PXIe-4135 Specifications

2025-03-10

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PXIe-4135 Specifications

These specifications apply to the PXIe-4135.

> **Note** In this document, the PXIe-4135 (40W) and PXIe-4135 (20W) are referred to inclusively as the PXIe-4135. The information in this document applies to all versions of the PXIe-4135 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-4135 (40W) shows ***NI PXIe-4135 (40W)***, and the PXIe-4135 (20W) shows as ***NI PXIe-4135***.
> - **Device front panel**—The PXIe-4135 (40W) shows ***PXIe-4135 40W System SMU***, and the PXIe-4135 (20W) shows ***NI PXIe-4135 Precision System SMU*** on the front panel.

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

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

Conditions

Specifications are valid under the following conditions unless otherwise noted.

- Ambient temperature[1] of 23 °C ± 5 °C
- Relative humidity between 10% and 70%, noncondensing up to 35 °C. Derate max relative humidity 3% per °C for ambient temperatures between 35 °C and 50 °C. From 50 °C to 55 °C, relative humidity between 10% and 25%, noncondensing. See Current for humidity performance restrictions.
- Chassis with slot cooling capacity ≥38 W[2]
  - 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)
- Triax cover installed on unused triax connections

Cleaning Statement

> **Notice** 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.

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

Device Capabilities

The following table and figure illustrate the voltage and the current source and sink

1. The ambient temperature of a PXI system is defined as the temperature at the chassis fan inlet (air intake).
2. For increased capability, NI recommends installing the PXIe-4135 (40W) in a chassis with slot cooling capacity ≥58 W.

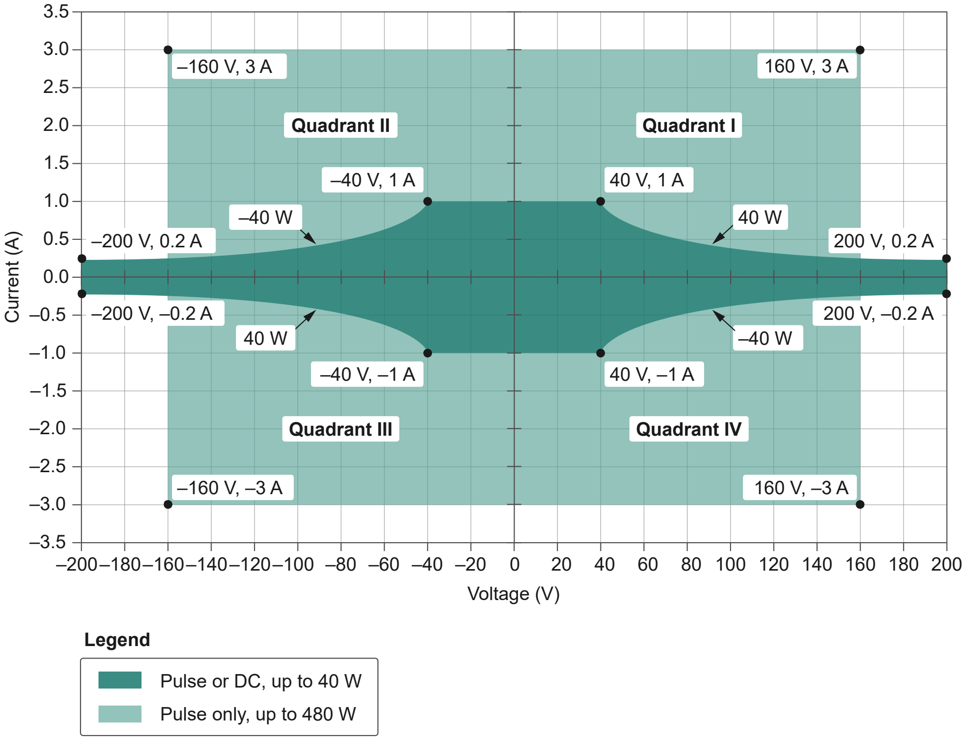
ranges of the PXIe-4135.

Table 1. Current Source and Sink Ranges

DC voltage ranges	DC current source and sink ranges
600 mV 6 V 20 V 200 V[3]	10 nA 1 µA 100 µA 1 mA 10 mA 100 mA 1 A 3 A[4]

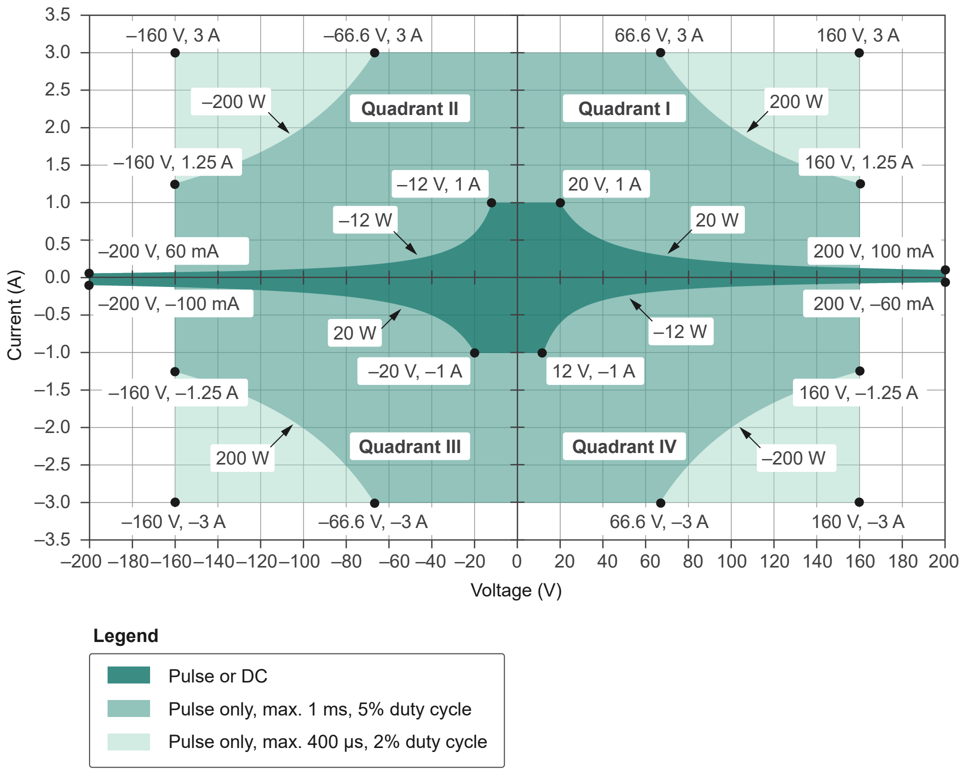
3. Voltage levels and limits >|40 VDC| require the safety interlock input to be closed.
4. Current is limited to 1 A DC. Higher levels are pulsing only.

Figure 1. Quadrant Diagram for PXIe-4135 (40W)



For additional information related to the Pulse Voltage or Pulse Current settings of the Output Function, for the PXIe-4135 (40W), including pulse on time and duty cycle limits for a particular operating point, refer to Pulsed Operation. For supplementary examples, refer to Examples of Determining Extended Range Pulse Parameters and Optimizing Slew Rate using NI SourceAdapt.

Figure 1. Quadrant Diagram for PXIe-4135 (20W)



DC sourcing power and sinking power are limited to the values in the following table, regardless of output voltage. [5]

Table 2. DC Sourcing & Sinking Power

Model Variant	Chassis Type	DC Sourcing Power	DC Sinking Power
PXIe-4135 (40W)	≥58 W Slot Cooling Capacity	40 W	40 W
	<58 W Slot Cooling Capacity	20 W	12 W
PXIe-4135 (20W)	≥58 W Slot Cooling Capacity	20 W	12 W
	<58 W Slot Cooling Capacity	20 W	12 W

Caution Limit DC power sinking to 12 W where applicable as indicated in the above table. For <58 W cooling slots,

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

- 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 reference:

- Sinking Power vs. Ambient Temperature Derating
- Extended Range Pulsing for PXIe-4135 (40W)
- Extended Range Pulsing for PXIe-4135 (20W)

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)[6]		Tempco ± (% of voltage + offset)/°C, 0 °C to 55 °C
			T_{cal} ±5 °C [7] 7	T_{cal} ±1 °C [7]	
600 mV	100 nV	2 µV	0.020% + 50 µV	0.017% + 30 µV	0.0005% + 1 µV
6 V	1 µV	6 µV	0.020% + 320 µV	0.017% + 90 µV	
20 V	10 µV	20 µV	0.022% + 1 mV	0.017% + 400 µV	
200 V	100 µV	200 µV	0.025% + 10 mV	0.020% + 2.5 mV	

Related reference:

- Noise
- Load Regulation
- Remote Sense

6. Accuracy is specified for no load output configurations. Refer to ***Load Regulation*** and ***Remote Sense*** sections for additional accuracy derating and conditions.
7. T_{cal} is the internal device temperature recorded by the PXIe-4135 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) [8], [9]		Tempco ± (% of current + offset)/°C, 0 °C to 55 °C
			T_{cal} ±5 °C [10] 10	T_{cal} ±1 °C [10]	
10 nA [11] [11], 12 [12]	10 fA	150 fA [13]	0.06% + 2 pA	0.05% + 750 fA	0.0006% + 400 fA
10 nA [14]	10 fA	1 pA	0.06% + 6 pA	0.05% + 5 pA	0.0006% + 400 fA
1 µA	100 fA	4 pA	0.03% + 100 pA	0.022% + 40 pA	0.0006% + 4 pA
100 µA	10 pA	200 pA	0.03% + 6 nA	0.022% + 2 nA	0.0006% + 200 pA
1 mA	100 pA	2 nA	0.03% + 60 nA	0.022% + 20 nA	0.0006% + 2 nA
10 mA	1 nA	20 nA	0.03% + 600 nA	0.022% + 200 nA	0.0006% + 20 nA
100 mA	10 nA	200 nA	0.03% + 6 µA	0.022% + 2 µA	0.0006% + 200 nA
1 A	100 nA	2 µA	0.04% +	0.035% +	0.0006% + 2 µA

8. Relative humidity between 10% and 70%, noncondensing up to 35 °C. Derate max relative humidity 3% per °C for ambient temperatures between 35 °C and 50 °C. From 50 °C to 55 °C, relative humidity between 10% and 25%, noncondensing.
9. Add 30 pA to accuracy specifications when operating with relative humidity greater than 50%.
10. T_{cal} is the internal device temperature recorded by the PXIe-4135 at the completion of the last self-calibration.
11. Under the following additional specification conditions: 10 PLC, 11-point median filter, measurements made within one hour after offset null.
12. Specifications in this row are typical for the following PXIe-4135 (20W) revisions: 157420C-03L, 157420D-03L and 157420E-03L.
13. Measured with no connections to the PXIe-4135 (20W).
14. Under default specification conditions.

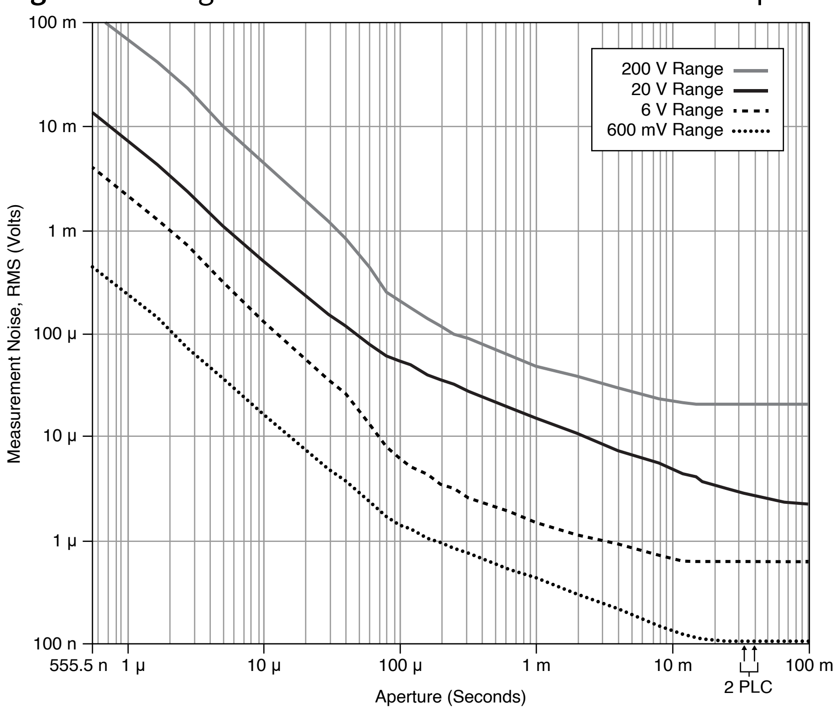
Range	Resolution (noise limited)	Noise (0.1 Hz to 10 Hz, peak to peak), Typical	Accuracy (23 °C ±5 °C) ± (% of current + offset) ,		Tempco ± (% of current + offset)/°C, 0 °C to 55 °C
			T_{cal} ±5 °C [10]	T_{cal} ±1 °C [10]	
			60 µA	20 µA	
3 A [15]	1 µA	20 µA	0.08% + 900 µA	0.075% + 600 µA	0.0018% + 20 µA

Noise

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

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

Figure 1. Voltage Measurement Noise vs. Measurement Aperture, Nominal

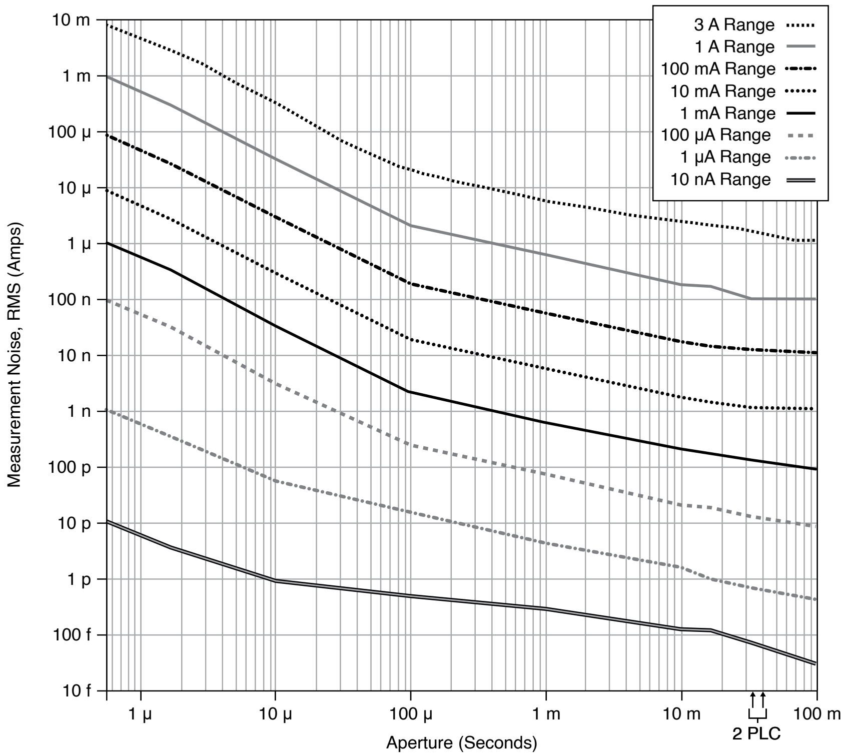


Note When the aperture time is set to 2 power-line cycles (PLCs),

15. 3 A range above 1 A is for pulsing only.

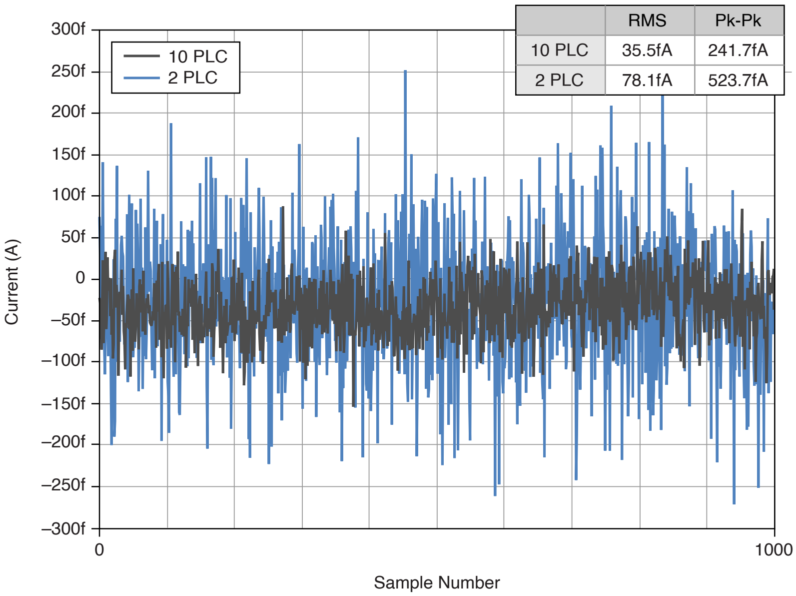
measurement noise differs slightly depending on whether the Power Line Frequency is set to 50 Hz or 60 Hz.

Figure 1. Current Measurement Noise vs. Measurement Aperture, Nominal



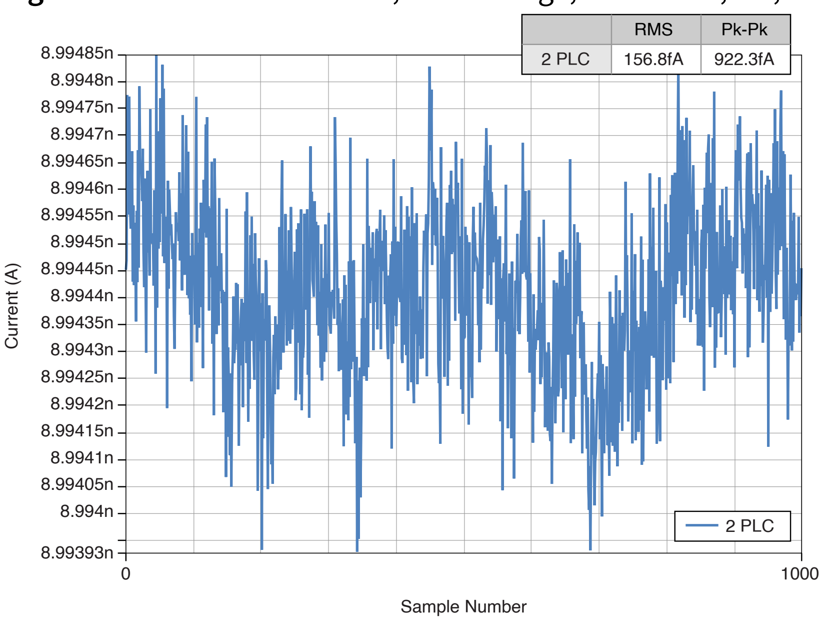
Note When the aperture time is set to 2 power-line cycles (PLCs), measurement noise differs slightly depending on whether the Power Line Frequency is set to 50 Hz or 60 Hz.

Figure 1. Measurement Noise, 10 nA Range, No Load, 0 V, 3 m Cables, Nominal



	RMS	Pk-Pk
10 PLC	35.5fA	241.7fA
2 PLC	78.1fA	523.7fA

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



	RMS	Pk-Pk
2 PLC	156.8fA	922.3fA

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

Related reference:

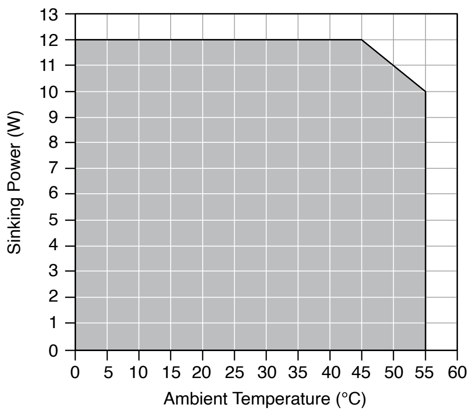
- Voltage

Sinking Power vs. Ambient Temperature Derating

The following figure illustrates sinking power derating as a function of ambient temperature.

This applies to the PXIe-4135 (20W) when used with any chassis and only applies to the PXIe-4135 (40W) when used with a chassis with slot cooling capacity <58 W.

Figure 1. Sinking Power vs. Ambient Temperature Derating



> **Note** When using the PXIe-4135 (40W) with a chassis with slot cooling capacity ≥58 W, ambient temperature derating does not apply.

Related reference:

- Device Capabilities

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} ±5 °C[16]
10 nA	0 to ±500 MΩ	±500 MΩ to ±infinity	0.03%
1 µA	0 to ±5 MΩ	±5 MΩ to ±infinity	
100 µA	0 to ±50 kΩ	±50 kΩ to ±infinity	

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

Current Level/Limit Range	Programmable Resistance Range, Voltage Mode	Programmable Resistance Range, Current Mode	Accuracy ± (% of resistance setting), T_{cal} ±5 °C[16]
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 [17]	0 to ±500 mΩ	±500 mΩ to ±infinity	

Overvoltage Protection

Accuracy[18] (% of OVP limit + offset)	1% + 200 mV, typical
Temperature coefficient (% of OVP limit + offset)/°C	0.01% + 3 mV/°C, typical
Measurement location	Local sense
Maximum OVP limit value	210 V
Minimum OVP limit value	2 V

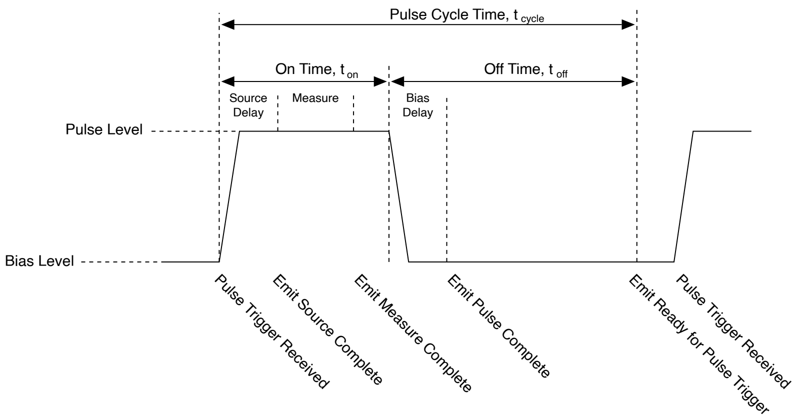
Pulsed Operation

Dynamic load, minimum pulse cycle time[19]	100 µs/A

17. 3 A range above 1 A is for pulsing only.
18. Overvoltage protection accuracy is valid with an ambient temperature of 23 °C ± 5 °C and with T_{cal} ±5 °C. T_{cal} is the internal device temperature recorded by the PXIe-4135 at the completion of the last self-calibration.
19. For example, given a continuous pulsing load, if the largest dynamic step in current that the load

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

Figure 1. Definition of Pulsing Terminology



Extended Range Pulsing for PXIe-4135 (40W)

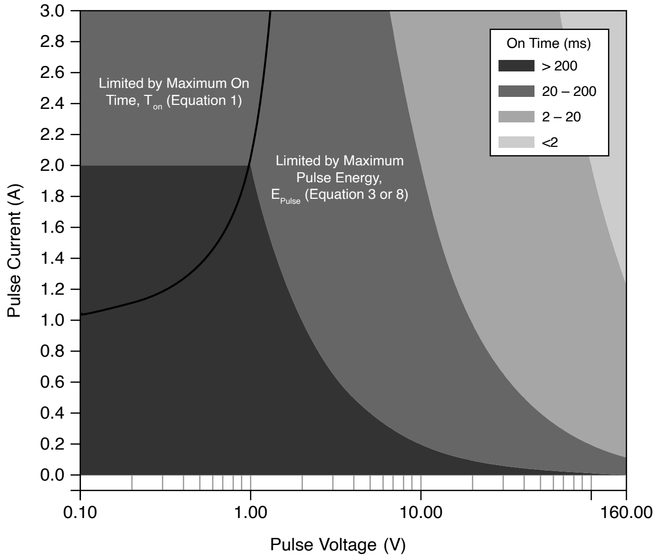
> **Note** Extended range pulses fall outside DC range limits for either current or power. In-range pulses fall within DC range limits and are not subject to extended range pulsing limitations. Extended range pulsing is enabled by setting the Output Function to Pulse Voltage or Pulse Current.

The following figures illustrate the maximum pulse on time and duty cycle for the PXIe-4135 (40W) in a ≥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.

sources/sinks is from 0.5 A to 1.0 A, then the maximum SMU current step is 0.5 A. Thus, the minimum dynamic load pulse cycle time is 50 µs. Minimum dynamic load pulse cycle time is independent of output voltage.[20]

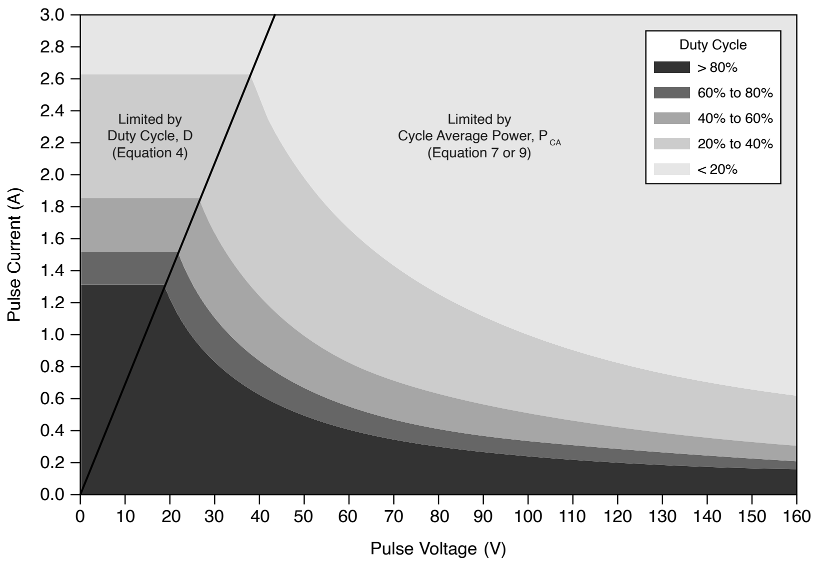
20. Measurable unit of µs/A is used because the minimum pulse cycle time is independent of output voltage

Figure 1. 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. Additionally, Equation 8 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 (40W).

Figure 1. Duty Cycle vs Pulse Current and Pulse Voltage



Note Equations to solve for maximum duty cycle, D_{Max}, are shown in Table 6. Additionally, Equation 9 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 (40W).

Bias level limits	
Maximum voltage, V_{bias}	200 V
Maximum current, I_{bias}	1 A

Table 6. PXIe-4135 (40W) Pulse Level Limits

Specification		Value	Equation
Maximum voltage, $V_{pulseMax}$		160 V	—
Maximum current, $I_{pulseMax}$		3 A	—
Maximum on time, t_{onMax}[21]	If $I_{pulse} > 1$ A and ≥58 W Slot Cooling Capacity Chassis	Calculate using the equation or refer to Figure 9 to estimate the value.	$t_{onMax} = 100\ \text{ms} * \frac{2\ \text{A}}{\lvert I_{pulse}\rvert - 1\text{A}}$, where t_{onMax} is ≤ 167 s ***(Equation 1)***
	If $I_{pulse} > 1$ A and <58 W Slot Cooling Capacity Chassis	Calculate using the equation.	$t_{onMax} = 10\ \text{ms} * \frac{2\ \text{A}}{\lvert I_{pulse}\rvert - 1\text{A}}$, where t_{onMax} is ≤ 167 s ***(Equation 2)***
	If $I_{pulse} \le 1$ A	$t_{onMax} = 167$ s	—
Maximum pulse energy, $E_{pulseMax}$[22]		0.4 J	$E_{pulse} = \lvert V_{pulse} * I_{pulse} * t_{on} \rvert$, where $E_{pulse} < E_{pulseMax}$ ***(Equation 3)***

21. ***Pulse on time*** is measured from the start of the leading edge to the start of the trailing edge. See GUID-2E9B16BD-1A40-4F06-8896-84F9B325AF7C.html#GUID-2E9B16BD-1A40-4F06-8896-84F9B325AF7C__FIG_JFH_D4Z_DNB.
22. Refer to Figure 9 to estimate the value and determine the limiting equation for a PXIe-4135 (40W) in a ≥58 W Slot Cooling Capacity Chassis.

Specification		Value	Equation
Maximum duty cycle, D_{Max}[23]	If ≥58 W Slot Cooling Capacity Chassis	Calculate using the equation or refer to Figure 10 to estimate the value.	$D_{Max} = \frac{(1.18\ A)^2 - \lvert I_{bias}\rvert^2}{\lvert I_{pulse}\rvert^2 - \lvert I_{bias}\rvert^2} * 100\%$ ***(Equation 4)***
	If <58 W Slot Cooling Capacity Chassis	Calculate using the equation.	$D_{Max} = \frac{(1\ A)^2 - \lvert I_{bias}\rvert^2}{\lvert I_{pulse}\rvert^2 - \lvert I_{bias}\rvert^2} * 100\%$ ***(Equation 5)***
Minimum pulse cycle time, $t_{cycleMin}$		5 ms	$t_{cycle} = t_{on} + t_{off}$, where $t_{cycle} > t_{cycleMin}$ ***(Equation 6)***
Maximum cycle average power, P_{CAMax}[24]	≥58 W Slot Cooling Capacity Chassis	20 W	$P_{CA} = \frac{\lvert V_{pulse} * I_{pulse} * t_{on}\rvert + \lvert V_{bias} * I_{bias} * t_{off}\rvert}{t_{on} + t_{off}}$, where $P_{CA} < P_{CAMax}$ ***(Equation 7)***
	<58 W Slot Cooling Capacity Chassis	10 W	

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

Related reference:

- Device Capabilities

23. Refer to Figure 10 to estimate the value and determine the limiting equation for a PXIe-4135 (40W) in a ≥58 W Slot Cooling Capacity Chassis. If D≥100%, consider switching Output Function from Pulse mode to DC mode.
24. Refer to Figure 10 to estimate the value and determine the limiting equation for a PXIe-4135 (40W) in a ≥58 W Slot Cooling Capacity Chassis.

Extended Range Pulsing for PXIe-4135 (20W)

Note 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.

Bias level limits	
Maximum voltage	200 V
Maximum current	1 A
Pulse level limits	
Maximum voltage	160 V
Maximum current	3 A
Maximum on time[25]	1 ms
Minimum pulse cycle time	5 ms
Energy	0.2 J
Maximum cycle average power	10 W
Maximum duty cycle	5%

25. ***Pulse on time*** is measured from the start of the leading edge to the start of the trailing edge. See GUID-2E9B16BD-1A40-4F06-8896-84F9B325AF7C.html#GUID-2E9B16BD-1A40-4F06-8896-84F9B325A

Related reference:

- Device Capabilities

Transient Response and Settling Time

Transient response[26]	
3 A to 100 μA ranges	<70 μs, typical
1 μA range[27][27]	<1 ms, typical
10 nA range[27]	<10 ms, typical
Maximum slew rate[28, 29]	0.5A/μs
Settling time[30]	
Voltage mode, 180 V step, unloaded[31]	<500 μs, typical
Voltage mode, 5 V step or smaller, unloaded[32]	<70 μs, typical
Current mode, full-scale step, 3 A to 100 μA ranges[33][33]	<50 μs, typical

F7C__FIG_JFH_D4Z_DNB.

26. Time to recover within 0.1% of voltage range after a load current change from 10% to 90% of range, device configured for fast transient response.
27. Measured with guarded load and HI/Sense HI triax cable ≤ 3 m
28. Optimize transient response, overshoot, and slew rate with NI SourceAdapt by adjusting the Transient Response.
29. To improve the slew rate, see Examples of Determining Extended Range Pulse Parameters and Optimizing Slew Rate using NI SourceAdapt.
30. Measured as the time to settle to within 0.1% of step amplitude, device configured for fast transient

Current mode, full-scale step, 3 A to 1 µA range[27], [33]	<2 ms, typical
Current mode, full-scale step, 3 A to 10 nA range[27], [33]	<15 ms, typical

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

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

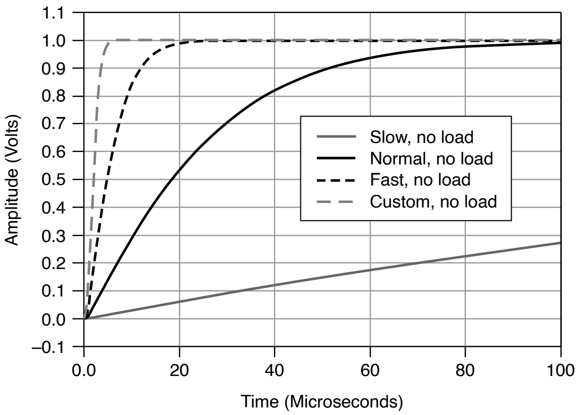
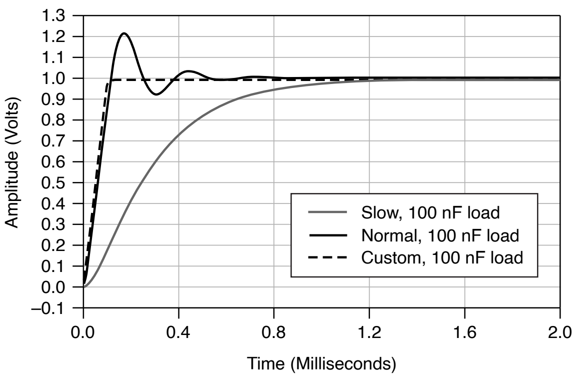


Figure 1. 1 mA Range, 100 nF Load Step Response, Nominal



Load Regulation

Voltage

response.

31. Current limit set to ≥60 µA and ≥60% of the selected current limit range.
32. Current limit set to ≥20 µA and ≥20% of selected current limit range.
33. Voltage limit set to ≥2 V, resistive load set to 1 V/selected current range.

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

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

Related reference:

- Voltage

Expected Relay Life

Output Connected	≥100 k cycles

Note To avoid excessive relay wear, do not set Output Connected to **TRUE** when a non-zero voltage is connected to the output.

Measurement and Update Timing Characteristics

Available sample rates[34]	(1.8 MS/s)/N where N = 1, 2, 3, … 2^{24}, nominal
Sample rate accuracy	Equal to PXIe_CLK100 accuracy, nominal

34. 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.

Maximum measure rate to host	1.8 MS/s per channel, continuous, nominal
Maximum source update rate[35]	
Sequence mode	100,000 updates/s (10 µs/update), nominal
Timed output mode	80,000 updates/s (12.5 µs/update), nominal
Input trigger to	
Source event delay	10 µs, nominal
Source event jitter	1 µs, nominal
Measure event jitter	1 µs, nominal
Pulse mode timing and accuracy[36]	
Minimum pulse on time[37]	
PXIe-4135 (40W)[38]	10 µs, nominal
PXIe-4135 (20W)	50 µs, nominal
Minimum pulse off time [39]	50 µs, nominal
Pulse on time or off time programming resolution	100 ns, nominal

35. 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 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).

Pulse on time or off time programming accuracy	±5 µs, nominal
Pulse on time or off time jitter	1 µs, nominal

Remote Sense

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

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

Related reference:

36. 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-4135 (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.
37. ***Pulse on time*** is measured from the start of the leading edge to the start of the trailing edge. See GUID-2E9B16BD-1A40-4F06-8896-84F9B325AF7C.html#GUID-2E9B16BD-1A40-4F06-8896-84F9B325AF7C__FIG_JFH_D4Z_DNB.
38. Optimize transient response, overshoot, and slew rate with NI SourceAdapt by adjusting the Transient Response.
39. 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.

- Voltage

Safety Interlock

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

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

> **Attention** Des tensions dangereuses allant jusqu'à la tension maximale du PXIe-4135 peuvent apparaître aux terminaux de sortie si le terminal de verrouillage de sécurité est fermé. Ouvrez le terminal de verrouillage de sécurité lorsque les connexions de sortie sont accessibles. Lorsque le terminal de verrouillage de sécurité est ouvert, le niveau ou la limite de tension de sortie est limité à ± 40 V CC, et la protection se déclenchera si la tension mesurée entre les terminaux HI et LO de l'appareil dépasse ± (42 Vpic ± 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.

> **Attention** N'appliquez pas de tension aux entrées du connecteur de verrouillage de sécurité. Le connecteur de verrouillage est conçu pour accepter uniquement des connexions à fermeture de contact passives, normalement ouvertes.

Safety interlock terminal open

Output	<±42.4 V peak
Setpoint	<±40 V DC
Safety interlock terminal closed	
Output	Maximum voltage of the device
Setpoint	Maximum selected voltage range

Examples of Calculating Accuracy Specifications

> **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 µA range under the following conditions:

Ambient temperature	28 °C
Internal device temperature	within T_{cal} ±5 °C[40]
Self-calibration	within the last 24 hours

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

0.03% + 100 pA

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

Calculate the accuracy using the following formula:

$$\text{Accuracy} = (900\ \text{nA} * 0.03\ \%) + 100\text{pA}$$
$$= 270\text{pA} + 100\text{pA}$$
$$= 370\text{pA}$$

Therefore, the actual output is within 370 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: Because the device internal temperature is within T_{cal} ±5 °C and the ambient temperature is within 23 °C ±5 °C, the appropriate accuracy specification is the following value:

0.02% + 50 µV

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

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

Calculate the remote sense accuracy using the following formula:

$$\text{Accuracy} = (500\ \text{mV} * 0.02\ \% + 50\ \mu\text{V}) + \frac{600\ \text{mV} * 3\ \text{ppm}}{1\ V \text{of lead drop}} * 3\ V + \frac{1\ \mu V}{V * \Omega} * 3\ V * 2\ \Omega + \frac{1\ \mu V}{V * \Omega} * 2.5\ V * 1.5\Omega$$
$$= 100\mu\text{V} + 50\mu\text{V} + 1.8\mu\text{V} * 3 + 6\mu\text{V} + 3.75\mu\text{V}$$
$$= 165.15\mu\text{V}$$

Therefore, the actual output is within 165.15 μV of 500 mV.

Example 3: Calculating Accuracy with Temperature Coefficient

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

Ambient temperature	15 °C

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

0.03% + 100 pA

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

0.0006% + 4 pA

Calculate the accuracy using the following formula:

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

$$\text{Accuracy} = (900\ \text{nA} * 0.03\ \% + 100\ \text{pA}) + \frac{900\ \text{nA} * 0.0006\ \% + 4\ pA}{1\ {}^\circ C} * 3\ {}^\circ C$$

$$= 370\ \text{pA} + 28.2\ \text{pA}$$

$$= 398.2\ \text{pA}$$

Therefore, the actual output is within 398.2 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-4135 (40W)

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

Output function	Pulse Current
Pulse voltage limit, V_{pulse}	80 V
Pulse current level, I_{pulse}	3 A
Bias voltage limit, V_{bias}	0.1 V
Bias current level, I_{bias}	0 A
Pulse on time, t_{on}	1.5 ms
Chassis' slot cooling capacity	≥58 W

Solution

Begin by calculating the pulse power using the following equation.

Pulse power = $V_{pulse} * I_{pulse}$
= 80 V * 3 A
= 240 W

For PXIe-4135 (40W), refer to the following figures to identify next steps. First, verify the the region of operation using Figure 1, which shows 240 W is in the extended range pulsing region.

Next, refer to GUID-CABA0054-BF9F-4E2F-99B3-67B9894D8290.html#GUID-CABA0054-BF9F-4E2F-99B3-67B9894D8290__FIG_LNR_2ZZ_5MB, which shows the maximum pulse on time, t_{on}, is limited by the maximum pulse energy, $E_{pulseMax}$. Use the pulse energy equation ***(Equation 3)*** from GUID-CABA0054-BF9F-4E2F-99B3-67B9894D8290.html#GUID-CABA0054-BF9F-4E2F-99B3-67B9894D8290__TABLE_CJS_41C_1NB to calculate the maximum pulse on time, t_{onMax}***(Equation 8)***.

$$t_{onMax} = \left| \frac{E_{pulseMax}}{V_{pulse} * I_{pulse}} \right| \quad \left(Eq.8 \right)$$

$$= \left| \frac{0.4\ \mathrm{J}}{80\ \mathrm{V} * 3\ \mathrm{A}} \right|$$

$$= 1.67\ \mathrm{ms}$$

Next, refer to GUID-CABA0054-BF9F-4E2F-99B3-67B9894D8290.html#GUID-CABA0054-BF9F-4E2F-99B3-67B9894D8290__FIG_EQB_BZZ_5MB, which shows the maximum duty cycle, D, is limited by the cycle average power, P_{CA}.If the required pulse on time is 1.5 ms and the module is installed in a chassis with slot cooling capacity ≥58 W, use the cycle average power equation ***(Equation7)*** from GUID-CABA0054-BF9F-4E2F-99B3-67B9894D8290.html#GUID-CABA0054-BF9F-4E2F-99B3-67B9894D8290__TABLE_CJS_41C_1NB to calculate the minimum pulse off time, t_{offMin}***(Equation 9)***.

$$t_{offMin} = \left| \frac{P_{CA} * t_{on} - V_{pulse} * I_{pulse} * t_{on}}{P_{CA} - V_{bias} * I_{bias}} \right| \quad \left(Eq.9 \right)$$

$$= \left| \frac{20\ \mathrm{W} * 1.5\ \mathrm{ms} - 80\ \mathrm{V} * 3\ \mathrm{A} * 1.5\ \mathrm{ms}}{20\ \mathrm{W} - 0.1\ \mathrm{V} * 0\ \mathrm{A}} \right|$$

$$= 16.5\ \mathrm{ms}$$

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

$$t_{cycle} = t_{on} + t_{off} \quad \text{(Eq. 6)}$$

$$= 1.5\ \mathrm{ms} + 16.5\ \mathrm{ms}$$

=18 ms

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

Therefore, a 80 V, 3 A pulse with an on time of 1.5 ms and a pulse off time of 16.5 ms is supported, since it fulfills the following criteria:

- Greater than the minimum pulse on time of 10 µs
- Equal to the minimum pulse off time of 16.5 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-4135 (20W)

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

Output function	Pulse Current
Pulse voltage limit, V_{pulse}	80 V
Pulse current level, I_{pulse}	3 A
Bias voltage limit, V_{bias}	0.1 V
Bias current level, I_{bias}	0 A
Pulse on time, t_{on}	1.5 ms
Chassis' slot cooling capacity	≥58 W

Solution

Begin by calculating the pulse power using the following equation.

Pulse power = $V_{pulse} * I_{pulse}$
= 80 V * 3 A

$=240\ W$

Since the pulse power of 240 W is within the 480 W region of GUID-F6A69CB1-8128-4008-937F-4F11666F190F.html#GUID-F6A69CB1-8128-4008-937F-4F11666F190F__FIG_20WQUADDIAGRAM, the maximum configurable on time is 400 µs and maximum duty cycle is 2%.

For example, if the required pulse on time is 100 µs, and the required pulse cycle time is 10 ms, calculate the pulse off time and verify the duty cycle using the following equations.

$t_{off} = t_{cycle} - t_{on}$
$= 10\ ms - 100\ \mu s$
$= 9.9\ ms$

Duty cycle $= \frac{t_{on}}{t_{cycle}} * 100\%$
$= 1\ \%$

Therefore, a pulse with an on time of 100 µs and 1% duty cycle would be supported, since it fulfills the following criteria:

- Greater than the minimum pulse on time of 50 µs
- Less than the maximum pulse on time of 400 µs 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

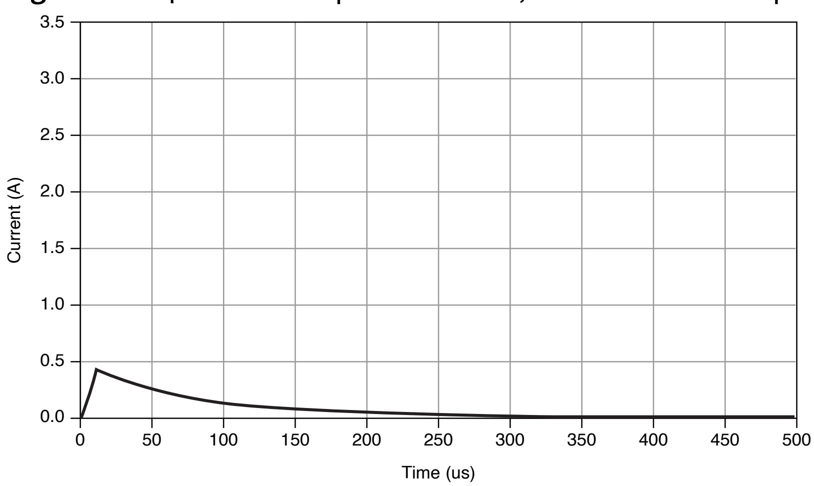
Determine the appropriate operating parameters and custom transient response settings, assuming the following example parameters.

Output function	Pulse Current
Pulse voltage limit, V_{pulse}	160 V
Pulse current level, I_{pulse}	3 A
Bias voltage limit, V_{bias}	0.1 V

Bias current level, I_{bias}	0 A
Transient response	Fast
Load, cable impedance	22.3 Ω, 1.8 µH
Pulse on time, t_{on}	10 µs
Pulse off time, t_{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[41] 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 1. 10 µs Pulse Output with Load, Fast Transient Response



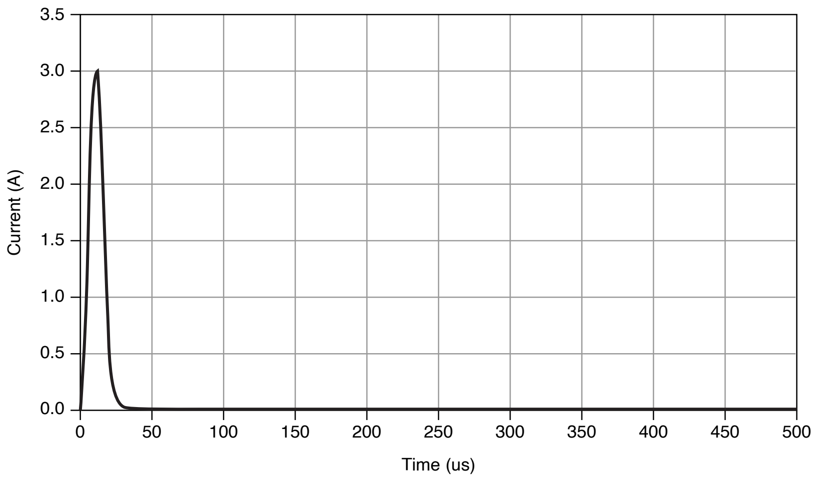
Solution

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.

41. Visit ni.com for more information about NI SourceAdapt Next-Generation SMU Technology.

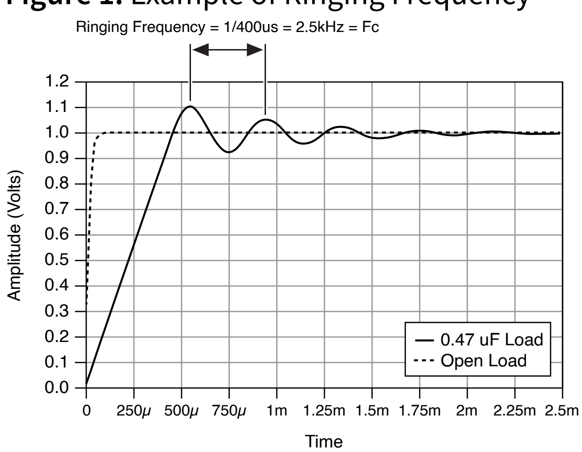
Figure 1. 10 µs Pulse Output with Load, Custom Transient Response



Transient response	Custom
Current: Gain bandwidth	900 kHz
Current: Compensation frequency	200 kHz
Current: Pole-zero ratio	2

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 1. 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 Fc in the figure above, 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
Sources (PXI trigger lines <0...7>) [42]	
Polarity	Configurable
Minimum pulse width	100 ns, nominal
Destinations[43] **(PXI trigger lines <0...7>)**	
Polarity	Active high (not configurable)
Pulse width	>200 ns, typical

42. Pulse widths and logic levels are compliant with ***PXI Express Hardware Specification Revision 1.0 ECN 1.***
43. Input triggers can be re-exported.

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 μs, nominal

Protection

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

Safety Voltage and Current

Notice The protection provided by the PXIe-4135 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.

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	±200 V
Channel-to-earth ground isolation	
Continuous	250 V DC, CAT I
Withstand	1,000 V RMS, verified by a 5 s withstand

Caution Do not connect the PXIe-4135 to signals or use for measurements within Measurement Categories II, III, or IV.

Attention Ne connectez pas le PXIe-4135 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	±1 A; ±3 A, pulse only

Guard Output Characteristics

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

Calibration Interval

Recommended calibration interval	1 year

Power Requirement

PXIe-4135 (40W)	3.0 A from the 3.3 V rail and 6.0 A from the 12 V rail
PXIe-4135 (20W)	2.5 A from the 3.3 V rail and 2.7 A from the 12 V rail

Physical

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	
PXIe-4135 (20W)	419 g (14.8 oz)
PXIe-4135 (40W)	440 g (15.5 oz)
Front panel connectors	2 × 3 lug triaxial connectors, 1 × 4.08 mm (3 position) combicon

Environmental Characteristics

Temperature	
Operating	0 °C to 55 °C
Storage	-40 °C to 71 °C
Humidity	
Operating	10% to 90%, noncondensing
Storage	5% to 95%, noncondensing
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