# PXIe-4051 Specifications

2024-04-16

# Contents

# PXIe-4051 Specifications

## 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.

## Conditions

Specifications are valid under the following conditions unless otherwise noted.

- Chassis with ≥ 58 W slot cooling capacity.

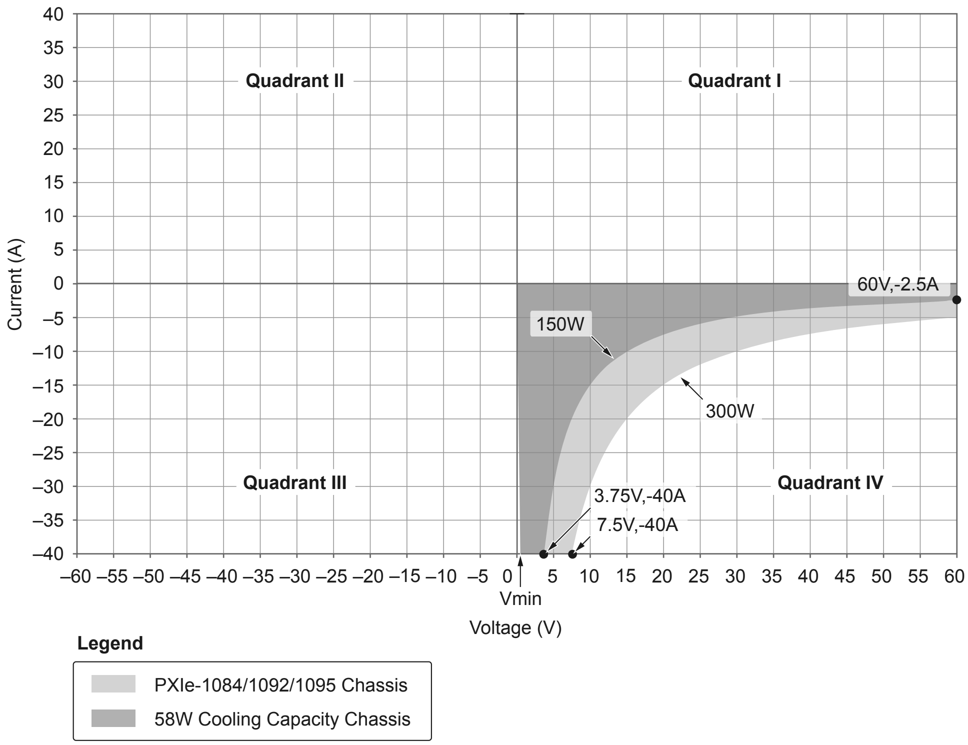
> **Note** For more information on maximum sinking power chassis dependencies, refer to **Instrument Capabilities**.

- Calibration interval of 2 years.
- Warm-up time of 30 minutes.
- Self-calibration performed within the last 24 hours.
- Ambient temperature of 23 °C ± 5 °C.
- NI-DCPower Aperture Time is set to 2 power-line cycles (PLC).

# Instrument Capabilities

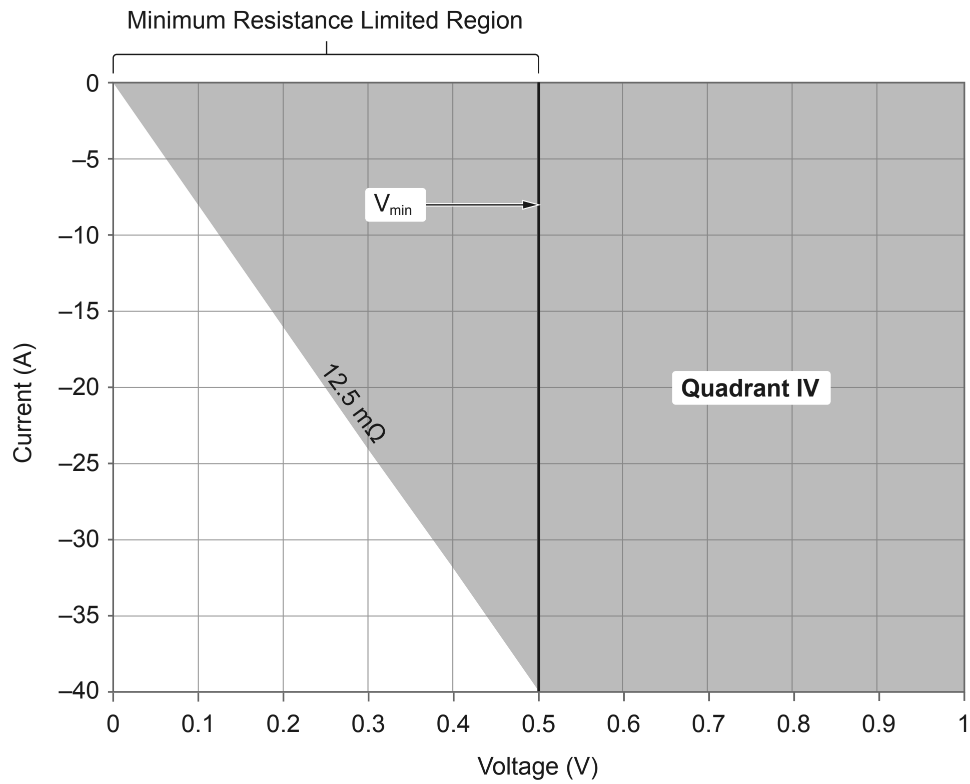
| | |
|---|---|
| DC voltage ranges | 6 V, 60 V |
| DC current ranges | 4 A, 40 A |

**Figure 1.** PXIe-4051 Quadrant Diagram




**Note** For more information on operation at voltages below $V_{min}$, refer to the following figure.

**Figure 2.** Expanded View of Minimum Resistance Limited Region




> **Note** The PXIe-4051 electronic load is a single quadrant instrument operating in quadrant IV (sink power). To match historical industry behavior of electronic loads, all other sections of the PXIe-4051 documentation and the NI-DCPower driver use a positive sign convention for current levels/limits and measurements. For code compatibility with SMU instruments, use the Instrument Mode property to determine the sign convention being used by NI-DCPower.

**Table 1.** Minimum Resistance Limited Region

| | |
|---|---|
| Minimum Operating Voltage ($V_{min}$) | 500 mV at 40 A, typical |
| Minimum Force Resistance ($R_{min}$) | 12.5 mΩ, typical |

**Note** Operation below $V_{min}$ is possible when current is limited to levels below $V_{input}$ / $R_{min}$. Configuring levels outside the curve in **Figure 2** will result in a loss of regulation as the result of the power stage saturating at $R_{min}$.

**Table 2.** DC Sinking Power

| Chassis Type | Max DC Sinking Power |
|---|---|
| PXIe-1084[1], PXIe-1092, PXIe-1095 | 300 W |
| 58 W Slot Cooling Capacity | 150 W |
| 38 W Slot Cooling Capacity | Not Supported |

# 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 ± (% of Voltage + Offset)[2] | Tempco[3] ± (% of Voltage + Offset)/°C |
|---|---|---|---|---|
| | | | $T_{ambient}$ 23 °C ± 5 °C, $T_{cal}$[4] ± 5 °C | $T_{ambient}$ 0 °C to 40 °C, $T_{cal}$ ± 5 °C |
| 6 V | 1 µV | 6 µV | 0.03% + 600 µV | 0.0005% + 1 µV |
| 60 V | 10 µV | 60 µV | 0.03% + 6 mV | |

1 The PXI Platform Services driver must be updated to version 2023 Q2 or later.
2 Refer to the Remote Sense section for additional accuracy derating and conditions.
3 Temperature coefficient applies beyond 23 °C ± 5 °C ambient within ± 5 °C of $T_{cal}$.
4 $T_{cal}$ is the internal device temperature recorded by the PXIe-4051 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 ± (% of Current + Offset) | Tempco[5] ± (% of Current + Offset)/°C |
|---|---|---|---|---|
| | | | $T_{ambient}$ 23 °C ± 5 °C, $T_{cal}$[6] ± 5 °C | $T_{ambient}$ 0 °C to 40 °C, $T_{cal}$ ± 5 °C |
| 4 A | 10 µA | 60 µA | 0.05% + 700 µA | 0.003% + 2 µA |
| 40 A | 100 µA | 350 µA | 0.07% + 13 mA | 0.0039% + 20 µA |

# Noise

The following figure illustrates measurement noise as a function of measurement aperture time for the PXIe-4051.

5 Temperature coefficient applies beyond 23 °C ± 5 °C ambient within ± 5 °C of $T_{cal}$.

6 $T_{cal}$ is the internal device temperature recorded by the PXIe-4051 at the completion of the last self-calibration.

**Figure 3.** Voltage RMS Noise Versus Aperture Time, Nominal

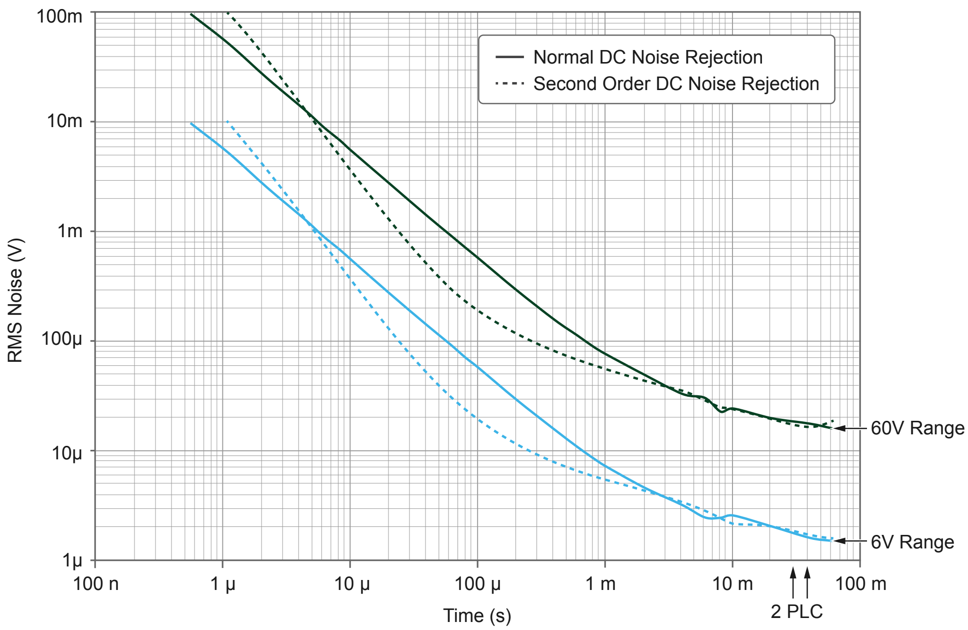
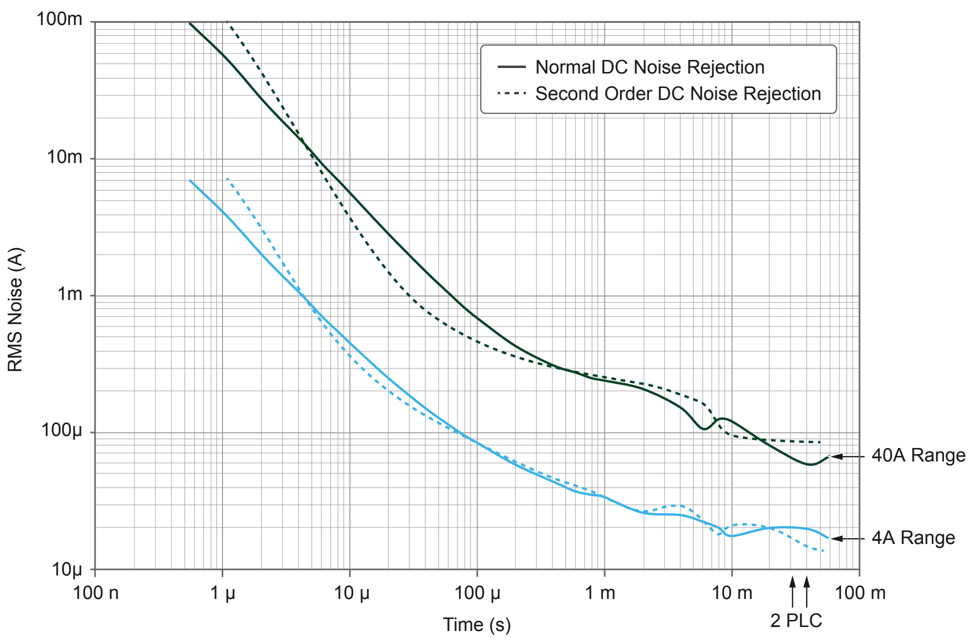



**Figure 4.** Current RMS Noise Versus Aperture Time, Nominal




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

**Note** Use the DC Noise Rejection property to configure normal or second-order DC noise rejection.

# Inputs

## Programmable Conduction Voltage

**Table 5.** Conduction Voltage Threshold (Von / Voff) Programming Accuracy/Resolution

| | |
|---|---|
| Accuracy | ± (6% of threshold setpoint + 50 mV), typical |
| Resolution | 30 mV, typical |

**Note** For more information, refer to **Vload_min, Turn-on Behavior, and Conduction Voltage Settings** in the PXIe-4051 User Manual.

## Protection

| **Channel protection** | |
|---|---|
| Overtemperature | Automatic shutdown |
| Overpower | Automatic shutdown |
| Overcurrent | Automatic shutdown |

## Series and Parallel Operation

Identically rated electronic load modules can be used in parallel in constant current modes. NI does not recommend using load modules in series.

### Related information:

- Vload_min, Turn-on Behavior, and Conduction Voltage Settings

# Transient Response

**Table 6.** DC Current Transient Response Performance

| Transient Response Setting | Rise Time[7] | Slew Rate[8] | Setpoint Step Conditions |
|---|---|---|---|
| Slow | 443 μs rise time | 0.07 A/μs | 1 A to 39 A |
| Normal | 53 μs rise time | 0.59 A/μs | |
| Fast | 10 μs rise time | 3 A/μs | |

**Table 7.** DC Voltage Transient Response Performance

| Transient Response Setting | Rise Time[9] | Slew Rate[10] | Setpoint Step Conditions |
|---|---|---|---|
| Slow | 26.4 ms, typical | 0.001 V/μs | 1 V to 50 V |
| Normal | 1.2 ms, typical | 0.033 V/μs | |
| Fast | 103 μs, typical | 0.38 V/μs | |

**Note** These rates are typical of the SourceAdapt presets. Depending on the setup and configuration, using custom transient response can increase the slew rates beyond the performance shown. Setting a higher Gain Bandwidth than your system and setup physically allows (due to cables, inductances, capacitances, and so on.) may result in instability.

**Table 8.** Setpoint Slew Rate Programmable Range

| NI-DCPower Property | Current Level Range | Programmable Range |
|---|---|---|
| Current Level Rising Slew Rate / Current Level Falling Slew Rate | 4 A | 10 nA/μs - 2.4 A/μs |
| | 40 A | 10 nA/μs - 24 A/μs |

7 Measured as the time to transition from 10% to 90% of setpoint transition.
8 Measured as change in current divided by time between the 10% and 90% points of the setpoint transition.
9 Measured as the time to transition from 10% to 90% of setpoint transition.
10 Measured as change in current divided by time between the 10% and 90% points of the setpoint transition.

**Note**

- Maximum realizable slew rates are constrained by the programmed Gain Bandwidth and the limitations of the setup and system. Use programmable slew rate to obtain slower slew rates, independent rising and falling slew rates, or unique slew rates for each step in a sequence.
- If the slew rates are programmed to be slower than the sequence/step time then you will not be able to achieve the steady state programmed current or voltage within that step timing.
- Programmable Slew rates are available for Constant Current Mode only.
- For more information, refer to **Transient Response** in the PXIe-4051 User Manual.

**Related information:**

- Transient Response

# Remote Sense

| | |
|---|---|
| Voltage accuracy | Add 5 ppm of voltage measurement per 1 Ω of sense lead resistance if the maximum sense lead resistance specification is exceeded. |
| Maximum sense lead resistance | 1 Ω |

# Measurement and Update Timing Characteristics

**Note** In the following section, any references in the NI-DCPower API to a **source** actually refers to the sink functionality of the electronic load.

| | |
|---|---|
| Available sample rates[11] | (1.8 MS/s)/N where N = 1, 2, 3, … $2^{24}$, nominal |
| Sample rate accuracy | Equal to PXIe_CLK100 accuracy, nominal |
| Maximum measure rate to host | 1.8 MS/s per channel, continuous, nominal |
| **Maximum update rate[12]** | |
| Sequence mode | 100,000 updates/s (10 µs/update), nominal |
| **Input trigger to** | |
| Source event delay | 10 µs, nominal |
| Source event jitter | 4 µs peak-to-peak, nominal |
| Measure event jitter | 2 µs peak-to-peak, nominal |

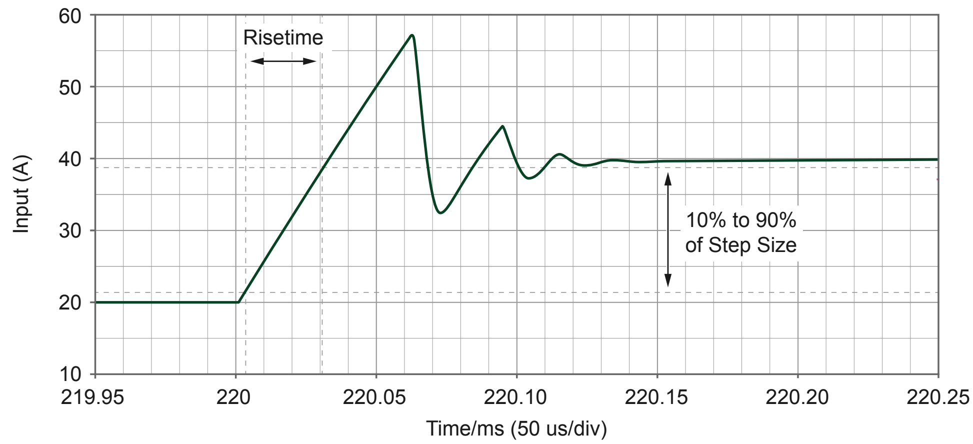
# Using NI SourceAdapt to Optimize Transient Response

NI SourceAdapt optimizes system transient response and interconnects for the following conditions:

- Faster slew rates
- Reduced overshoots
- Ringing

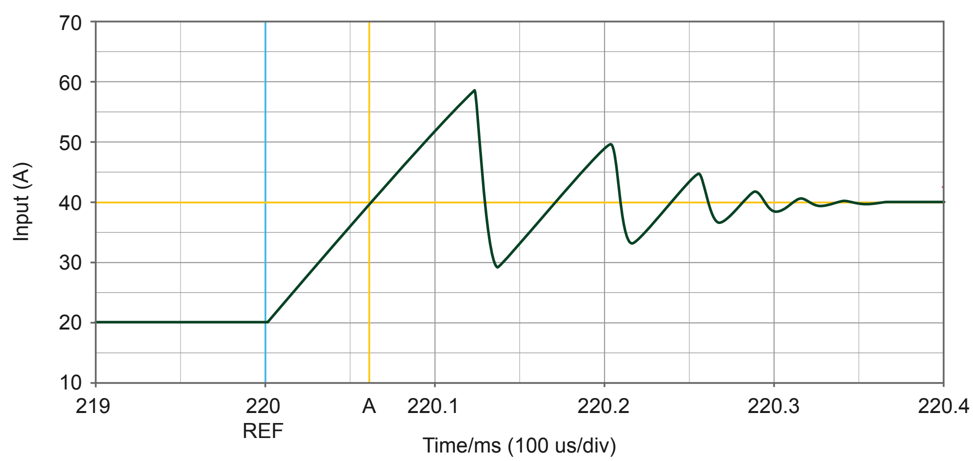
Long cables and high inductance between the DUT and the electronic load can lead to an unstable or oscillatory system. The following graph is an example of how SourceAdapt can be used to optimize a system with long cable length or high cable inductance and high required current setpoints.

[11] 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.
[12] As the Source Delay is adjusted, or if advanced sequencing is used, maximum update rates vary.




Before tuning with SourceAdapt, set the slew rate (if adjustable) to the maximum so that the slew rate limits do not mask the optimum rise times that you could possibly have with your system.

The following graph is an example of an initial transient response in a system with constant current mode and a long cable. The ringing and slew rate is limited by the inductance of the system.

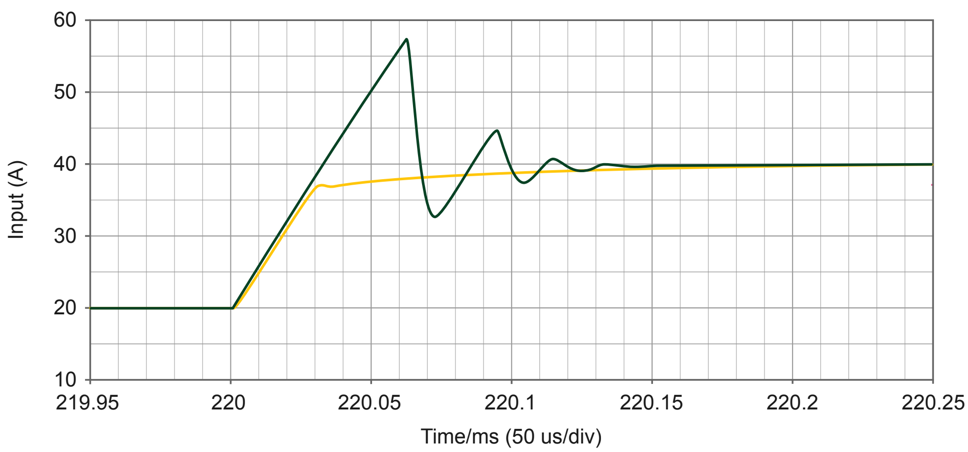



Use the Gain Bandwidth (GBW) property to decrease the bandwidth of the system until the oscillations are acceptable with no overshoots.

NI recommends using the GBW of the system inductance limited rise time from the above graph with the following formula:

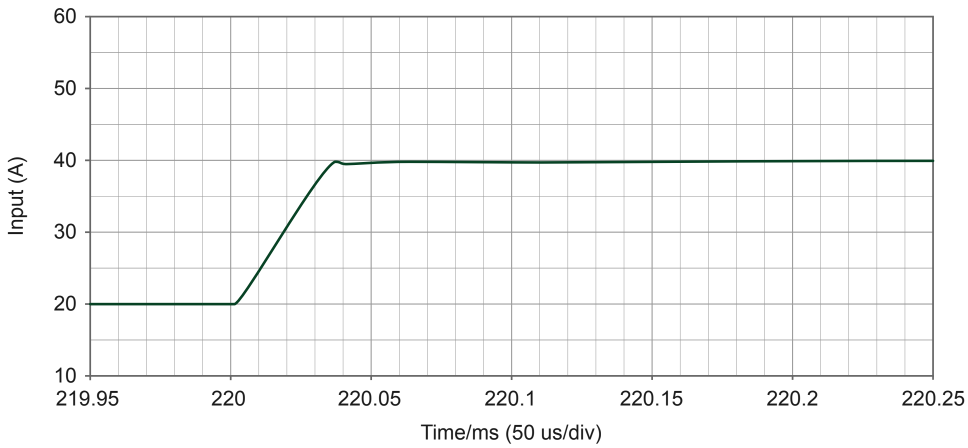
$$GBW = \frac{.35}{2 * \ Rise \ \ Time}$$

The rise time must stay within certain limits determined by the given slew rate and the resonant frequency of the system. These limits are influenced by the natural inductance of the cable. Balancing these factors is essential to ensuring the system works well and remains stable. If the system is in full oscillation, you can begin by setting a low GBW (1kHz or less) to gain stability prior to further tuning.




Tune the response by adjusting the compensation frequency and the pole-zero ratio to place additional pole and zero into the system. For example, by adjusting the compensation frequency to equal the GBW and slowly reducing the pole-zero ratio to less than unity (<1), you can optimize the step response.

> **Note** During the tuning process, thread slowly. Overcompensation can result in overshoot and/or oscillations.




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 Source: Transient Response set to Custom and Source: Transient Response. The Voltage or Current setting depends on the source mode in the property node.

# Trigger Characteristics

**Note** In the following section, any references in the NI-DCPower API to a **source** actually refers to the sink functionality of the electronic load.

| **Input triggers** | |
|---|---|
| Types | Start, Source, Sequence Advance, Measure |
| **Sources (PXI trigger lines <0...7>)** | |
| Polarity | Active high (not configurable) |

| | |
|---|---|
| Minimum pulse width | 100 ns, nominal |
| **Destinations[13, 14] (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 |
| **Destinations[15, 16] (PXI trigger lines <0...7>)** | |
| Polarity | Active high (not configurable) |
| Pulse width | >230 ns, typical |

## Fault

| | |
|---|---|
| Connector | AUX I/O |
| Direction | Output |
| Logic type | 3.3 V CMOS |
| Polarity | Active low (not configurable) |

[13] Pulse widths and logic levels are compliant with **PXI Express Hardware Specification Revision 1.0 ECN 1**.
[14] Input triggers can be re-exported.
[15] Pulse widths and logic levels are compliant with **PXI Express Hardware Specification Revision 1.0 ECN 1**.
[16] Output triggers can be re-exported.

## Safety Voltage and Current

**Notice** The protection provided by the PXIe-4051 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 | 60 V |
| **Channel-to-earth ground isolation** | |
| Continuous | 150 VDC, CAT I |
| Withstand | 800 Vpk |

**Caution** Do not connect the PXIe-4051 to signals or use for measurements within Measurement Categories II, III, or IV.

> **Attention** Ne connectez pas le PXIe-4051 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 | 4 A<br><br>40 A |

## Physical

| | |
|---|---|
| Dimensions | 3U, three-slot, PXI Express/CompactPCI Express module<br><br>6.0 cm × 13.0 cm × 23.7 cm<br>(2.4 in. × 5.1 in. × 9.3 in.) |
| **Weight** | |
| PXIe-4051 | 1010 g (35.6 oz) |
| **Front Panel Connectors** | |

| | |
|---|---|
| Input Channels | OMNIMATE Hybrid, 7.62 mm (4 position), 2.54 mm (6 position) |
| AUX I/O | MICRO COMBICON - DFMC 0, 5, 2.54 mm (8 position) |

# Calibration Interval

| | |
|---|---|
| Recommended calibration interval | 2 years |

# Power Requirement

| **PXI Express power requirement** | |
|---|---|
| PXIe-4051 | 1.5 A from the 3.3 V rail and 3 A from the 12 V rail |

# Environmental Characteristics

| **Temperature** | |
|---|---|
| Operating | 0 °C to 40 °C |
| Storage | -40 °C to 71 °C |
| **Humidity** | |
| Operating | 10% RH to 90% RH, noncondensing |
| Storage | 5% RH to 95% RH, noncondensing |
| Pollution Degree | 2 |
| Maximum Altitude | 2000 m |

| 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 |

# 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 programming / measurement accuracy of a 20 A input in the 40 A range under the following conditions:

| | |
|---|---|
| Ambient temperature | 28 °C |
| Internal device temperature | Within $T_{cal}$[17] ± 5 °C |
| Self-calibration | Within the last 24 hours. |

Solution

Since the device internal temperature is within $T_{cal}$[18] ± 5 °C and the ambient temperature is within 23 °C ± 5 °C, the appropriate accuracy specification is:

0.07%+ 13 mA

Calculate the accuracy using the following equation:

[17] $T_{cal}$ is the internal device temperature recorded by the PXIe-4051 at the completion of the last self-calibration.

[18] $T_{cal}$ is the internal device temperature recorded by the PXIe-4051 at the completion of the last self-calibration.

$$\text{Accuracy} = 20\,A * 0.07\,\% + 13\,\text{mA}$$

$$= 14\,\text{mA} + 13\,\text{mA}$$

$$= 27\,\text{mA}$$

Therefore, the actual input will be within 27 mA of 20 A.

## Example 2: Calculating Remote Sense Accuracy

Calculate the remote sense accuracy of measuring 15 V in the 60 V range. Assume the same conditions as in Example 1, with the following differences:

| | |
|---|---|
| HI sense lead resistance | 5 Ω |
| LO sense lead resistance | 1.5 Ω |

Solution

Since the device internal temperature is within $T_{cal}$[19] ± 5 °C and the ambient temperature is within 23 °C ± 5 °C, the appropriate accuracy specification is:

0.03% + 6 mV

Since the device is using remote sense and the sense lead resistance exceeds the maximum sense lead resistance spec, use the remote sense accuracy specification.

Add 5 ppm of voltage measurement per 1 Ω of sense lead resistance.

Calculate the remote sense accuracy using the following equation:

$$\text{Accuracy} = (15\,V * 0.03\,\% + 6\,\text{mV}) + (15\,V * 5\,\text{ppm}/\Omega) * (5\,\Omega + 1.5\,\Omega - 1\,\Omega)$$

$$= 10.5\,\text{mV} + 488\,\mu\text{V}$$

19 $T_{cal}$ is the internal device temperature recorded by the PXIe-4051 at the completion of the last self-calibration.

$= 10.988\ \text{mV}$

Therefore, the actual input will be within 10.988 mV of 15 V.

# Example 3: Calculating Accuracy with Temperature Coefficient

Calculate the accuracy of 10 A loading in the 40 A range. Assume the same conditions as in Example 1, with the following differences:

| | |
|---|---|
| Ambient temperature | 15 °C |

Solution

Since the device internal temperature is within $T_{cal}$[20] ± 5 °C, the appropriate accuracy specification is:

0.07% + 13 mA

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

0.0039% + 20 µA

Calculate the accuracy using the following equation:

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

$$\text{Accuracy} = (10\ A * 0.07\% + 13\ \text{mA}) + (10\ A * 0.0039\%/°C + 20\ \mu\text{A}/°C) * 3\ °C$$

$$= 20\ \text{mA} + 1.23\ \text{mA}$$

[20] $T_{cal}$ is the internal device temperature recorded by the PXIe-4051 at the completion of the last self-calibration.

$= 21.23\ \text{mA}$

Therefore, the actual input will be within 21.23 mA of 10 A.