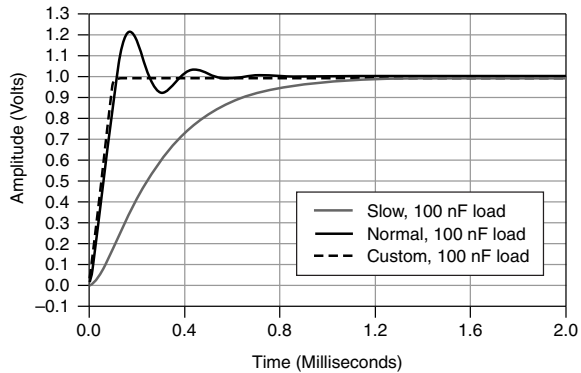
<sup>21</sup> Current limit set to  $\geq 20 \mu\text{A}$  and  $\geq 20\%$  of selected current limit range.

<sup>22</sup> Voltage limit set to  $\geq 2 \text{ V}$ , resistive load set to 1 V/selected current range.

**Figure 9.** 1 mA Range, No Load Step Response, Nominal



**Figure 10.** 1 mA Range, 100 nF Load Step Response, Nominal



## Load Regulation

### Voltage

Device configured for local sense

100  $\mu\text{V}$  per mA of output load change (measured between output channel terminals), typical

Device configured for remote sense

Load regulation effect included in voltage accuracy specifications

Current, device configured for local or remote sense

Load regulation effect included in current accuracy specifications

## Related Information

[Voltage](#) on page 6

[Current](#) on page 7

# Measurement and Update Timing Characteristics

Available sample rates <sup>23</sup>	(1.8 MS/s)/ $N$ where $N = 1, 2, 3, \dots, 2^{24}$ , 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 <sup>24</sup>	
Sequence mode	100,000 updates/s (10 $\mu$ s/update), nominal
Timed output mode	80,000 updates/s (12.5 $\mu$ s/update), nominal
Input trigger to	
Source event delay	10 $\mu$ s, nominal
Source event jitter	1 $\mu$ s, nominal
Measure event jitter	1 $\mu$ s, nominal
Shutdown <sup>25</sup>	100 $\mu$ s, typical

<sup>23</sup> When sourcing while measuring, both the **Source Delay** and **Aperture Time** affect the sampling rate. When taking a measure record, only the **Aperture Time** affects the sampling rate.

<sup>24</sup> As the source delay is adjusted or if advanced sequencing is used, maximum source rates vary. Timed output mode is enabled in Sequence Mode by setting the **Sequence Step Delta Time Enabled** to True. Additional timing limitations apply when operating in pulse mode (**Output Function** is set to Pulse Voltage or Pulse Current).

<sup>25</sup> Time from PXI Trigger sent until SMU output goes to high impedance.

## Pulse mode timing and accuracy<sup>26</sup>

Minimum pulse on time <sup>27</sup>	
PXIe-4139 (40W) <sup>28</sup>	10 $\mu$ s, nominal
PXIe-4139 (20W)	50 $\mu$ s, nominal
Minimum pulse off time <sup>29</sup>	50 $\mu$ s, nominal
Pulse on time or off time programming resolution	100 ns, nominal
Pulse on time or off time programming accuracy	$\pm$ 5 $\mu$ s, nominal
Pulse on time or off time jitter	1 $\mu$ s, nominal

## Remote Sense

Voltage accuracy	Add (3 ppm of voltage range + 11 $\mu$ V) per volt of HI lead drop plus 1 $\mu$ V per volt of lead drop per $\Omega$ of corresponding sense lead resistance to voltage accuracy specifications.
Maximum sense lead resistance	100 $\Omega$
Maximum lead drop per lead	3 V, characteristic



**Note** Exceeding the maximum lead drop per lead value may result in additional error.

## Examples of Calculating Accuracy



**Note** Specifications listed in examples are for demonstration purposes only and do not necessarily reflect specifications for this device.

### Example 1: Calculating 5 °C Accuracy

Calculate the accuracy of 900 nA output in the 1  $\mu$ A range under the following conditions:

<sup>26</sup> Pulse mode is enabled when the **Output Function** is set to Pulse Voltage or Pulse Current. This mode enables access to extended range pulsing capabilities. For PXIe-4139 (20W), shorter minimum on times for in-range pulses can be achieved using Sequence mode or Timed Output mode with the **Output Function** set to Voltage or Current.

<sup>27</sup> *Pulse on time* is measured from the start of the leading edge to the start of the trailing edge. See [Figure 6](#), on page 12.

<sup>28</sup> Optimize transient response, overshoot, and slew rate with NI SourceAdapt by adjusting the **Transient Response**.

<sup>29</sup> 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.

ambient temperature	28 °C
internal device temperature	within $T_{\text{cal}} \pm 5 \text{ }^\circ\text{C}$
self-calibration	within the last 24 hours.

#### Solution

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

$$0.03\% + 100 \text{ pA}$$

Calculate the accuracy using the following equation:

$$\begin{aligned} \text{Accuracy} &= 900 \text{ nA} * 0.03\% + 100 \text{ pA} \\ &= 270 \text{ pA} + 100 \text{ pA} \\ &= 370 \text{ pA} \end{aligned}$$

Therefore, the actual output will be within 370 pA of 900 nA.

### Example 2: Calculating 1 °C Accuracy

Calculate the accuracy of 900 nA output in the 1  $\mu\text{A}$  range. Assume the same conditions as in Example 1, with the following differences:

internal device temperature	within $T_{\text{cal}} \pm 1 \text{ }^\circ\text{C}$
-----------------------------	--

#### Solution

Since the device internal temperature is within  $T_{\text{cal}} \pm 1 \text{ }^\circ\text{C}$  and the ambient temperature is within  $23 \text{ }^\circ\text{C} \pm 5 \text{ }^\circ\text{C}$ , the appropriate accuracy specification is:

$$0.022\% + 40 \text{ pA}$$

Calculate the accuracy using the following equation:

$$\text{Accuracy} = 900 \text{ nA} * 0.022\% + 40 \text{ pA}$$

---

<sup>30</sup>  $T_{\text{cal}}$  is the internal device temperature recorded by the PXIe-4139 at the completion of the last self-calibration.

$$= 238 \text{ pA}$$

Therefore, the actual output will be within 238 pA of 900 nA.

### Example 3: 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 2, with the following differences:

HI path lead drop	3 V
HI sense lead resistance	2 $\Omega$
LO path lead drop	2.5 V
LO sense lead resistance	1.5 $\Omega$

Solution

Since the device internal temperature is within  $T_{cal} \pm 1 \text{ }^\circ\text{C}$  and the ambient temperature is within  $23 \text{ }^\circ\text{C} \pm 5 \text{ }^\circ\text{C}$ , the appropriate accuracy specification is:

$$0.016\% + 30 \text{ } \mu\text{V}$$

Since the device is using remote sense, use the remote sense accuracy specification:

Add (3 ppm of voltage range + 11  $\mu\text{V}$ ) per volt of HI lead drop plus 1  $\mu\text{V}$  per volt of lead drop per  $\Omega$  of corresponding sense lead resistance to voltage accuracy specifications.

Calculate the remote sense accuracy using the following equation:

$$\begin{aligned} \text{Accuracy} &= \left( 500 \text{ mV} * 0.016\% + 30 \mu\text{V} \right) + \frac{600 \text{ mV} * 3 \text{ ppm} + 11 \mu\text{V}}{1 \text{ V of lead drop}} * 3 \text{ V} + \frac{1 \mu\text{V}}{\text{V} * \Omega} * 3 \text{ V} \\ &\quad * 2 \Omega + \frac{1 \mu\text{V}}{\text{V} * \Omega} * 2.5 \text{ V} * 1.5 \Omega \\ &= 80 \mu\text{V} + 30 \mu\text{V} + 12.8 \mu\text{V} * 3 + 6 \mu\text{V} + 3.8 \mu\text{V} \\ &= 158.2 \mu\text{V} \end{aligned}$$

Therefore, the actual output will be within 158.2  $\mu\text{V}$  of 500 mV.

### Example 4: Calculating Accuracy with Temperature Coefficient

Calculate the accuracy of 900 nA output in the 1  $\mu\text{A}$  range. Assume the same conditions as in Example 2, with the following differences:

ambient temperature	15 °C
---------------------	-------

**Solution**

Since the device internal temperature is within  $T_{cal} \pm 1\text{ }^{\circ}\text{C}$ , the appropriate accuracy specification is:

$$0.022\% + 40\text{ pA}$$

Since the ambient temperature falls outside of  $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ , use the following temperature coefficient per degree Celsius outside the  $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$  range:

$$0.0006\% + 4\text{ pA}$$

Calculate the accuracy using the following equation:

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

$$\text{Accuracy} = \left(900\text{ nA} * 0.022\% + 40\text{ pA}\right) + \frac{900\text{ nA} * 0.0006\% + 4\text{ pA}}{1^{\circ}\text{C}} * 3^{\circ}\text{C}$$

$$= 238\text{ pA} + 28.2\text{ pA}$$

$$= 266.2\text{ pA}$$

Therefore, the actual output will be within 266.2 pA of 900 nA.

## Examples of Determining Extended Range Pulse Parameters and Optimizing Slew Rate using NI SourceAdapt



**Note** Specifications listed in examples are for demonstration purposes only and do not necessarily reflect specifications for this device.

### Example 1: Determining Extended Range Pulse On Time and Duty Cycle Parameters for the PXIe-4139 (40W)

Determine the extended range pulsing parameters, assuming the following operating point.

Output function	Pulse Current
Pulse voltage limit, $V_{\text{pulse}}$	40 V
Pulse current level, $I_{\text{pulse}}$	6 A
Bias voltage limit, $V_{\text{bias}}$	0.1 V
Bias current level, $I_{\text{bias}}$	0 A
Pulse on time, $t_{\text{on}}$	1.5 ms
Chassis' slot cooling capacity	$\geq 58$ W

**Solution**

Begin by calculating the pulse power using the following equation.

$$\begin{aligned}
 \text{Pulse power} &= V_{\text{pulse}} * I_{\text{pulse}} \\
 &= 40 \text{ V} * 6 \text{ A} \\
 &= 240 \text{ W}
 \end{aligned}$$

For PXIe-4139 (40W), refer to the following figures to identify next steps. First, verify the the region of operation using [Figure 1](#). on page 4, which shows 240 W is in the extended range pulsing region.

Next, refer to [Figure 7](#). on page 13, which shows the maximum pulse on time,  $t_{\text{on}}$ , is limited by the maximum pulse energy,  $E_{\text{pulseMax}}$ . Use the pulse energy equation ([Equation 2](#)) from [Table 6](#). on page 14 to calculate the maximum pulse on time,  $t_{\text{onMax}}$  ([Equation 6](#)).

$$\begin{aligned}
 t_{\text{onMax}} &= \left| \frac{E_{\text{pulseMax}}}{V_{\text{pulse}} * I_{\text{pulse}}} \right| \quad \left( \text{Eq.6} \right) \\
 &= \left| \frac{0.4 \text{ J}}{40 \text{ V} * 6 \text{ A}} \right| \\
 &= 1.67 \text{ ms}
 \end{aligned}$$

Next, refer to [Figure 8](#). on page 14, which shows the maximum duty cycle, D, is limited by the cycle average power,  $P_{\text{CA}}$ . If the required pulse on time is 1.5 ms and the module is installed in a chassis with slot cooling capacity  $\geq 58$  W, use the cycle average power equation ([Equation 5](#)) from [Table 6](#). on page 14 to calculate the minimum pulse off time,  $t_{\text{offMin}}$  ([Equation 7](#)).



$$\begin{aligned}
 t_{\text{offMin}} &= \left| \frac{P_{\text{CA}} * t_{\text{on}} - V_{\text{pulse}} * I_{\text{pulse}} * t_{\text{on}}}{P_{\text{CA}} - V_{\text{bias}} * I_{\text{bias}}} \right| \quad (\text{Eq.7}) \\
 &= \left| \frac{40 \text{ W} * 1.5 \text{ ms} - 40 \text{ V} * 6 \text{ A} * 1.5 \text{ ms}}{40 \text{ W} - 0.1 \text{ V} * 0 \text{ A}} \right| \\
 &= 7.5 \text{ ms}
 \end{aligned}$$

Finally, verify that the pulse cycle time,  $t_{\text{cycle}}$ , is greater than or equal to the minimum pulse cycle time,  $t_{\text{cycleMin}}$  (5 ms). To calculate the pulse cycle time, use the following equation:

$$\begin{aligned}
 t_{\text{cycle}} &= t_{\text{on}} + t_{\text{off}} \quad (\text{Eq. 4}) \\
 &= 1.5 \text{ ms} + 7.5 \text{ ms} \\
 &= 9 \text{ ms}
 \end{aligned}$$

In this case, the pulse cycle time meets the minimum pulse cycle time specification.

Therefore, a 40 V, 6 A pulse with an on time of 1.5 ms and a pulse off time of 7.5 ms is supported, since it fulfills the following criteria:

- Greater than the minimum pulse on time of 10  $\mu\text{s}$
- Equal to the minimum pulse off time of 7.5 ms to meet maximum cycle average power
- Greater than the minimum pulse cycle time of 5 ms

## Example 2: Determining Extended Range Pulse On Time and Duty Cycle Parameters for the PXIe-4139 (20W)

Determine the extended range pulsing parameters, assuming the following operating point.

Output function	Pulse Current
Pulse voltage limit, $V_{\text{pulse}}$	40 V
Pulse current level, $I_{\text{pulse}}$	6 A
Bias voltage limit, $V_{\text{bias}}$	0.1 V
Bias current level, $I_{\text{bias}}$	0 A

Pulse on time, $t_{on}$	1.5 ms
Chassis' slot cooling capacity	$\geq 58$ W

Solution

Begin by calculating the pulse power using the following equation.

$$\begin{aligned}
 \text{Pulse power} &= V_{\text{pulse}} * I_{\text{pulse}} \\
 &= 40 \text{ V} * 6 \text{ A} \\
 &= 240 \text{ W}
 \end{aligned}$$

Since the pulse power of 240 W is within the 500 W region of *Figure 2*. on page 5, the maximum configurable on time is 400  $\mu\text{s}$  and maximum duty cycle is 2%.

For example, if the required pulse on time is 100  $\mu\text{s}$ , and the required pulse cycle time is 10 ms, calculate the pulse off time and verify the duty cycle using the following equations.

$$\begin{aligned}
 t_{\text{off}} &= t_{\text{cycle}} - t_{\text{on}} \\
 &= 10 \text{ ms} - 100\mu\text{s} \\
 &= 9.9 \text{ ms}
 \end{aligned}$$

$$\begin{aligned}
 \text{Duty cycle} &= \frac{t_{\text{on}}}{t_{\text{cycle}}} * 100\% \\
 &= 1\%
 \end{aligned}$$

Therefore, a pulse with an on time of 100  $\mu\text{s}$  and 1% duty cycle would be supported, since it fulfills the following criteria:

- Greater than the minimum pulse on time of 50  $\mu\text{s}$
- Less than the maximum pulse on time of 400  $\mu\text{s}$  and duty cycle of 2%
- Greater than the minimum pulse cycle time of 5 ms

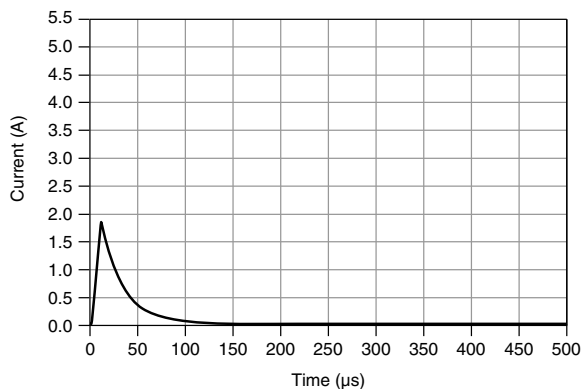
### Example 3: Using NI SourceAdapt to Increase the Slew Rate of the Pulse

Determine the appropriate operating parameters and custom transient response settings, assuming the following example parameters.

Output function	Pulse Current
Pulse voltage limit, $V_{\text{pulse}}$	50 V
Pulse current level, $I_{\text{pulse}}$	5 A
Bias voltage limit, $V_{\text{bias}}$	0.1 V
Bias current level, $I_{\text{bias}}$	0 A
Transient response	Fast
Load, cable impedance	4.5 $\Omega$ , 40 $\mu\text{H}$
Pulse on time, $t_{\text{on}}$	10 $\mu\text{s}$
Pulse off time, $t_{\text{off}}$	4.99 ms

The SMU **Transient Response** can be configured to three predefined settings, Slow, Normal, and Fast. If these settings do not provide the desired pulse response, a fourth setting, Custom, enables NI SourceAdapt<sup>31</sup> technology which provides the ability to customize the SMU response to any load, and achieve an ideal response with minimum rise times and no overshoots or oscillations.

**Figure 11.** 10  $\mu\text{s}$  Pulse Output with Load, Fast Transient Response



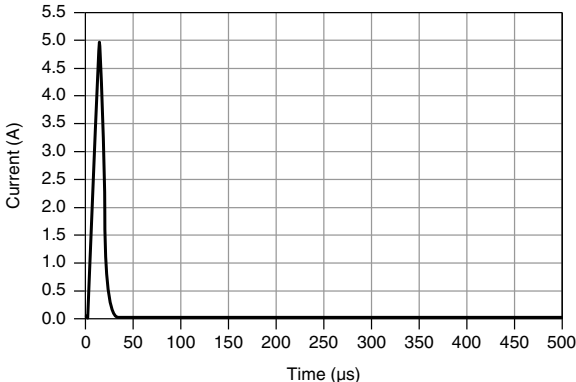
Solution

<sup>31</sup> Visit [ni.com](http://ni.com) for more information about NI SourceAdapt Next-Generation SMU Technology.

SourceAdapt allows users to set the desired gain bandwidth, compensation frequency, and pole-zero ratio through custom transient response to obtain the desired pulse waveform. To use SourceAdapt, first set the **Transient Response** to Custom.

To achieve the resulting waveform in the following figure, use the parameters in the following table.

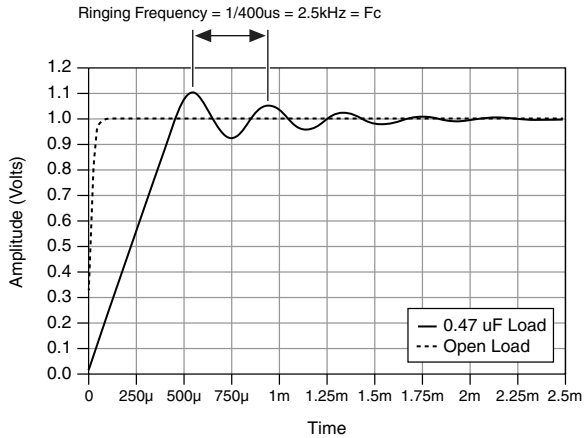
**Figure 12.** 10  $\mu$ s Pulse Output with Load, Custom Transient Response



Transient response	Custom
Current: Gain bandwidth	260 kHz
Current: Compensation frequency	140 kHz
Current: Pole-zero ratio	0.75

Gain bandwidth is directly proportional to the step response slew rate. The higher the gain bandwidth, the higher the slew rate. It is worth noting that increasing the gain bandwidth will likely increase ringing. However, this can likely be removed by appropriately setting the compensation frequency and the pole-zero ratio.

**Figure 13. Example of Ringing Frequency**



Compensation frequency and pole-zero ratio are used to determine the frequencies of the SMU control loop pole and zero, which can be used to optimize the system transient response by increasing phase margin and reducing ringing. To reduce the overshoot, it is recommended to set the compensation frequency close to the overshoot ringing frequency, see  $F_c$  in [Figure 13](#), on page 29, and set the pole-zero ratio to be greater than 1.

For reference, the pole frequency and zero frequency are derived by the following equations.

$$\text{Pole frequency} = \text{Compensation frequency} * \sqrt{\text{Pole-zero ratio}}$$

$$\text{Zero frequency} = \frac{\text{Compensation frequency}}{\text{Pole-zero ratio}}$$

These settings can be accessed through the **Transient Response** set to Custom: Voltage or Current.

## Trigger Characteristics

### Input triggers

Types

Start, Source, Sequence Advance, Measure, Pulse; Shutdown

Sources (PXI trigger lines <0...7>)	
Polarity	Configurable
Minimum pulse width	100 ns, nominal
Destinations <sup>33</sup> (PXI trigger lines <0...7>)	
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
Destinations (PXI trigger lines <0...7>)	
Polarity	Configurable
Pulse width	Configurable between 250 ns and 1.6 $\mu$ s, nominal

## Protection

### Output channel protection

Overcurrent or overvoltage	Automatic shutdown, output disconnect relay opens
Overtemperature	Automatic shutdown, output disconnect relay opens

## Safety Voltage and Current



**Notice** The protection provided by the PXIe-4139 can be impaired if it is used in a manner not described in the user documentation.



**Warning** Take precautions to avoid electrical shock when operating this product at hazardous voltages.

<sup>32</sup> Pulse widths and logic levels are compliant with *PXI Express Hardware Specification Revision 1.0 ECN 1*.

<sup>33</sup> Input triggers can be re-exported.



**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.



**Attention** Les tensions nominales d'isolation s'appliquent à la tension mesurée entre n'importe quelle broche de voie et la masse du châssis. Lors de l'utilisation de voies en série ou flottantes en plus des références de tension externes, assurez-vous qu'aucun terminal ne dépasse cette valeur nominale.

DC voltage	±60 V
Channel-to-earth ground isolation	
Continuous	150 VDC, CAT I
Withstand	1,000 V RMS, verified by a 5 s withstand



**Caution** Do not connect the PXIe-4139 to signals or use for measurements within Measurement Categories II, III, or IV.



**Attention** Ne connectez pas le PXIe-4139 à des signaux et ne l'utilisez pas pour effectuer des mesures dans les catégories de mesure II, III ou IV.

Measurement Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as *MAINS* voltage. *MAINS* is a hazardous live electrical supply system that powers equipment. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.



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

DC current range	±3 A
	±10 A, pulse only

## Guard Output Characteristics

Cable guard	
Output impedance	2 kΩ, nominal
Offset voltage	1 mV, typical

# Calibration Interval

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Recommended calibration interval	1 year
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# Power Requirement

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## PXI Express power requirement

PXIe-4139 (40W)	3.0 A from the 3.3 V rail and 6.0 A from the 12 V rail
PXIe-4139 (20W)	2.5 A from the 3.3 V rail and 2.2 A from the 12 V rail

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# Physical

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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.)
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## Weight

PXIe-4139 (40W)	427 g (15.1 oz)
PXIe-4139 (20W)	419 g (14.8 oz)
Front panel connectors	5.08 mm (8 position)

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# Environmental Guidelines

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**Notice** This product is intended for use in indoor applications only.



**Notice** Cover all empty slots using filler panels.

# Environmental Characteristics

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## Temperature

Operating	0 °C to 55 °C
Storage	-40 °C to 71 °C

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## Humidity

Operating	10% to 90%, noncondensing
Storage	5% to 95%, noncondensing

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

## Environmental Standards

This product meets the requirements of the following environmental standards for electrical equipment.

- IEC 60068-2-1 Cold
- IEC 60068-2-2 Dry heat
- IEC 60068-2-78 Damp heat (steady state)
- IEC 60068-2-64 Random operating vibration
- IEC 60068-2-27 Operating shock



**Note** To verify marine approval certification for a product, refer to the product label or visit [ni.com/certification](https://ni.com/certification) and search for the certificate.

## Safety Compliance Standards

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 safety certifications, refer to the product label or the [Product Certifications and Declarations](#) section.

# Electromagnetic Compatibility

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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
- AS/NZS CISPR 11: Group 1, Class A emissions



**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 [Product Certifications and Declarations](#) section.

## Environmental Management

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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 *Commitment to the Environment* web page at [ni.com/environment](https://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](https://ni.com/environment/weee).

## 电子信息产品污染控制管理办法（中国 RoHS）



NI 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 NI 中国 RoHS 合规性信息, 请登录 [ni.com/environment/rohs\\_china](https://ni.com/environment/rohs_china)。  
(For information about China RoHS compliance, go to [ni.com/environment/rohs\\_china](https://ni.com/environment/rohs_china).)

## Product Certifications and Declarations

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Refer to the product Declaration of Conformity (DoC) for additional regulatory compliance information. To obtain product certifications and the DoC for NI products, visit [ni.com/product-certifications](https://ni.com/product-certifications), search by model number, and click the appropriate link.

# NI Services

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Visit [ni.com/support](https://ni.com/support) to find support resources including documentation, downloads, and troubleshooting and application development self-help such as tutorials and examples.

Visit [ni.com/services](https://ni.com/services) to learn about NI service offerings such as calibration options, repair, and replacement.

Visit [ni.com/register](https://ni.com/register) to register your NI product. Product registration facilitates technical support and ensures that you receive important information updates from NI.

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