

NI DC Power Supplies and SMUs Help

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This help file contains fundamental and advanced concepts necessary for using NI power supplies and SMUs and the NI-DCPower instrument driver. In addition to device-specific information, this help file contains getting started steps for creating an application using LabVIEW, LabWindows[™]/CVI[™], and Microsoft Visual Basic and includes LabVIEW and C/CVI/VB programming references.

National Instruments power supplies and SMUs include the following devices:

Device	Details
NI PXI- 4110	Three single-quadrant DC power supply channels
NI PXI- 4130	Two output channels: Channel 0 is a single-quadrant power supply; Channel 1, the SMU channel, is a four-quadrant, bipolar power source-measure unit

For more information about this help file, refer to the following topics:

Using Help

Related Documentation

<u>Glossary</u>

Important Information

Technical Support and Professional Services

To comment on this documentation, refer to the <u>National Instruments</u> <u>Web site</u>.

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Related Documentation

Most NI power supply and SMU manuals also are available as PDFs. You must have Adobe Reader with Search and Accessibility 5.0.5 or later installed to view the PDFs. Refer to the <u>Adobe Systems Incorporated</u> <u>Web site</u> at www.adobe.com to download Adobe Reader. Refer to the <u>National Instruments Product Manuals Library</u> at ni.com/manuals for updated documentation resources.

The following documents contain information that you may find helpful as you use this help file.

- <u>NI-DCPower Readme</u>
- <u>NI DC Power Supplies and SMUs Getting Started Guide</u> (PDF)

NI PXI-4110

- <u>NI PXI-4110 Specifications</u> (PDF)
- NI PXI-4110 Calibration Procedure (PDF)

NI PXI-4130

- <u>NI PXI-4130 Specifications</u> (PDF)
- NI PXI-4130 Calibration Procedure (PDF)

Using Help

<u>Conventions</u> <u>Navigating Help</u> <u>Searching Help</u> <u>Printing Help File Topics</u>

Conventions

This help file uses the following formatting and typographical conventions:

< > Angle brackets that contain numbers separated by an ellipsis represent a range of values associated with a bit or signal name—for example, AO <0..3>. [] Square brackets enclose optional items—for example, [response]. The » symbol leads you through nested menu items and » dialog box options to a final action. The sequence File»Page Setup»Options directs you to pull down the File menu, select the Page Setup item, and select Options from the last dialog box. P This icon denotes a tip, which alerts you to advisory information. N This icon denotes a note, which alerts you to important information. ∕∧ This icon denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash. bold Bold text denotes items that you must select or click on in the software, such as menu items and dialog box options. Bold text also denotes parameter names, emphasis, or an introduction to a key concept. dark red Text in this color denotes a caution. Underlined text in this color denotes a link to a help topic, green help file, or Web address. italic Italic text denotes variables, emphasis, cross-references, or an introduction to a key concept. Italic text also denotes text that is a placeholder for a word or value that you must supply. monospace Text in this font denotes text or characters that you should enter from the keyboard, sections of code, programming

examples, and syntax examples. This font is also used for

the proper names of disk drives, paths, directories, programs, subprograms, subroutines, device names, functions, operations, variables, filenames, and extensions.

monospace Bold text in this font denotes the messages and responses
bold that the computer automatically prints to the screen. This font also emphasizes lines of code that are different from the other examples.

monospace Italic text in this font denotes text that is a placeholder for a *italic* word or value that you must supply.

Navigating Help (Windows Only)

To navigate this help file, use the **Contents**, **Index**, and **Search** tabs to the left of this window or use the following toolbar buttons located above the tabs:

- Hide—Hides the navigation pane from view.
- Locate—Locates the currently displayed topic in the Contents tab, allowing you to view related topics.
- **Back**—Displays the previously viewed topic.
- **Forward**—Displays the topic you viewed before clicking the **Back** button.
- **Options**—Displays a list of commands and viewing options for the help file.

Searching Help (Windows Only)

Use the **Search** tab to the left of this window to locate content in this help file. If you want to search for words in a certain order, such as "related documentation," add quotation marks around the search words as shown in the example. Searching for terms on the **Search** tab allows you to quickly locate specific information and information in topics that are not included on the **Contents** tab.

Wildcards

You also can search using asterisk (*) or question mark (?) wildcards. Use the asterisk wildcard to return topics that contain a certain string. For example, a search for "prog*" lists topics that contain the words "program," "programmatically," "progress," and so on.

Use the question mark wildcard as a substitute for a single character in a search term. For example, "?ext" lists topics that contain the words "next," "text," and so on.



Note Wildcard searching will not work on Simplified Chinese, Traditional Chinese, Japanese, and Korean systems.

Nested Expressions

Use nested expressions to combine searches to further refine a search. You can use Boolean expressions and wildcards in a nested expression. For example, "example AND (program OR VI)" lists topics that contain "example program" or "example VI." You cannot nest expressions more than five levels.

Boolean Expressions

Click the **•** button to add Boolean expressions to a search. The following Boolean operators are available:

- **AND** (default)—Returns topics that contain both search terms. You do not need to specify this operator unless you are using nested expressions.
- **OR**—Returns topics that contain either the first or second term.
- **NOT**—Returns topics that contain the first term without the second term.
- **NEAR**—Returns topics that contain both terms within eight words of each other.

Search Options

Use the following checkboxes on the **Search** tab to customize a search:

- Search previous results—Narrows the results from a search that returned too many topics. You must remove the checkmark from this checkbox to search all topics.
- Match similar words—Broadens a search to return topics that contain words similar to the search terms. For example, a search for "program" lists topics that include the words "programs," "programming," and so on.
- Search titles only—Searches only in the titles of topics.

Printing Help File Topics (Windows Only)

Complete the following steps to print an entire book from the **Contents** tab:

- 1. Right-click the book.
- 2. Select **Print** from the shortcut menu to display the **Print Topics** dialog box.
- 3. Select the **Print the selected heading and all subtopics** option.
 - Note Select Print the selected topic if you want to print the single topic you have selected in the **Contents** tab.
- 4. Click the **OK** button.

Printing PDF Documents

This help file may contain links to PDF documents. To print PDF documents, click the print button located on the Adobe Acrobat Viewer toolbar.

Fundamentals

This book contains information on the nomenclature and concepts related to NI power supplies and SMUs, explaining the specific terms used to describe device performance. This book is divided into the following topics:

- Accuracy
- <u>Compliance</u>
- <u>Constant Current Mode</u>
- <u>Constant Voltage Mode</u>
- <u>Cabling and Current-Resistance Loss</u>
- Line Regulation
- Load Considerations
- Load Regulation
- Local and Remote Sense
- <u>Measurements</u>
- Measuring Resistance
- <u>Noise</u>
- Ranges
- <u>Resolution</u>
- <u>Rise Time</u>
- Sinking and Sourcing

Accuracy

A measurement or output level on a power supply or SMU can differ from the actual or requested value. *Accuracy* represents the uncertainty of a given measurement or output level and can be defined in terms of the deviation from an ideal transfer function, as follows:

y = mx + b

where

m is the ideal gain of the system

x is the input to the system

b is the offset of the system

Applying this example to a power supply or SMU signal measurement, y is the reading obtained from the device with x as the input, and b is an offset error that you may be able to null before the measurement is performed. If m is 1 and b is 0, the output measurement is equal to the input. If m is 1.0001, then the error from the ideal is 0.01%.

Parts per million (ppm) is another common unit used to represent accuracy. The following table shows ppm to percent conversions.

ppm	Percent
1	0.0001
10	0.001
100	0.01
1,000	0.1
10,000	1

Most high-resolution, high-accuracy power supplies and SMUs describe accuracy as a combination of an offset error and a gain error. These two error terms are added to determine the total accuracy specification for a given measurement. NI power supplies and SMUs typically specify offset errors with absolute units (for example, mV or μ A), while gain errors are specified as a percentage of the reading or the requested value.

The following example illustrates how to calculate the accuracy of a 1 mA current measurement in the 2 mA range of an SMU with an accuracy specification of $0.03\% + 0.4 \mu$ A:

Accuracy = $(0.0003 \times 1 \text{ mA}) + 0.4 \mu\text{A} = 0.7 \mu\text{A}$

Therefore, the reading of 1 mA should be within ±0.7 μA of the actual current.



Note Temperature can have a significant impact on the accuracy of a power supply or SMU and is a common problem for precision measurements. The temperature coefficient, or **tempco**, expresses the error caused by temperature. Errors are calculated as $\pm(\% \text{ of reading + offset range})/^{\circ}C$ and are added to the accuracy specification when operating outside the power supply or SMU rated accuracy temperature range (usually 23±10°C or 23±5°C).

Compliance

For power supplies and SMUs, a channel is operating in compliance when it cannot reach the requested output level because the programmed limit has been reached.

The following two figures help to graphically describe compliance for a specific application: the output function is set to NIDCPOWER VAL DC VOLTAGE using the

<u>niDCPower_ConfigureOutputFunction</u> function or **DC Voltage** using the <u>niDCPower Configure Output Function</u> VI with a 1.5 mA current limit.



Because the 20 k Ω load resistance in the figure on the left never allows the output current to exceed the current limit of 1.5 mA (given a maximum requested voltage of 20 V), the source driving this load never enters compliance. This circuit always operates in Constant Voltage mode.

In contrast, the 10 k Ω load resistance in the figure on the right causes a higher current draw. The output voltage of the power supply or SMU operates in Constant Voltage mode up to 15 V. Above the 15 V requested output, the load draws 1.5 mA, thus the source operates in Constant Current mode at the current limit. While operating at the current limit, the channel is said to be in compliance. In this case, although the requested output voltage is > 15 V, the actual voltage does not exceed 15 V because the current limit has been reached.

You can query a channel to determine if it is in compliance using the <u>niDCPower Query in Compliance</u> VI or the <u>niDCPower_QueryInCompliance</u> function.

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Note The NI-DCPower <u>Soft Front Panel</u> displays Cmpl when a channel is in compliance.

Cabling and Current-Resistance Loss

Current-resistance loss is introduced by the cabling wires that connect the power supply or SMU to the load terminals. The voltage drop due to current-resistance loss is determined by the resistance of the cabling wire (a property of the wire gauge and length) and the amount of current flowing through the wire. Devices with <u>remote sense</u> capabilities can compensate for current-resistance loss by measuring the voltage across the load terminals with a second set of leads that do not carry a significant current.

To minimize voltage drop caused by cabling, keep each wire pair as short as possible and use the thickest wire gauge appropriate for your application. The lower the American Wire Gauge (AWG) rating, the thicker the wire. NI recommends 18 AWG or lower.

To reduce noise picked up by cabling connecting a power supply or SMU to a load, twist each wire pair. Refer to the following table to determine the wire gauge appropriate for your application.

Caution Use wire that is thick enough to avoid overheating if the output current from the power supply or SMU were to short circuit.

AWG Rating	mΩ/m (mΩ/ft)
10	3.3 (1.0)
12	5.2 (1.6)
14	8.3 (2.5)
16	13.2 (4.0)
18	21.0 (6.4)
20	33.5 (10.2)
22	52.8 (16.1)
24	84.3 (25.7)
26	133.9 (40.8)
28	212.9 (64.9)

Calculating Maximum Voltage Drop

When cabling a power supply or SMU to a constant load, be sure to account for voltage drop in your application. If necessary, adjust the output voltage of the device or, if available, use <u>remote sensing</u>.

Use the amount of current flowing through the cabling wires and the resistance of the wires to calculate the total voltage drop for each load, as shown in the following example:

Example

Operating within the recommended current rating, determine the maximum voltage drop across a 1 m, 16 AWG wire carrying 1 A:

 $V = I \times R$

 $V = 1 A \times (13.2 \text{ m}\Omega/\text{m} \times 1 \text{ m})$

V = 13.2 mV

As illustrated in the preceding example, a 1 m, 16 AWG wire carrying 1 A results in a voltage drop of 13.2 mV.

Note When calculating voltage drop for a pair of wires, multiply the voltage drop by two. Thus, the total voltage drop for a pair of wires in the previous example is 26.4 mV. To compensate for the voltage drop across the wire pair and ensure the correct power is supplied to the load, increase the output voltage of the power supply by 26.4 mV, or if available, use remote sensing.

Cabling for Low-Level Measurements

Low-level measurements require tight control over system setup and cabling. Long cables and large current loops degrade source and measurement quality even in low-noise environments.

To maintain measurement quality, always limit the length of the cables involved in your system setup. Also, keep the current return path as close as possible to the current source path by employing twisted pair cabling.

To reduce the susceptibility of low currents to noise and other unwanted interfering signals, use shielded cables (for example, coaxial cable). Connect the outer conductor to the common or ground terminal of the channel.

Related Topics

Local and Remote Sense

Constant Current Mode

An output channel is operating in Constant Current mode when either a load attempts to draw more current than the programmed limit and the output function is set to NIDCPOWER_VAL_DC_VOLTAGE using the niDCPower_ConfigureOutputFunction function or **DC Voltage** using the niDCPower Configure Output Function VI, or when the voltage across the load is less than the voltage limit and the output function is set to NIDCPOWER_VAL_DC_CURRENT using the niDCPower_ConfigureOutputFunction function or **DC Current** using the niDCPower_Configure Output Function VI.

In Constant Current mode, the current flowing through the output terminals is held constant while the voltage across the output terminals may change depending on loading conditions. The output channel behaves like a current source when in this mode.



Note Constant Current mode is synonymous with Current-Controlled mode.

To determine when an output channel is operating in Constant Current mode, use the status indicators on the front panel of the device, the <u>niDCPower Query Output State</u> VI, or the <u>niDCPower_QueryOutputState</u> function.

Related Topics

Constant Voltage Mode Load Considerations Load Regulation

Constant Voltage Mode

An output channel is operating in Constant Voltage mode when either a load attempts to draw less current than the current limit and the output function is set to NIDCPOWER_VAL_DC_VOLTAGE using the niDCPower_ConfigureOutputFunction function or **DC Voltage** using the niDCPower Configure Output Function VI, or when the voltage across the load is greater than the voltage limit and the output function is set to NIDCPOWER_VAL_DC_CURRENT using the niDCPower_ConfigureOutputFunction function or **DC Current** using the niDCPower_ConfigureOutputFunction VI.

In Constant Voltage mode, the voltage across the output terminals is held constant while the current through the output terminals may change depending on loading conditions. The output channel behaves like a voltage source when in this mode.



Note Constant Voltage mode is synonymous with Voltage-Controlled mode.

To determine when an output channel is operating in Constant Voltage, use the status indicators on the front panel of the device, the <u>niDCPower Query Output State</u> VI, or the <u>niDCPower_QueryOutputState</u> function.

Related Topics

Constant Current Mode Load Considerations Load Regulation

Line Regulation

Line regulation is a measure of the ability of the power supply or SMU to maintain the output voltage given changes in the input line voltage. Line regulation is expressed as percent of change in the output voltage relative to the change in the input line voltage.

For NI DC power supplies and SMUs, the line regulation specification applies to the auxiliary power input.

Load Considerations

This topic contains information you may find useful as you connect specific types of loads to a power supply or SMU.

Capacitive Loads

Generally, a power supply or SMU remains stable when driving a capacitive load. Occasionally, certain capacitive loads can cause ringing in the transient response of the device. When the output voltage is reprogrammed while capacitive loads are present, the device may temporarily move into Constant Current mode or unregulated mode.

The *slew rate* is the maximum rate of change of the output voltage as a function of time. When driving a capacitor, the slew rate is limited to the output current limit divided by the total load capacitance, as expressed in the following equation:

 $(\Delta V / \Delta t) = (I / C)$

where ΔV is the change in the output voltage

 Δt is the change in time

I is the current limit

C is the total capacitance across the load

Series resistance or lead inductance from cabling can affect the stability of the device. In some situations, it might be necessary to increase the capacitive load or locally bypass the circuit or system being powered to stabilize the power supply or SMU.

Inductive Loads

In Constant Voltage mode, most inductive loads remain stable. However,when operating in Constant Current mode in higher current ranges, increasing output capacitance may help improve stability. You can select the output capacitance of some power supplies or SMUs using the <u>niDCPower Output Capacitance</u> property or the <u>NIDCPOWER_ATTR_OUTPUT_CAPACITANCE</u> attribute.

Pulse Loads

Load current can vary between a minimum and a maximum value in some applications. In the case of a varying load, or pulse load, the constant current circuit of the power supply or SMU limits the output current. Occasionally, a peak current may try to exceed the current limit and cause the power supply or SMU to temporarily move into Constant Current mode or unregulated mode.

To avoid pulse loads and remain within the power supply or SMU output specifications, use the <u>niDCPower Configure Current Limit</u> VI or the <u>niDCPower ConfigureCurrentLimit</u> function to configure the current limit to a value greater than the expected peak current of the load. In extreme situations, it may be possible to parallel connect multiple power supply channels to provide higher peak currents. SMU output channels should not be placed in parallel because SMUs are four quadrant devices, and some combination of <u>sourcing and sinking</u> occurs if the output voltages of the channels are not exactly identical.

Reverse Current Loads

Occasionally, an active load may pass a reverse current to the power supply or SMU. To avoid reverse current loads, use a bleed-off load to preload the output of the device. Ideally, a bleed-off load should draw the same amount of current from the device that an active load may pass to the power supply or SMU.



Caution Power supplies not designed for <u>4-quadrant</u> operation may become damaged if reverse currents are applied to their output terminals. Reverse currents can cause the device to move into an unregulated mode and can damage the device. Refer to <u>NI</u> <u>PXI-4110</u> or <u>NI PXI-4130</u> for more information about device channel capabilities.



Note The sum of the bleed-off load current and the current supplied to the load must be less than the maximum current of the device.

Related Topics

Constant Current Mode Constant Voltage Mode Load Regulation

Load Regulation

Load regulation is a measure of the ability of an output channel to remain constant given changes in the load. Depending on the control mode enabled on the output channel, the load regulation specification can be expressed in one of two ways:

- In Constant Voltage mode, variations in the load result in changes in the output current. This variation is expressed as a percentage of output voltage range per amp of current change, and is synonymous with a series resistance. When using <u>local sense</u> in Constant Voltage mode, the load regulation specification defines how close the output series resistance is to 0 Ω —the series resistance of an ideal voltage source.
- In Constant Current mode, variations in the load result in changes to the voltage across the load. This variation is expressed as a percentage of change in the output current range, in amps per volt, and is synonymous with a resistance in parallel with the output channel terminals. In Constant Current mode, the load regulation specification defines how close the output shunt resistance is to infinity—the parallel resistance of an ideal current source. In fact, when load regulation is specified in Constant Current mode, parallel resistance is expressed as 1/load regulation.
Related Topics

Constant Current Mode Constant Voltage Mode

Local and Remote Sense

A measurement made with *local sense* uses a single set of leads for output and voltage measurement, as illustrated in the following figure:



An error in the DUT voltage measurement is due to the output current and the resistance of the leads used to connect the power supply or SMU to the load. This error can be calculated using the following equation:

Local Sense Error (Volts) = $I_{out}(R_{lead1} + R_{lead2})$

When the device is operating in Constant Voltage mode, local sense forces the requested voltage at the output terminals of the device. The actual voltage at the DUT terminals is lower than the requested output because of the output lead resistance error.

Measurements made using *remote sense*, sometimes referred to as *4-wire sense*, require 4-wire connections to the DUT (and 4-wire switches if a switching system is used to expand the channel count). Using remote sense offers the benefit of more accurate voltage output and measurements when the output lead voltage drop is significant. In a remote sense configuration, one set of leads carries the output current, while another set of leads is used to measure voltage directly at the DUT terminals, as illustrated in the following figure:



Although the current flowing in the output leads can be several amps or more depending on the power supply or SMU, a very small amount of current flows through the sense leads resulting in a much smaller voltage drop error for measurements versus the local sense error. When using remote sense in the DC Voltage <u>output function</u>, the output voltage is forced at the end of the sense leads instead of the output terminals. When using remote sense in the DC Current <u>output function</u>, the voltage limit is measured at the end of the sense leads instead of at the output terminals. Using remote sense results in a voltage at the DUT terminals that is more accurate than what can be achieved using local sense. Ideally, the sense leads should be connected as close to the DUT terminals as possible.

When using remote sense, it is important to remember that the magnitude of the voltage drop across the higher current output leads is usually limited to one or two volts per lead, depending on the power supply or SMU. When attempting to force a voltage using the DC Voltage output function, dropping more voltage across the output leads than the specified maximum in remote sense mode may result in a voltage at the load that is less than the requested level. When attempting to force a current using the DC Current output function while using either local or remote sense, excessive line drop may force the power supply or SMU into Constant Voltage mode before the requested current level can be reached.

Configuring a channel for remote sense operation without connecting the sense leads to the DUT can result in measurements that do not meet the published specifications. If a channel is configured for remote sense and the remote sense leads are left open, the channel may source a voltage as large as 20% higher than the voltage level or voltage limit.

Refer to your <u>device specifications</u> document for more information about remote sense support and the maximum output lead voltage drop allowed.

Remote sense can be enabled or disabled using the <u>niDCPower</u> <u>Configure Sense</u> VI, or the <u>niDCPower_ConfigureSense</u> function on a per output basis for channels that support this feature.

Devices with Remote Sense Capabilities		
Device	Channel(s)	
NI PXI-4130	1	

Related Topics

Cabling and Current-Resistance Loss

Measuring Resistance

Power supplies and SMUs are capable of making resistance measurements because they can both generate and measure test voltages and currents. Because they can operate as precision current sources up to 2 A, these modules are well suited to measure low resistance values.

To measure a resistance with an NI power supply or SMU, select a test current that creates a voltage drop within module capabilities. After the channel output is enabled and settled, use the <u>Measure Multiple</u> VI to measure the actual current being delivered to the resistor as well as the measured voltage across the resistor. To determine the accuracy a resistance measurement, the accuracy specifications of both current and voltage measurements for the power supply or SMU should be taken into account. For channels with remote sense capabilities, enabling this feature results in a more accurate voltage measurement at the resistor terminals.

Compensation for Offset Voltages

When measuring low-value resistances thermal voltages may introduce significant offsets into the resistance measurement path. If an offset voltage exists in series with the resistance to be measured as in the following figure, taking a second measurement at a different current output setpoint allows the offset to be accounted for in the resistance calculation.

The two test currents, I_1 and I_2 , create voltage drops of V_1 and V_2 respectively. Thus, the following two equations can be derived:

$$V_1 = I_1 R + V_{OS}$$
$$V_2 = I_2 R + V_{OS}$$

Rearranging these two equations allows for the calculation of the unknown resistance *R* without measuring V_{OS} . Assuming the currents I_1 and I_2 are different the following equation can be derived:

$$R = \frac{V_2 - V_1}{I_2 - I_1}$$

For the best signal-to-noise performance, test currents of opposite polarity should be used (for example, + 100 mA and 100 mA). If currents of opposite polarity are not feasible, the next best solution is to use test currents that are 100x apart (that is, if your first current is 1 A, you should choose a second test current of 0.01 mA).

Resistor Self-Heating

As power dissipation in a resistor increases, the temperature of the resistor increases and causes a change in the resistance value. You can calculate how much error is introduced in your measurement by resistor self-heating from the derating curve of Rated Power(%) vs. Ambient Temperature commonly given in resistor specifications.

The specifications of resistors include a derating curve, similar to the one shown in the following graph. Notice that this curve does not show the temperature change of the resistor due to self-heating. The curve shows the percentage of the rated power that you can apply to a resistor vs. the ambient temperature. So at 70 °C of ambient temperature, you can apply up to 100% of the rated power, but at 100 °C you can only apply up to 65% of the rated power.



At any temperature, the resistor will have a temperature change due to self-heating (ΔT_{SH}), so the actual temperature of the resistor is the ambient temperature plus an unknown ΔT_{SH} . Even though this graph does not directly show the value of ΔT_{SH} , you can still calculate it.

Notice that at 70 °C, applying 100% of the rated power, the temperature of the resistor is equal to 70 °C plus ΔT_{SH} . At 150 °C, you cannot apply any power to the resistor, so the temperature of the resistor is equal to the ambient temperature. You can thus infer that when applying 100% of the rated power at 70 °C the total temperature of the resistor is 150 °C. Therefore, above 70 °C, the value of ΔT_{SH} increases in such a way that when you add to it the ambient temperature it surpasses 150 °C. Therefore, you need to limit the power you apply to the resistor to keep the total temperature of the part under 150 °C. Hence, the value of ΔT_{SH} is a function of the power applied to the part.

The thermal resistance (θ) is equal to the absolute value of the slope between the 70 °C and the 150 °C points in the derating curve shown above.

$$\theta = (150 \text{ °C}-70 \text{ °C})/\Delta P = (150 \text{ °C}-70 \text{ °C})/P_{max} \circ C/W$$

If the resistor has a Rated Power at 70 $^\circ\text{C}$ equal to 0.25 W, then the value for θ would be equal to:

 θ = (150 °C—70 °C)/ Δ P = (150 °C—70 °C)/250 mW = 80 °C/(250*10⁻ ³ W) = 320 °C/W = 0.32 °C/mW

To decrease the thermal resistance, you must look for a resistor with higher rated power, or find a way to "heat sink" the resistor to the environment. This can become complicated and expensive unless the resistor is specifically designed for heat sinking.

You can now calculate the change in temperature due to power dissipation using the thermal resistance (θ) and the power being dissipated in the resistor (product of voltage and current). Then you can use the temperature coefficient of the resistor (usually given in ppm/ °C) to calculate the change in the resistance value.

Resistor self-heating is more relevant when measuring currents above 400 mA. The self-heating of the current shunts in the largest current ranges for the NI PXI-4110/4130 cause an additional derating on those modules in these current ranges. For more information about additional derating in these ranges, refer to your <u>device specifications</u> document. To minimize the self-heating effect of current shunts for the largest current ranges in these devices, measurements should be made as soon as possible after enabling the output, before the shunt has had the opportunity to heat itself.

Related Topics

Rise Time

Noise

Noise—unwanted signals present on the output channels—can affect devices connected to the output channels.

Noise can be characterized as normal-mode or common-mode noise. Regardless of its characterization, noise is meaningful only when it is specified with an associated bandwidth.

Normal-Mode Noise

Normal-mode noise is present between the output HI terminal and the output common LO terminal, appearing either in series (Constant Voltage mode) or parallel (Constant Current mode) with the output of the device. Normal-mode noise can be expressed as voltage noise or current noise, depending on the control mode of the output channel.

AC to DC rectification causes *ripple*, a type of periodic normal-mode noise.

Common-Mode Noise

Common-mode noise is present between the output common LO terminal and the chassis or earth ground. In this sense, the equivalent circuit is a current noise source connected across these two terminals. When you connect an impedance between the output common/ground and chassis or earth ground, a noise current can flow in the impedance, resulting in an unexpected offset or other undesirable error.

Output Capacitance Considerations

To help reduce noise and ripple when the device is operating in a highcurrent range, NI recommends setting the <u>niDCPower Output</u> <u>Capacitance</u> property or the

<u>NIDCPOWER ATTR OUTPUT CAPACITANCE</u> attribute to HIGH for devices that support this feature. Remember that a larger capacitance results in a slower output response. Refer to <u>Load Considerations</u> for more information about capacitive loads.



Note The only valid output capacitance setting on all channels for the NI PXI-4110 is HIGH. For more information about reducing noise in high-current ranges with the NI PXI-4130, refer to <u>Output</u> <u>Capacitance Selection</u>.

Measurement Noise Rejection

In many environments, line noise (for example, 50 Hz or 60 Hz) or other unwanted periodic signals may be present in a system and can degrade measurement quality. You can program your device to reject periodic signals and their harmonics by configuring the <u>niDCPower Samples to</u> <u>Average</u> property or the <u>NIDCPOWER ATTR SAMPLES TO AVERAGE</u> attribute according to the following table.

Number of Samples to Average	Frequencies Rejected for 3 kHz Sample Rate
1	3 kHz
50	60 Hz
60	50 Hz
300	50 Hz and 60 Hz

For frequencies not listed in this table, use the following formula:

 $N = 3000/F_{r}$

where *N* is the number of samples to average and F_r is the frequency rejected.



Note To improve noise reduction while keeping frequency rejection, set the number of samples to average to *N*, 2*N*, 3*N*, and so on. The maximum allowed samples to average is 511.

Related Topics

Constant Current Mode Constant Voltage Mode Load Considerations Considerations When Measuring Noise

Considerations When Measuring Noise

Exercise care when measuring noise on an output device, such as a power supply or SMU. When verifying the specified wideband noise of a device, the effects of ground loops, unnecessarily long probe ground leads, and electrically noisy environments can combine and skew your measurements.

Observe the following recommendations when measuring the noise of a power supply or SMU:

- Connect the probe directly to the terminals of the power supply or SMU. Do *not* use long leads, loose wires, or unshielded cables.
- Limit the probe ground lead to a few inches at most. Connect this lead directly to the output common/ground terminal of the appropriate channel.
- Limit the bandwidth of the measurement device to the bandwidth of interest. For example, making a 20 MHz noise measurement with a 200 MHz bandwidth instrument, may not yield the specified values.
- To avoid measuring the environment noise instead of the device noise, exercise caution when making measurements in a modern laboratory environment with computers, electronic ballasts, switching power supplies, and so on.

Related Topic

<u>Noise</u>

Ranges

NI power supplies and SMUs use one or more ranges for voltage and current output, as well as one or more ranges for voltage and current measurement. Use the highest resolution (smallest) range possible for a particular application to get maximum output and measurement accuracy. Refer to the <u>specifications document</u> for your device or <u>NI PXI-4110</u> or <u>NI PXI-4130</u> for more information about what ranges are available for a particular channel on your device.

Ranges are typically described as the maximum possible value from zero that the range can output or measure (not including the overrange). For example, in the 20 mA current level range, the current level can be configured up to 20 mA.

When configuring an output range, if you request a range that differs from the ranges described in your <u>device specifications</u>, NI-DCPower selects the highest resolution (smallest) range available that accommodates the requested range. For example, on a device with only 20 mA and 200 mA current limit ranges, if you request 100 mA for the current range, NI-DCPower selects the 200 mA range.

There are four configurable output ranges for each device channel : voltage level range, current limit range, current level range, voltage limit range. When the output function is set to

NIDCPOWER_VAL_DC_VOLTAGE using the

<u>niDCPower_ConfigureOutputFunction</u> function or **DC Voltage** using the <u>niDCPower Configure Output Function</u> VI, the voltage level range and current limit range are in use. When the output function is set to NIDCPOWER_VAL_DC_CURRENT using the

niDCPower_ConfigureOutputFunction function or **DC Current** using the niDCPower Configure Output Function VI, the current level range and voltage limit range are in use.

Changing Ranges

You can use the following four VIs and functions to configure output ranges for your device.

VI Name	Function Name
niDCPower Configure Voltage Level Range	niDCPower_ConfigureVoltageLevelRange
niDCPower Configure Current Limit Range	niDCPower_ConfigureCurrentLimitRange
niDCPower Configure Voltage Limit Range	niDCPower_ConfigureVoltageLimitRange
niDCPower Configure Current Level Range	niDCPower_ConfigureCurrentLevelRange

The configured range must be able to accommodate the configured output value. For example, if the current limit range is 1 A and the current limit is 50 mA, changing the current limit range to 20 mA is not allowed because 50 mA is not possible in the new range. When changing ranges in <u>immediate configuration mode</u> be aware of the order of the output range and output value changes because the configuration change takes effect immediately in this mode. To avoid ordering issues, NI recommends that you configure the output range and output value in <u>delayed configuration mode</u>. In this mode you can configure the output range and the output value in any order. Alternatively, you can enable autoranging for the range you want to change.

Overranging

If the <u>niDCPower Overranging Enabled</u> property or the <u>NIDCPOWER_ATTR_OVERRANGING_ENABLED</u> attribute is set to TRUE, the valid values for the programmed output (voltage level, current limit, current level, and voltage limit) may be extended beyond their normal operating range on channels that support this feature. Enabling overranging for a particular device enables this feature for both output current and voltage on all channels. Refer to <u>NI PXI-4110</u> or <u>NI PXI-4130</u> to determine if your device supports overranging.

Output Autoranging

When autoranging is enabled for an output range, NI-DCPower automatically changes the output range based on the configuration output value. NI-DCPower automatically changes to the highest resolution (smallest) range that can accommodate the configured output value. You can selectively enable autoranging for any output range on a channel.

Use the following properties and attributes to configure your device for autoranging.

Attributes	Properties
NIDCPOWER_ATTR_VOLTAGE_LEVEL_AUTORANGE	<u>niDCPower</u> <u>Voltage Level</u> Autorange
NIDCPOWER_ATTR_CURRENT_LIMIT_AUTORANGE	<u>niDCPower</u> <u>Current Limit</u> Autorange
NIDCPOWER_ATTR_CURRENT_LEVEL_AUTORANGE	<u>niDCPower</u> <u>Current Level</u> Autorange
NIDCPOWER_ATTR_VOLTAGE_LIMIT_AUTORANGE	<u>niDCPower</u> Voltage Limit Autorange

Related Topics

NI PXI-4130 Range Considerations

Resolution

Resolution is applicable to both output and measurement circuits of power supplies and SMUs.

For power supplies and SMUs, output and measurement resolution are usually specified in absolute units, like μV or nA.

Output Resolution

Resolution of a power supply or SMU output channel is the smallest possible change that can be made to the output voltage or current level. This limitation is imposed because of the finite number of steps that are available in the device DAC circuit.

Output resolution can be calculated by dividing the total span of the output range by the number of possible quantized values the DAC allows.

For example, consider a ± 6 V output range when using a 16-bit DAC:

Resolution = (+6 V (6 V)) / $(2^{16}1) = 12 V / 65535 = 183 \mu V$

Measurement Resolution

Measurement resolution of a power supply or SMU is the smallest change in the voltage or current measurement that can be detected by hardware. The resolution for a particular channel is based on the resolution of the ADC used to digitize the measured signal. When taking a measurement of the output, the ideal ADC coerces the actual value to the nearest ADC code. The codes are equally spaced across the measurement range of the ADC, each separated from the previous and next code by the magnitude of the power supply or SMU resolution.

For example, consider a \pm 200 μA measurement range when using an 18-bit ADC:

Resolution = (+200 μ A - (-200 μ A)) / (2¹⁸-1) = 400 μ A / 262143 = 1.5 nA

Sensitivity

Sensitivity is the smallest unit of a given parameter that can be meaningfully detected with an instrument under specified conditions. This unit is generally equal to the resolution in the smallest range of a power supply or SMU.

Rise Time

Rise time specifies the time duration for the output to transition from 10% to 90% of the programmed voltage at the maximum current. Use the following equation to calculate the rise time for a single-pole system.

Rise Time = $2.2 \times \text{time constant}$

Bandwidth

Using the rise time, you can calculate the bandwidth using the following equation.

Bandwidth = 0.35 / Rise Time

Settling Time

Settling time specifies the time required for an output channel to reach a stable mode of operation. You can calculate the settling time to any maximum level of error desired for a single-pole system using the time constant and the following rule:

Settling Time = (*decades* × 2.3 × time constant)

where *decades* is decades of settling as determined by the desired maximum error (settling to 1% error = 2 decades, 0.1% = 3 decades, and so on). For example, calculating the settling to 1% error, settling time is (2 × 2.3 × time constant); calculating the settling time to 0.1% error, settling time is (3 × 2.3 × time constant).

If the maximum error desired falls on an uneven number of decades, use the following equation to calculate settling time:

```
Settling Time = -Ln(maximum error desired) × time constant
```

where Ln is the natural logarithm.

For example, calculating the settling to 0.05% error, settling time is (- $Ln(0.0005) \times time constant$), or (7.6 × time constant).

Settling time can be added by placing a delay between the function used to set an output and the function used to measure the output. In LabVIEW, the Wait(ms), Wait Until Next ms Multiple, or Time Delay functions can be used to add additional delay time. Refer to the *LabVIEW Help* for more information about these VIs.

Sourcing and Sinking

The terms *sourcing* and *sinking* describe power flow into and out of a device. Devices that are sourcing power are delivering power into a load, while devices that are sinking power behave like a load, absorbing power that is being driven into them and providing a return path for current.

A battery is one example of a device that is capable of both sourcing and sinking power. During the charging process the battery acts as a power sink by drawing current from the charging circuit. After it has been removed from the charger and installed into an electronic device, the battery begins to act as a source that delivers power to a load.

The following quadrant diagram graphically represents whether a particular channel is sourcing or sinking power. Quadrants consist of the various combinations of positive and negative currents and voltages. Quadrants I and III represent sourcing power, while quadrants II and IV represent sinking power.



For example, when you have a positive voltage and current flowing out of the positive terminal (that is, a positive current), the output operation falls within Quadrant I and is sourcing power. When you have a positive voltage and a current flowing into the positive terminal (that is, a negative current), the output operation falls within Quadrant II, and is sinking power.

A single-quadrant channel on a power supply can operate only in one quadrant. For example, while the <u>NI PXI-4110</u> has multiple channels capable of sourcing power in either Quadrant I or Quadrant III, individually, each channel on the NI PXI-4110 can operate only within one quadrant (channels 0 and 1 operate only within Quadrant I, and channel

2 operates only within Quadrant III). Thus, all channels on the NI PXI-4110 are single-quadrant supplies.

Devices that are capable of sourcing power in both Quadrant I and III are sometimes referred to as *bipolar* because they can generate both positive and negative voltages and currents. Bipolar output channels may or may not have current sinking capabilities (Quadrants II and IV).

An output channel on a *four-quadrant power supply or SMU* can both source and sink power with a positive or negative voltage and current. For example, the <u>NI PXI-4130</u> SMU channel (channel 1) is capable of both sourcing power in Quadrant I or Quadrant III and sinking power in Quadrant II or Quadrant II or Quadrant III or Quadrant IV. Thus, the NI PXI-4130 SMU channel is a bipolar, four-quadrant device. For NI four-quadrant devices, it is important to remember that an auxiliary power supply is required for both sourcing and sinking power to reach the full current capability of the device. For more information about auxiliary power, refer to the *Internal and Auxiliary Power* topic for your device.

Because of the required power dissipation, sourcing and sinking capabilities for a channel are not always identical. Refer to <u>NI PXI-4110</u> or <u>NI PXI-4130</u> for more information about the sourcing and sinking capabilities of your device.

The following table summarizes the power capabilities per channel for each NI power supply and SMU device.

Dovico Namo	Name Channel	Quadrant			
Device Maine		I	II	- 111	IV
NI PXI-4110	0	6 W			
	1	20 W			
	2			20 W	
NI PXI-4130	0	6 W			
	1	40 W	10 W*	40 W	10 W*
*These values are valid only up to an ambient temperature of 30°C.					

Devices

Expand this book for NI power supply and SMU device-specific information.

NI PXI-4110

The NI PXI-4110 has three <u>single-quadrant</u> DC power supply channels. The following table lists the DC voltage ranges supported by each channel.

Channel	Range	
	Output	Measurement
0	+6 V	+6 V
1	+20 V	+20 V
2	-20 V	-20 V

These channels support 5% <u>overranging</u> when overranging is enabled.

The following table lists DC current ranges supported by the NI PXI-4110.

Channel	Range	
Channel	Output	Measurement
0	1 A	1 A
1 and 2	20 mA	20 mA
	1 A*	1 A*
*Mithout auxiliary power, the maximum current in the 1A range is 100		

*Without auxiliary power, the maximum current in the 1A range is 100 mA.

These channels support 5% overranging when this overranging is enabled.

The following diagrams illustrate the output voltage and current capabilities of each channel on the NI PXI-4110:



Note Channel 2 on the NI PXI-4110 is a single-quadrant power supply and always operates within Quadrant III. However, the polarity of the measured voltage is negative (measured using the <u>niDCPower Measure</u> VI or the <u>niDCPower Measure Multiple</u> VI) and the polarity of the measured current is positive. The difference in polarities is due to the positive current direction on channel 2 being defined as current flowing into the common floating GND.

For more information about the NI PXI-4110 specifications, refer to <u>Related Documentation</u>.

NI PXI-4110 Front Panel

The following figure illustrates the NI PXI-4110 front panel.



	Item	Description
А	Output Connector, Terminal 0	Channel 0 (0 to +6 V)
В	Output Connector, Terminal 1	GND
С	Output Connector, Terminal 2	Channel 1 (0 to +20 V)
D	Output Connector, Terminal 3	Common Floating GND
		İ

E	Output Connector, Terminal 4	Common Floating GND
F	Output Connector, Terminal 5	Channel 2 (0 to -20 V)
G	Auxiliary Power Input Connector, Terminal 0	Auxiliary Power Input (+11 V to +15.5 V)
Н	Auxiliary Power Input Connector, Terminal 1	GND
I	Auxiliary Power Input Fuse Holder	—
J	Auxiliary Power Input Status Indicator	LED
Κ	Channel 2 Output Status Indicator	LED
L	Channel 1 Output Status Indicator	LED
Μ	Channel 0 Output Status Indicator	LED
Status Indicators

Status indicators on the front panel of the NI PXI-4110 provide feedback about device operation.

Use the following table to determine the state of an output channel using a status indicator.

Status Indicator	Channel Output State
(Off)	Disabled
Green	Enabled (<u>Constant Voltage mode</u>)
Amber	Enabled (<u>Constant Current mode</u>)
Red	Disabled because of error, such as an overtemperature condition

Use the following table to determine the state of the auxiliary power input using the status indicator.

Status Indicator	Auxiliary Power Input State
(Off)	Auxiliary power input disconnected or out of range
Green*	Auxiliary power input connected and within range
*Does not indicate that the auxiliary power is in use. To determine if the NI PXI-4110 is using auxiliary power, use the <u>niDCPower Power Source</u> In Use property or the <u>NIDCPOWER_ATTR_POWER_SOURCE_IN_USE</u> attribute.	

Operating the Device

Expand this book for information about using the NI PXI-4110.

Internal and Auxiliary Power

When drawing internal power from the PXI backplane, channels 1 and 2 of the NI PXI-4110 are fully operational at a lower output current(≤ 100 mA) and do not require an auxiliary power source.

If your application requires additional current, you can connect an auxiliary DC power supply capable of providing 11 V to 15.5 V and \geq 60 W to increase the output current capability of these channels to 1 A. NI offers the APS-4100, an auxiliary power source for NI DC power supplies. Visit ni.com for more information.



Note Channel 0 has the same output capabilities under internal power as auxiliary power.

Using Auxiliary Power

Complete the following steps to connect and use auxiliary power:

- 1. Connect a 11 V to 15.5 V, ≥60 W power source to the auxiliary power input connector on the NI PXI-4110 front panel.
- 2. Open a new session to the device. NI-DCPower automatically uses the auxiliary power source when available. To override this feature, use the <u>niDCPower Power Source</u> property or the <u>NIDCPOWER_ATTR_POWER_SOURCE</u> attribute.
 - **Tip** Use the <u>niDCPower Power Source In Use</u> property or the <u>NIDCPOWER_ATTR_POWER_SOURCE_IN_USE</u> attribute to programmatically determine which power source is in use.

Resuming Operation After a Shutdown

In case of auxiliary power loss during operation, the isolated outputs (channels 1 and 2) are disabled, and the power supply is shut down to prevent damage to the NI PXI-4110 and the load. If a shutdown occurs, complete the following steps to resume operation:

- 1. <u>Troubleshoot</u> the failure.
- 2. Restore auxiliary power.
- 3. Reset the power supply using the <u>niDCPower Reset</u> VI or the <u>niDCPower_reset</u> function.
- 4. Reconfigure the power supply.

Changing/Removing Auxiliary Power

Complete the following steps to change or remove auxiliary power from the NI PXI-4110:



Tip It is often more convenient to close the existing session and open a new session to the device when managing auxiliary power state changes.

- 1. Disable the output channels.
- 2. Disconnect/connect the auxiliary power source.
- 3. Reset the power supply using the <u>niDCPower Reset</u> VI or the <u>niDCPower_reset</u> function.
- 4. Reconfigure the power supply.

Cascading Outputs



Caution Do *not* exceed 60 VDC from any terminal to ground when cascading power supplies.

Because channels 1 and 2 on the NI PXI-4110 are isolated outputs, you can cascade multiple channels in series to generate greater output voltage. For safety reasons, all the terminals must be <60 VDC from ground. Any terminal on the isolated channels can be connected to ground. When you cascade channels in series, the NI PXI-4110 can generate up to 46 V at 1 A, as illustrated in the following figures:



Note The NI APS-4100 is required for current above 100 mA.

Caution The NI PXI-4110 does *not* provide isolation when using CH 0.



Similarly, you can use the NI PXI-4110 to cascade multiple channels in parallel to generate greater output current. NI recommends cascading no more than two output channels in parallel. Cascade channels 0 and 1 in parallel to generate up to 2 A at 6 V, as shown in the following figure:



Note The NI APS-4100 is required for current above 1.1 A in this cascaded configuration.





Note When cascading multiple channels in parallel, verify that all the channels you are cascading are set to output the same voltage level or voltage limit.

For more information about cascading the outputs of the NI PXI-4110, refer to the NI Developer Zone document, *Cascading the Outputs of a DC Power Supply to Extend Voltage and Current Ranges* at <u>ni.com/zone</u>.

Measurement Averaging

The NI PXI-4110 averages measurement samples to reduce noise and improve sensitivity. You can set the number of samples to average programmatically using the <u>niDCPower Samples To Average</u> property or the <u>NIDCPOWER ATTR SAMPLES TO AVERAGE</u> attribute.

Note When you set the niDCPower Samples To Average property or the NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE attribute, the output channel measurements may move out of synchronization. Refer to the <u>niDCPower Reset Average Before Measurement</u> property or the <u>NIDCPOWER ATTR RESET AVERAGE BEFORE MEASUREMENT</u>

attribute for more information about measurement averaging and synchronization.

Determining Measurement Rate

Although the measurement speed of the NI PXI-4110 is 3 kS/s for all voltage and current measurements, the measurement rate of the NI PXI-4110 can vary depending on the setting of the niDCPower Samples To Average property or the NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE attribute.

The default value of the niDCPower Samples To Average property and the NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE attribute is 10. As expressed in the following equation, the NI PXI-4110 returns 300 measurements per second using the default value.

 $\frac{3000 \text{ samples}}{\text{second}} \times \frac{1 \text{ measurement}}{10 \text{ samples}} = \frac{300 \text{ measurements}}{\text{second}}$

If no measurement averaging is used(Samples To Average = 1), the NI PXI-4110 returns 3,000 measurements per second.

While measuring without averaging yields the fastest measurement rate, noise from the environment (for example, the 50 Hz or 60 Hz noise introduced by cabling) increases measurement uncertainty.

Adjust the niDCPower Samples To Average property or the NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE attribute as necessary to optimize the noise performance and measurement rate for your application.



Note Measurement rate refers only to the hardware measurement rate and does not include software latency.

Rejecting Noise

If you know the noise frequency, you can reject it from the signal. To determine the number of measurements necessary to reject noise from a signal, divide the measurement speed of the NI PXI-4110 by a full wavelength cycle of noise.

Example 1

To reject 60 Hz noise frequency from a signal, average 50 measurements (3 kHz/60 Hz = 50).

Example 2

To reject 50 Hz noise frequency from a signal, average 60 measurements (3 kHz/50 Hz = 60).



Tip Set the niDCPower Samples To Average property or the NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE attribute to 300, an even multiple of both 60 kHz and 50 kHz, to actively reject both noise frequencies.

Protection

The output channels and the auxiliary power input of the NI PXI-4110 are protected against overcurrent, overvoltage, inverse voltage, and overtemperature conditions.

Output Channel Protection

All output channels on the NI PXI-4110 are current-limited and fused. In the event of an overcurrent, overvoltage, or inverse voltage condition, an output channel fuse may blow to protect the NI PXI-4110 and the load. When its fuse is blown, an output channel can source only a few milliamperes of current regardless of the programmed current limit.



Caution Each output channel of the NI PXI-4110 can withstand the application of an external voltage up to 10 V beyond the rated output level. Applying an external voltage greater than 10 V beyond the rated output level can damage the output channel.

In the event of an overtemperature condition (that is, the enclosure or component temperatures exceed safe operating limits), the thermal shutdown circuits on the NI PXI-4110 disable the output channel that indicated the failure condition. When disabled, an output channel can only be reset programmatically after the failure condition is cleared.

Auxiliary Input Protection

The auxiliary power input of the NI PXI-4110 can accept voltages from 11 V to 15.5 V. Applying a voltage below 11 V or above 15.5 V disables the auxiliary power input.

In the event of an overvoltage condition (that is, applying voltages >20 V to the auxiliary power input), *crowbar protection* is enabled. Crowbar protection shunts the auxiliary power input to ground.

In the event of an overcurrent (>6.3 A) or an inverse voltage condition, the auxiliary power input fuse may blow to protect the NI PXI-4110 and the load. You can use the <u>niDCPower Auxiliary Power Source Available</u> property or the

NIDCPOWER_ATTR_AUXILIARY_POWER_SOURCE_AVAILABLE attribute to troubleshoot the auxiliary power input fuse.

Related Topics

Replacing a Fuse Troubleshooting

Range Considerations

It is not possible to change the measurement range of the NI PXI-4110 independently of the output range. The measurement range is implicitly selected based on the configured output range. The selected measurement range is large enough to measure any voltage or current possible in the configured output range.

The voltage output can be set to any value between 0% and 100% of the active range using the <u>niDCPower Configure Voltage Level</u> VI or the <u>niDCPower ConfigureVoltageLevel</u> function, or the <u>niDCPower Configure</u> Voltage Limit VI or the <u>niDCPower_ConfigureVoltageLimit</u> function. Current output can be set to any value between 1% and 100% of the active range using the <u>niDCPower Configure Current Level</u> VI or the <u>niDCPower ConfigureCurrentLevel</u> VI or the <u>niDCPower ConfigureCurrentLevel</u> function, or the <u>niDCPower ConfigureCurrentLevel</u> VI or the <u>niDCPower ConfigureCurrentLevel</u> function. Measurements for both voltage and current can be made from 0% to 105% of the active range using the <u>niDCPower Measure Multiple</u> VI or the <u>niDCPower MeasureMultiple</u> function. Refer to <u>Overranging</u> for general information about enabling overranging in software.

Overranging

Enabling overranging for a particular channel of the NI PXI-4110 extends current and voltage output setpoint capabilities up to 105% of the output range. Overranging is applicable to output ranges only and does not apply to measurement ranges (the NI PXI-4110 is capable of making measurements up to 105% of the output range by default).

An auxiliary power supply providing at least 12 V at the input terminals should be used when enabling overranging for channel 1. Refer to <u>Ranges</u> for more information about enabling or disabling overranging for a particular channel.

Related Topics

Ranges

Replacing a Fuse

All of the input and output connections on the NI PXI-4110 front panel have user-replaceable fuses. Refer to the table below for fuse ratings and manufacturer information.

Input/Output	Fuse Rating	Description	Recommended Manufacturer Part Number
Channels 0, 1, and 2	F 1.5 A 125 V	User-replaceable chip fuse	Littelfuse 045301.5
Auxiliary power input	T 6.3 A L 250 V	User-replaceable 5 x 20 mm glass fuse	Littelfuse 21806.3

To replace a fuse on the NI PXI-4110, complete the following steps:

- 1. Shut down the chassis.
- 2. Disconnect all output and auxiliary power connections.
- 3. Remove the NI PXI-4110 from the chassis.
- 4. Identify the fuse you want to replace using the following figure:



2 Output Channel Fuse (Channel 2)

Fuse

- 3 Output Channel Fuse (Channel 1)
- 5. Remove the fuse.
 - (Output channel fuse) Using small pliers, gently pull the fuse to release it from the fuse holder.
 - (Auxiliary input fuse)
 - a. Using a flathead screwdriver, turn the fuse holder cap counter-clockwise to release it from the NI PXI-4110 front panel.
 - b. Gently pull the auxiliary power input fuse to release it from the fuse holder cap.
- 6. Install the replacement fuse.
 - (Output channel fuse) Using small pliers, gently place the replacement fuse into the fuse holder.
 - Note You can use the spare fuse included on the NI PXI-4110 to replace an output channel fuse.
 - (Auxiliary input fuse) Slide the replacement fuse into the fuse holder cap, and screw the cap clockwise to replace it on the NI PXI-4110 front panel.

Troubleshooting

If the NI PXI-4110 is operating incorrectly, perform the following actions:

- Verify that the hardware and software are properly installed.
- Verify that all connections, including the front panel connections to the output channels and auxiliary power supply (if applicable), are secure.
- Verify that the output channels are enabled. If necessary, use the <u>niDCPower Configure Output Enabled</u> VI or the <u>niDCPower_ConfigureOutputEnabled</u> function to enable the output channels.
- Inspect all fuses, and verify that each is in working condition. If necessary, <u>replace</u> any blown fuses.
 - **Tips** Although blown output channel and auxiliary power input fuses are not software detectable, you can use the <u>niDCPower Auxiliary Power Source Available</u> property or the <u>NIDCPOWER ATTR AUXILIARY POWER SOURCE AVAILAB</u> attribute to troubleshoot the auxiliary power input fuse.

If you suspect a blown output channel fuse, keep in mind that an output channel with a blown fuse can source only a few milliamperes of current regardless of the programmed current limit.

 Run a self-test on the NI PXI-4110 using the <u>niDCPower Self Test</u> VI or the <u>niDCPower_self_test</u> function. If the NI PXI-4110 is damaged, <u>contact</u> NI for information about repair.

NI PXI-4130

The NI PXI-4130 consists of two output channels. Channel 0, also referred to as the *utility channel*, is a <u>single-quadrant</u> power supply. Channel 1, the SMU channel, is a <u>four-quadrant</u>, bipolar power source-measure unit. The following table lists the DC voltage ranges supported by each channel.

Channel	Range		
	Output	Measurement	
0	+6 V	+6 V	
1	±20 V	±20 V	
	±6 V		

These channels support 5% overranging when overranging is enabled.

The following table lists DC current ranges supported by the NI PXI-4130.

Channel	Range		
Channel	Output	Measurement	
0	1 A	1 A	
1	200 µA	200 µA	
	2 mA	2 mA	
	20 mA	20 mA	
	200 mA*	200 mA*	
	2 A*	2 A*	
*See Internal and Au	<mark>uxiliary Power</mark> for lin	nitations when this device is	

under internal power.

These channels support 5% overranging when overranging is enabled.

The following diagrams illustrate the output voltage and current capabilities of each channel on the NI PXI-4130:



For more information about the NI PXI-4130 specifications, refer to <u>Related Documentation</u>.

Theory of Operation

The following figure represents the block diagram for a single output channel on the NI PXI-4130.



Each output channel on the NI PXI-4130 has a preregulation switching stage and a linear regulation stage. To improve efficiency and to reduce heat dissipation on the power supply, the preregulation stage controls the voltage level across the control element in the linear regulation stage.

The voltage and current control loops work together through the linear regulation stage to provide the <u>constant voltage mode</u> and <u>constant</u> <u>current mode</u>. In constant current mode, the NI PXI-4130 acts as a precision current source. Thus, regardless of the output voltage, the current through the load is held constant at the programmed value.

The isolated output (channel 1) on the NI PXI-4130 can operate from the PXI chassis power (internal power) or from an auxiliary DC power supply. When operating from internal power, the isolated output channels are restricted to lower power levels. When operating from an auxiliary power source, the isolated output channel can increase the current to 2 A, delivering a maximum of 40 W.

NI PXI-4130 Front Panel

The following figure illustrates the NI PXI-4130 front panel.



	Item	Description
А	Output Connector, Terminal 0	Channel 0 (0 to +6 V)
В	Output Connector, Terminal 1	GND
С	Output Connector, Terminal 2	Channel 1 Output HI (±20 V)
D	Output Connector, Terminal 3	Channel 1 Output LO

Е	Output Connector, Terminal 4	Channel 1 Remote Sense -
F	Output Connector, Terminal 5	Channel 1 Remote Sense +
G	Auxiliary Power Input Connector, Terminal 0	Auxiliary Power Input (+11 V to +15.5 V)
Н	Auxiliary Power Input Connector, Terminal 1	GND
I	Auxiliary Input Fuse Holder	
J	Auxiliary Input Status Indicator	LED
Κ	Channel 1 Sense Status Indicator	LED
L	Channel 1 Output Status Indicator	LED
Μ	Channel 0 Output Status Indicator	LED

Status Indicators

Status indicators on the front panel of the NI PXI-4130 provide feedback about device operation.

Use the following table to determine the state of an output channel using a status indicator.

Status Indicator	Channel Output State
(Off)	Disabled
Green	Enabled (<u>Constant Voltage mode</u>)
Amber	Enabled (<u>Constant Current mode</u>)
Red	Disabled because of error, such as an overtemperature condition

Use the following table to determine the state of remote sense using the status indicator.

Status Indicator	Channel Sense State
(Off)	Local Sense Enabled
Green	Remote Sense Enabled

Use the following table to determine the state of the auxiliary power input using the status indicator.

Status Indicator Auxiliary Power Input State		
(Off)	Auxiliary power input disconnected or out of range	
Green*	Auxiliary power input connected and within range	
*Does not indicate that the auxiliary power is in use. To determine if the NI PXI-4130 is using auxiliary power, use the <u>niDCPower Power Source</u> In Use property or the <u>NIDCPOWER_ATTR_POWER_SOURCE_IN_USE</u>		
NI PXI-4130 is using auxiliary power, use the <u>niDCPower Power Source</u> In Use property or the <u>NIDCPOWER_ATTR_POWER_SOURCE_IN_USE</u> attribute.		

Operating the Device

Expand this book for information about using the NI PXI-4130.

Internal and Auxiliary Power

When drawing internal power from the PXI backplane, channel 1 of the NI PXI-4130 can source or sink up to 2 W of output power with a maximum current of 300 mA. The following figure illustrates the maximum capabilities of channel 1 when operating under internal power:



 $\overline{\mathbb{N}}$

Note Output current is limited to 100 mA when using the NI PXI-4130 <u>Soft Front Panel</u>.

If your application requires additional current, you can connect an auxiliary DC power supply capable of providing 11 V to 15.5 V and \geq 60 W to increase the output current capability of this channel to 2 A. NI offers the APS-4100, an auxiliary power source for NI DC power supplies. Visit ni.com for more information.



Note Channel 0 has the same output capabilities under internal power and auxiliary power.

Using Auxiliary Power

Complete the following steps to connect and use auxiliary power:

- 1. Connect a 11 V to 15.5 V, ≥60 W power source to the auxiliary power input connector on the NI PXI-4130 front panel.
- 2. Open a new session to the device. NI-DCPower automatically uses the auxiliary power source when available. To override this feature, use the <u>niDCPower Power Source</u> property or the <u>NIDCPOWER_ATTR_POWER_SOURCE</u> attribute.
 - **Tip** Use the <u>niDCPower Power Source In Use</u> property or the <u>NIDCPOWER_ATTR_POWER_SOURCE_IN_USE</u> attribute to programmatically determine which power source is in use.

Resuming Operation After a Shutdown

In case of auxiliary power loss during operation, the isolated output (channel 1) is disabled, and the power supply is shut down to prevent damage to the NI PXI-4130 and the load. If a shutdown occurs, complete the following steps to resume operation:

- 1. <u>Troubleshoot</u> the failure.
- 2. Restore auxiliary power.
- 3. Reset the power supply using the <u>niDCPower Reset</u> VI or the <u>niDCPower_reset</u> function.
- 4. Reconfigure the SMU.

Changing/Removing Auxiliary Power

Complete the following steps to change or remove auxiliary power from the NI PXI-4130:



Tip It is often more convenient to close the existing session and open a new session to the device when managing auxiliary power state changes.

- 1. Disable the output channels.
- 2. Disconnect/connect the auxiliary power source.
- 3. Reset the SMU using the <u>niDCPower Reset</u> VI or the <u>niDCPower_reset</u> function.
- 4. Reconfigure the SMU.

Cascading Outputs



Caution Do not exceed 60 VDC from any terminal to ground when cascading multiple channels on the NI PXI-4130.

Because channel 1 on the NI PXI-4130 is an isolated output, it can be cascaded in series with other output channels to generate larger output voltages. For safety reasons, all terminals must be <60 VDC from ground. Any terminal on an isolated channel can be connected to ground.

The SMU channel on the NI PXI-4130 cannot be used in parallel with other channels to generate larger output currents because it is a fourguadrant supply and may begin to sink current when connected in parallel to another channel with a higher voltage.



Note Auxiliary power is required for channel 1 output greater than 2 W or 300 mA. Refer to Internal and Auxiliary Power for more information about auxiliary power.



Caution The NI PXI-4130 does *not* provide isolation when using CH 0.

Measurement Averaging

The NI PXI-4130 averages measurement samples to reduce noise and improve sensitivity. You can set the number of samples to average programmatically using the <u>niDCPower Samples To Average</u> property or the <u>NIDCPOWER ATTR SAMPLES TO AVERAGE</u> attribute.

Note When you set the niDCPower Samples To Average property or the NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE attribute, the output channel measurements might move out of synchronization. Refer to the <u>niDCPower Reset Average Before Measurement</u> property or the <u>NIDCPOWER ATTR RESET AVERAGE BEFORE MEASUREMENT</u>

attribute for more information about measurement averaging and synchronization.

Determining Measurement Rate

Although the measurement speed of the NI PXI-4130 is 3 kS/s for all voltage and current measurements, the measurement rate of the NI PXI-4130 can vary depending on the setting of the niDCPower Samples To Average property or the NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE attribute.

The default value of the niDCPower Samples To Average property and the NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE attribute is 10. As expressed in the following equation, the NI PXI-4130 returns 300 measurements per second using the default value.

 $\frac{3000 \text{ samples}}{\text{second}} \times \frac{1 \text{ measurement}}{10 \text{ samples}} = \frac{300 \text{ measurements}}{\text{second}}$

If no measurement averaging is used (Samples To Average = 1), the NI PXI-4130 returns 3,000 measurements per second.

While measuring without averaging yields the fastest measurement rate, noise from the environment (for example, the 50 Hz or 60 Hz noise introduced by cabling) increases measurement uncertainty.

Adjust the niDCPower Samples To Average property or the NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE attribute as necessary to optimize the noise performance and measurement rate for your application.



Note Measurement rate refers only to the hardware measurement rate and does not include software latency.

Rejecting Noise

If you know the noise frequency, you can reject it from the signal. To determine the number of measurements necessary to reject noise from a signal, divide the measurement speed of the NI PXI-4130 by a full wavelength cycle of noise.

Example 1

To reject 60 Hz noise frequency from a signal, average 50 measurements (3 kHz/60 Hz = 50).

Example 2

To reject 50 Hz noise frequency from a signal, average 60 measurements (3 kHz/50 Hz = 60).



Tip Set the niDCPower Samples To Average property or the NIDCPOWER_ATTR_SAMPLES_TO_AVERAGE attribute to 300, an even multiple of both 60 kHz and 50 kHz, to actively reject both noise frequencies.
Output Capacitance Selection

A switchable output capacitor can be enabled on channel 1 of the NI PXI-4130 to help the device operate normally under unstable conditions. Enabling this output capacitor can also be useful in filtering ripple in higher current ranges. Use the <u>niDCPower Output Capacitance</u> property or the <u>NIDCPOWER_ATTR_OUTPUT_CAPACITANCE</u> attribute to enable or disable the capacitor.

Note Changing the output capacitance requires channel 1 to be disabled, and may cause a glitch in the device output.

Output Capacitance Setting	Output Capacitance
Low	10 nF
High	6.8 µF

Instability in the SMU Output on Low Capacitance Setting

When using the SMU with the Low Capacitance setting, the combination of output currents 200 mA and above, inductive loads greater than 2 μ H, and resistances below 1 Ω can induce instabilities in the device output. The following list includes examples where these instabilities may be found:

- Driving current sense or power resistors
- Wirewound loads
- Transformers
- Shorted leads greater than 15 cm
- Any of the above combined with remote sense

In these cases, using the High Capacitance setting dramatically reduces the chances of observing resonance or oscillations between the SMU and the load. Alternatively, you can provide an external capacitance at the load. NI recommends starting with a capacitance of at least 0.1 μ F. More than 10 μ F should not be necessary, but can be used if required.

Remember that large capacitances (>0.1 μ F) result in a slower output response. Refer to <u>Load Considerations</u> for more information about capacitive loads.

Related Topics

Noise NI PXI-4130 Source Stability Under Reactive Loads

Power Measurements

NI-DCPower can be used to measure power flowing into or out of the NI PXI-4130. Use the <u>Measure Multiple</u> VI to measure both current and voltage for the channel you want to make the power measurement on. Be aware that these two measurements do not occur simultaneously, and as much as 250 µs may elapse between the two measurements. If the voltage and current have the same polarity (both positive or both negative), the NI PXI-4130 is <u>sourcing</u> power. If they have opposite polarities (one positive and one negative), the NI PXI-4130 is <u>sinking</u> power.

Protection

The output channels and the auxiliary power input of the NI PXI-4130 are protected against overcurrent, overvoltage, inverse voltage (CH 0 only), and overtemperature conditions.

Output Channel Protection

Both output channels on the NI PXI-4130 are current-limited, and channel 0 has a <u>user-replaceable fuse</u>. In the event of an overcurrent, overvoltage, or inverse voltage condition, this fuse may blow to protect the NI PXI-4130 and the load. When its fuse is blown, channel 0 can source only a few milliamperes of current regardless of the programmed current.



Caution Channel 0 can withstand the application of an external voltage up to 16 V. Applying an external voltage >16 V can damage the output channel.



Caution Channel 1 can withstand the application of an external voltage up to 50 V. Applying an external voltage >50 V can degrade or damage the output channel.

In the event of an overtemperature condition (that is, the enclosure or component temperatures exceed safe operating limits), the thermal shutdown circuits on the NI PXI-4130 disable the output channel that indicated the failure condition. When disabled, an output channel can only be reset programmatically after the failure condition is cleared.

Auxiliary Input Protection

The auxiliary power input of the NI PXI-4130 can accept voltages from 11 V to 15.5 V. Applying a voltage below 11 V or above 15.5 V disables the auxiliary power input.

In the event of an overvoltage condition (that is, applying voltages >20 V to the auxiliary power input), *crowbar protection* is enabled. Crowbar protection shunts the auxiliary power input to ground.

In the event of an overcurrent (>6.3 A) or an inverse voltage condition, the auxiliary power input fuse may blow to protect the NI PXI-4130 and the load. You can use the <u>niDCPower Auxiliary Power Source Available</u> property or the

NIDCPOWER_ATTR_AUXILIARY_POWER_SOURCE_AVAILABLE attribute to troubleshoot the auxiliary power input fuse.

Related Topics

Replacing a Fuse Troubleshooting

Pulsed Operation

Note Pulsed operation refers only to channel 1 of the NI PXI-4130.

When sourcing pulses with currents greater than 500 mA, the device power dissipation increases drastically if the duration of these pulses is below 10 milliseconds. This additional power may overheat the NI PXI-4130 components and thus engage the thermal protection forcing a channel shutdown.

When sinking power pulses, the limiting parameter is the average power being dissipated by the device. The maximum average power dissipation allowed is 10 W for ambient temperatures less than 30°C. For higher ambient temperatures, the maximum average power has to be derated by a factor of 0.2 W per degree Celsius.



Caution Exceeding the recommended maximum power sinking limits may result in undesired interruption of the SMU operation and excessive stress to the components that could result in damage to the device.

If the duration of the pulses is below 10 milliseconds, the channel may be forced to shut down because of an overtemperature condition. Please refer to the following graph to verify the conditions at which the SMU operates without interruption.





Note This graph is only valid up to an ambient temperature of 30°C. For higher ambient temperatures, derate according to the <u>device specifications</u>.



Note For pulses longer than 1 second, the operation is considered to be continuous and the peak power should be limited instead of average power.

Hot Surface Do not touch the outer shield of the NI PXI-4130 as it may become very hot during an overtemperature condition.

Related Topics

NI PXI-4130 Thermal Protections and Precautions NI PXI-4130 Troubleshooting

Range Considerations

It is not possible to change the measurement range for the NI PXI-4130 independently of the output range. The measurement range is implicitly selected based on the configured output range. The selected measurement range is large enough to measure any voltage or current possible in the configured output range.

The voltage output can be set to any value between 0% and 100% of the active range using the <u>niDCPower Configure Voltage Level</u> VI or the <u>niDCPower ConfigureVoltageLevel</u> function, or the <u>niDCPower Configure</u> Voltage Limit VI or the <u>niDCPower_ConfigureVoltageLimit</u> function. Current output can be set to any value between 2% and 100% of the active range using the <u>niDCPower Configure Current Level</u> VI or the <u>niDCPower ConfigureCurrentLevel</u> VI or the <u>niDCPower ConfigureCurrentLevel</u> function, or the <u>niDCPower ConfigureCurrentLevel</u> function. Measurements for both voltage and current can be made from 0% to 105% of the active range using the <u>niDCPower MeasureMultiple</u> function. Refer to <u>Overranging</u> for general information about enabling overranging in software.

Overranging

Enabling overranging for a particular channel of the NI PXI-4130 extends current and voltage output capabilities up to 105% and current setpoints down to 1% for the output range (without overranging, valid output values are between 2% and 100% of the current output range). Measurements in any given range may be made up to 105% of the range by default without enabling overranging.

An auxiliary power supply providing at least 12 V at the input terminals should be used when enabling overranging for channel 1. Refer to <u>Ranges</u> for more information about enabling or disabling overranging for a particular channel.

Considerations When Making Range Changes

Using <u>delayed configuration mode</u>, changes in voltage and current levels occur simultaneously when the device is initiated. These changes do not occur at the same time if there is a current range change involved. If the current range, current limit, and voltage level are all changed within the same delayed configuration, the current range and current limit change occur first immediately followed by the voltage level change.

Disabled State

When channel 1 is disabled, it is actively maintaining 0 V with a current limit of 20 mA. If a device capable of sourcing power is connected to channel 1 while the channel is disabled, the channel begins to sink power with a current limit of 20 mA.



Note All channels on the NI PXI-4130 power on in the disabled state.

Related Topics

Ranges

Replacing a Fuse

Refer to the following table for user-replaceable fuse ratings and manufacturer information for the NI PXI-4130.

Input/Output	Fuse Rating	Description	Recommended Manufacturer Part Number
Channel 0 (F1)	F 1.5 A 125 V	User-replaceable chip fuse	Littelfuse 045301.5
Auxiliary Power Input	T 6.3 A L 250 V	User-replaceable 5 x 20 mm glass fuse	Littelfuse 21806.3

To replace a fuse on the NI PXI-4130, complete the following steps:

- 1. Shut down the chassis.
- 2. Disconnect all output and auxiliary power connections.
- 3. Remove the NI PXI-4130 from the chassis.
- 4. Identify the fuse you want to replace using the following figure.



- 5. Remove the fuse.
 - (Output channel fuse) Using small pliers, gently pull the fuse to release it from the fuse holder.
 - (Auxiliary input fuse)
 - a. Using a flathead screwdriver, turn the fuse holder cap counter-clockwise to release it from the NI PXI-4130 front panel.
 - b. Gently pull the auxiliary power input fuse to release it from the fuse holder cap.
- 6. Install the replacement fuse.
 - (Output channel fuse) Using small pliers, gently place the replacement fuse into the fuse holder.
 - (Auxiliary input fuse) Slide the replacement fuse into the fuse holder cap, and screw the cap clockwise to replace it on the NI PXI-4130 front panel.

Source Stability Under Reactive Loads

In Constant Voltage mode, the NI PXI-4130 remains stable for most loads, even in the presence of low-equivalent series resistance (ESR) capacitors. However, when operating in Constant Current mode, particularly in higher current ranges, some inductive loads may cause the NI PXI-4130 source to become unstable, especially during high current operation. If the source becomes unstable, an oscillating or unregulated behavior can be observed across the output terminals. This situation yields excessive noise in the measurement, erratic behavior, or thermal shutdown.

After noticing any abnormalities, you can verify the behavior of your device by inspecting the voltage across the output terminals with an oscilloscope or a digitizer. To troubleshoot this issue, use the <u>niDCPower</u> <u>Output Capacitance</u> property or the <u>niDCPower_ATTR_Output_Capacitance</u> attribute to enable or disable the capacitor. For more information about operating your device under unstable conditions, refer to <u>Output</u> <u>Capacitance Selection</u>.

Thermal Protections and Precautions

Both channels of the NI PXI-4130 are protected against excessive temperatures and shut down in the presence of excessive heat.

During normal sourcing operation on channel 1 (up to 40 W output), the thermal protection should not engage over the rated ambient temperature range of the device. Also, sinking power levels within the rated specifications of the device should not trigger the thermal protection when the device is within the ambient temperature range.

Hot Surface Do not touch the outer shield of the NI PXI-4130 as it may become very hot during an overtemperature condition.

Thermal protection for channel 1 may also become engaged if the output becomes unstable because of inductive loads in the highest current range. If you are operating the NI PXI-4130 within the rated specifications and the thermal protection is engaging, refer to <u>Source Stability Under</u> <u>Reactive Loads</u> and <u>Output Capacitance Selection</u> to determine if instability may be a factor in overtemperature operation of your device.

Related Topics

NI PXI-4130 Pulsed Operation NI PXI-4130 Troubleshooting

Transients During Power-Up and Power-Down

Attention must be paid to the setup and operation of your NI PXI-4130. Transients may appear across the terminals (typically <1 V) during power-up, power-down, and when loading the device driver.

To minimize the risk of damage to sensitive devices, NI recommends that all power supplies and SMU connections are disconnected while performing any of the above operations.

In case of chassis power failure, transients may appear across the output terminals. Consider employing an uninterruptible power supply system to avoid damage to extremely sensitive devices.

Troubleshooting

If the NI PXI-4130 is operating incorrectly, perform the following actions:

- Verify that the hardware and software are properly installed.
- Verify that all connections, including the front panel connections to the output channels and auxiliary power supply (if applicable), are secure.
- Verify that the output channels are enabled. If necessary, use the <u>niDCPower Configure Output Enabled</u> VI or the <u>niDCPower_ConfigureOutputEnabled</u> function to enable the output channels.
- Inspect all fuses, and verify that each is in working condition. If necessary, <u>replace</u> any blown fuses.
 - **Tips** Although blown output channel and auxiliary power input fuses are not software detectable, you can use the <u>niDCPower Auxiliary Power Source Available</u> property or the <u>NIDCPOWER ATTR AUXILIARY POWER SOURCE AVAILAB</u> attribute to troubleshoot the auxiliary power input fuse.

If you suspect a blown output channel fuse, keep in mind that an output channel with a blown fuse can source only a few milliamperes of current regardless of the programmed current limit.

- Run a self-test on the NI PXI-4130 using the <u>niDCPower Self Test</u> VI or the <u>niDCPower_self_test</u> function. If the NI PXI-4130 is damaged, <u>contact</u> NI for information about repair.
- Verify that the output is stable when operating with reactive loads. Refer to <u>Source Stability Under Reactive Loads</u> and <u>Output</u> <u>Capacitance Selection</u> for more information about stable device operation.
- Check for any error conditions that may exist in the output channels such as thermal shutdown. If applicable, clear the error condition by resetting the device.

Integration and System Considerations

Expand this book for information related to integrating the NI power supplies and SMUs with other devices and environments.

Environment

NI power supplies and SMUs are designed to operate in any PXIcompliant chassis at an ambient temperature between 0 °C and 55 °C and at a relative humidity up to 90%.

For best performance, observe the following recommendations:

- Keep the power supply or SMU clean and free from contaminants.
- Use a chassis that has a well-designed cooling system. All NI PXI chassis meet this requirement.



Note To ensure that the power supply or SMU operates at peak performance within the PXI chassis, refer to <u>PXI Chassis</u> <u>Recommendations</u>.

Operating under high humidity (>90%) or dusty conditions may cause increased leakage between circuit components and can result in additional measurement errors.

PXI Chassis Recommendations

NI power supplies and SMUs are designed to operate in any PXIcompliant chassis. Temperature rise of the device can vary with slot position in the chassis. Observe the following recommendations to minimize this temperature variation and to ensure normal operating conditions for your device:

- Perform routine maintenance of the chassis cooling fan filters to assure continuous cooling effectiveness and to keep dust off of the device components. NI recommends cleaning the chassis fan filters at a maximum interval of six months and keeping the chassis environment clean to minimize the amount of dust that enters the chassis. For more information about cleaning the chassis fan filters, refer to the documentation for your chassis.
- Install PXI filler panels in all empty slots.
- Verify that the PXI chassis fans that provide forced air remain unobstructed to allow for proper cooling of the PXI chassis, devices, and controller.

NI-DCPower Soft Front Panel

Use the NI-DCPower Soft Front Panel (SFP) to configure and enable channels, monitor voltage and current measurements, and test the functionality of an NI DC power supply or SMU. To launch the NI-DCPower SFP, navigate to **Start»All Programs»National Instruments»NI-DCPower»NI-DCPower Soft Front Panel**.

토 NI-DCPower Sof	ft Front Pane	l: PXI1Slot2	🛛
<u>File H</u> elp			
Channel 0			NATIONAL DXT1Slot2/cb0
Output Function	DC Voltage	Output Enabled	- +0 0000 V
Voltage Level	+0.0000 V	🕏 Range 6 V	
Current Limit	0.1000 A	🕾 Range 1 A	→ +0.0000 A
			Cmpl CV CC
Channel 1			NATIONAL
Output Function	DC Voltage	Output Enabled	PINSTRUMENTS PXIISlot2/ch1
Voltage Level	+00.000 V	Range 20 V	+00.000 V
	0.4000.4		+0.0000 A
Current Limit	0.1000 A	😨 Range 2 A	
Sense	Local	~	Cmpl CV CC

When using the NI-DCPower SFP, you can make the following selections, based upon the measurement mode and functionality your application requires:

• Select the Output Function you want to use.

Output Function	DC Voltage	~
	🗸 DC Voltage	N
Voltage Level	DC Current	hì

• When using the DC Voltage output function, use the Voltage Level and Current Limit controls to set the voltage level and the current limit for a channel.

Voltage Level	+0.0000 V	Ð
Current Limit	0.1000 A	۲

• When using the DC Current output function, use the Current Level and Voltage Limit controls to set the current level and the voltage limit for a channel.

Current Level	+0.0200 A	Ð
Voltage Limit	6.0000 V	۲

• If applicable, select a voltage and/or current range for the channel from the Range drop-down listboxes.



Available ranges depend upon the power supply or SMU and the selected function you are using. The Range drop-down listboxes display a list of available ranges for each function and device.

 If you are using a device with remote sense capabilities, you can use the Sense drop-down listbox to select either Local or <u>Remote</u> <u>sense</u>.



• After you have configured the channel, click **Output Enabled** to enable the channel and begin supplying power.



As power is supplied, the NI-DCPower SFP displays voltage and current measurements.





Note When a channel is operating in <u>Constant Current</u> mode, the letters CC light up in the display. When a channel is operating in <u>Constant Voltage</u> mode, the letters CV light up in the display. When the channel is operating at the compliance limit, Cmpl lights up in the display. For more information about the compliance limit, refer to <u>Compliance</u>.

• When you are finished with your measurements, select **File**»**Exit** to close the NI-DCPower SFP.

Programming with NI-DCPower

NI-DCPower, an Interchangeable Virtual Instrument (IVI)–compliant instrument driver, is included with your NI power supply or SMU and communicates with all NI programmable power supplies and SMUs. NI-DCPower features a set of operations and properties that exercise the functionality of the power supply or SMU and includes an interactive <u>soft</u> <u>front panel</u>.

Examples

Refer to <u>Getting Started</u> to begin controlling your power supply with NI-DCPower. Refer to <u>Examples</u> for LabVIEW, LabWindows/CVI, and Visual Basic example locations.

Getting Started

This topic explains how to begin using NI-DCPower with your application development environment (ADE), lists any files to include in your application, and mentions considerations for each ADE.

To successfully build your application, you must have NI-DCPower and one of the following ADEs installed:

- LabVIEW
- LabWindows/CVI
- Visual C++
- Visual Basic

You can use the <u>NI-DCPower Express</u> VI to quickly begin using NI-DCPower in LabVIEW.

Using NI-DCPower in LabVIEW

This topic assumes that you are using LabVIEW to manage your code development and that you are familiar with the ADE.

To develop an NI-DCPower application in LabVIEW, follow these general steps:

- 1. Open an existing or new LabVIEW VI.
- 2. Locate the NI-DCPower VIs.
 - (LabVIEW 8.0 or later) From the **Functions** palette, select **Measurement I/O»NI-DCPower**.
 - (LabVIEW 7.x) From the Functions palette, select All Functions»Instrument I/O»Instrument Drivers»NI-DCPower.
- 3. Select the VIs that you want to use, and drop them on the block diagram to build your application.

Example Programs

You can use the LabVIEW Example Finder to search or browse examples. NI-DCPower examples are classified by keyword, so you can search for a particular device or measurement function.

To browse the NI-DCPower examples available in LabVIEW, launch LabVIEW, click **Find Examples**, and navigate to **Hardware Input and Output»Modular Instruments»NI-DCPower**.

For additional information regarding NI-DCPower examples, refer to <u>Examples</u>.

Considerations for Using the LabVIEW Real-Time Module

To develop an NI-DCPower application in the LabVIEW Real-Time Module, follow the same steps used for developing any application in the LabVIEW Real-Time Module, with the addition of using the <u>NI-DCPower</u> <u>LabVIEW VIs</u>.



Note Applications running NI-DCPower in the LabVIEW Real-Time Module on an RT target may be compromised and/or slow at 64 MB of memory.

Hardware Support

NI-DCPower supports all National Instruments power supplies and SMUs on RT targets.

Unsupported Features

When using NI power supplies and SMUs with the LabVIEW Real-Time Module, the following features are *not* supported:

- External calibration
- NI-DCPower Soft Front Panel (SFP)
- Express VIs
Related Documentation

- For configuration instructions for remote systems, refer to the *Remote Systems Help* in Measurement & Automation Explorer (MAX) by selecting Help»Help Topics»Remote Systems in MAX.
- For more information about the LabVIEW Real-Time Module, refer to the *LabVIEW Real-Time Module User Manual* at <u>ni.com/manuals</u>.
- For additional troubleshooting and support information, refer to the LabVIEW Real-Time Support main page at <u>ni.com/support/labview/real-time</u>.

Using NI-DCPower in LabWindows/CVI

This topic assumes that you are using the LabWindows/CVI ADE to manage your code development and that you are familiar with the ADE.

To develop an NI-DCPower application in LabWindows/CVI, follow these general steps:

- 1. Open an existing or new project file.
- 2. Load the NI-DCPower function panel, nidcpower.fp, at <IVI>\Drivers\niDCPower.
- 3. Use the function panel to navigate the function hierarchy and generate function calls with the proper syntax and variable values.

Example Programs

LabWindows/CVI users can use the NI Example Finder to search or browse examples. NI-DCPower example are classified by keyword, so you can search for a particular device or measurement function. To browse the NI-DCPower examples available in LabWindows/CVI, launch LabWindows/CVI, select **Help*Find Examples**, and navigate to **Hardware Input and Output*Modular Instruments*NI-DCPower**.

For additional information regarding NI-DCPower examples, refer to <u>Examples</u>.

Using NI-DCPower in Visual C++

This topic assumes that you are using the Microsoft Visual C++ ADE to manage your code development and that you are familiar with the ADE.

To develop an NI-DCPower application in Visual C++, follow these general steps:

- 1. Open an existing or new Visual C++ project.
- 2. Create source files of type .c (C source code) or .cpp (C++ source code) and add them to the project. Make sure that you include the NI-DCPower header file, nidcpower.h, in your source code files as follows: #include "nidcpower.h".
- Specify the directory that contains the NI-DCPower header file under the Preprocessor»Additional include directories settings in your compiler—for Visual C++ 6.0 these files are under Project»Settings»C/C++. The NI-DCPower header files are located at <IVI>\Include.
- 4. Add the NI-DCPower import library nidcpower.lib to the project under Link»General»Object/Library Modules. The NI-DCPower import library files are located in the <IVI>\Lib\msc directory within your NI-DCPower directory.
- 5. Add NI-DCPower function calls to your application.
- 6. Build your application.

String Passing

To pass strings, pass a pointer to the first element of the character array. Be sure that the string is null-terminated.

Parameter Passing

By default, C passes parameters by value. Remember to pass pointers to variables when you need to pass by address.

Using NI-DCPower in Visual Basic

This topic assumes that you are using the Microsoft Visual Basic ADE to manage your code development and that you are familiar with the ADE.

To develop an NI-DCPower application in Visual Basic, follow these general steps:

- 1. Open an existing or new Visual Basic project.
- 2. Create files necessary for your application: .frm (form definition and event handling code), .bas (Visual Basic generic code module), or .cls (Visual Basic class module). Add these files to the project.
- 3. Add a reference to the National Instruments DCPower Library (NIDCPower), which is part of the NI-DCPower DLL. In Visual Basic 6.0, select the **Project**»**References** menu option and **NI-DCPower**. If you do not see NI-DCPower listed there, use the Browse button and browse to <IVI>\bin\nidcpower_32.dll.
- 4. Use the Object Browser <F2> to find function prototypes and constants.
- 5. Add NI-DCPower function calls to your application.
- 6. Click Run.

Example Programs

For additional information regarding NI-DCPower examples, refer to <u>Examples</u>. To load an example project with Visual Basic 6.0, select **File»Open Project**, then select the .vbp file of your choice.

String Passing

In Visual Basic, variables of data type String do not need special modifications to be passed to NI-DCPower functions. Visual Basic automatically appends a null character to the end of a string before passing it (by reference, because strings cannot be passed by value in Visual Basic) to a procedure or function.

Parameter Passing

By default, Visual Basic passes parameters by reference. Prepend the ByVal keyword if you need to pass by value.

Programming Flow

To program an NI power supply or SMU, complete the following steps:

- 1. Open a session.
- 2. <u>Configure</u> the device for your application.
- 3. Measure and Query. (Optional)
- 4. <u>Close</u> the session.

Opening a Session

To open a session, use the <u>niDCPower Initialize</u> or <u>niDCPower Initialize</u> <u>With Options</u> VI or the <u>niDCPower_init</u> or <u>niDCPower_InitWithOptions</u> function.



Note When you execute the niDCPower Initialize VI or the niDCPower_init function with the **reset device** parameter set to TRUE (default value), a new session is opened and the device is automatically initiated. Upon initiation, the default session attributes are immediately applied to the device. To override this feature, execute the niDCPower Initialize VI or the niDCPower_init function with the **reset device** parameter set to FALSE.

Configuring the Device

NI-DCPower has two configuration modes—Immediate mode and Delayed Configuration mode. Configuration modes determine how configuration calls are applied to the device. In Immediate mode, every configuration call is immediately applied to the device. In Delayed Configuration mode all configuration changes are cached, and the device continues to operate in its last configured state until you execute the <u>niDCPower Initiate</u> VI or the <u>niDCPower_Initiate</u> function.

The first configuration or measurement call in a session not preceded by a call to the niDCPower Abort VI or the niDCPower_Abort function places the device in Immediate mode.

Execute the niDCPower Initiate VI or the niDCPower_Initiate function to place the device in Immediate mode. Execute the <u>niDCPower Abort</u> VI or the <u>niDCPower_Abort</u> function to place the device in Delayed Configuration mode.

Note When you execute the <u>niDCPower Initialize</u> VI or the <u>niDCPower_init</u> function with the **reset device** parameter set to TRUE (default value), a new session is opened in Immediate mode. Refer to <u>Opening a Session</u> for more information about opening sessions.

You can also use the niDCPower Initiate VI or the niDCPower_Initiate function and the niDCPower Abort VI or the niDCPower_Abort function to move between configuration modes. For example, execute the niDCPower Abort VI or the niDCPower_Abort function to move from Immediate mode to Delayed Configuration mode. To apply cached configuration changes to the device, execute the niDCPower Initiate VI or the niDCPower_Initiate function.

Tip In Immediate mode, configuration calls to multiple channels are performed sequentially, not simultaneously. Use the Delayed Configuration mode to simultaneously configure multiple attributes on one or more channels.

Attribute values do not persist between sessions. If you close a session and open a new one, all attributes assume their default values; however, the default values are not committed to the device until the session enters the Immediate mode. **Tip** To open a session and leave the device in its existing configuration without passing through a transitional output state, execute the niDCPower Initialize VI or the niDCPower_init function with the **reset device** parameter set to FALSE, and then immediately execute the niDCPower Abort VI or the niDCPower_Abort function. To apply a new configuration without disrupting the output channels of the device, configure the device in Delayed Configuration mode as in the previous session changing only the desired settings, and then execute the niDCPower Initiate VI or the niDCPower_Initiate function.

P

Closing a Session

Use the <u>niDCPower Close</u> VI or the <u>niDCPower_close</u> function to close a session.

When you close a session to a device, the device continues to operate in its last configured state. If you close the session while the output channels of the device are enabled and actively sourcing or sinking power, the device continues to source or sink power until it is disabled or reset.

Using Properties and Attributes

NI-DCPower contains high-level VIs and functions that set most of the device properties and attributes.

Refer to <u>NI-DCPower LabVIEW Reference</u> or <u>NI-DCPower Function</u> <u>Reference</u> for a complete a listing of the available properties and attributes in NI-DCPower.

Some properties and attributes are not accessible through the high-level VIs and functions. The values for these properties and attributes must be set using the appropriate property or attribute.

Accessing Properties

In LabVIEW, properties are accessed through the NI-DCPower property node. To access properties in LabVIEW, complete the following steps:

- 1. Open a VI.
- 2. In the block diagram view, navigate to the NI-DCPower palette.
 - (LabVIEW 8.0 or later) From the **Functions** palette, select **Measurement I/O»NI-DCPower**.
 - (LabVIEW 7.x) From the Functions palette, select All Functions»Instrument I/O»Instrument Drivers»NI-DCPower.
- 3. Drag and drop the property node icon to the block diagram.
- 4. Left-click the property node, and select the property that you want to use.
- 5. To add additional properties, resize the property node. To resize the property node, drag the resizing handle at the top or bottom of the node and release the mouse button.
- Note To access a channel-based property, you must pass an Active Channel. The Active Channel is listed first in the property node. To access a device-based property, do not pass an Active Channel or pass an empty string.

Accessing Attributes

In C and Visual Basic, attributes are accessed with the Get Attribute and Set Attribute functions. Get and Set Attribute functions exist for each supported data type in NI-DCPower.

Setting Properties and Attributes Before Reading Them

Properties and attributes are modified when you set them or when you call a configuration VI or function that sets them, respectively. It is important to set the properties or attributes or call any configuration VIs or functions before reading back any property or attribute values for the following reasons:

- Values read are coerced depending on the current configuration of the session. If you read a property or attribute value and then set other properties or attributes, the value read may no longer be valid.
- The driver verifies that the configuration of the device is valid at the time the property or attribute is read. It is possible to get an error when reading a property or attribute if the configuration is not valid at that point, even when a setting later could make it valid.
- Reading properties or attributes causes the driver to verify the current configuration. If you change some of the settings later, those settings need to be validated again.



Features

This book contains information about the following power supply, SMU, and NI-DCPower features:

- Detecting Internal/Auxiliary Power
- Enabling the Output
- <u>Measurements</u>
- Programming the Output
- Simulating a Power Supply or SMU

Detecting Internal/Auxiliary Power

Use an auxiliary power source to enable the full-power capabilities of NI power supplies and SMUs that support this feature. NI-DCPower can dynamically query whether the auxiliary power is connected to the device. The <u>niDCPower Auxiliary Power Source Available</u> property or the <u>NIDCPOWER ATTR AUXILIARY POWER SOURCE AVAILABLE</u> attribute returns TRUE if auxiliary power is connected to the device and FALSE if only internal power is available on the device.

NI power supplies and SMUs cannot differentiate between an auxiliary power loss or a blown fuse on the auxiliary power input line. If auxiliary power is properly connected and the niDCPower Auxiliary Power Source Available property or the

NIDCPOWER_ATTR_AUXILIARY_POWER_SOURCE_AVAILABLE attribute returns FALSE, you might need to <u>replace</u> the auxiliary power input fuse.

Enabling the Output

To power on or off the output channels, use the <u>niDCPower Configure</u> <u>Output Enabled</u> VI or the <u>niDCPower_ConfigureOutputEnabled</u> function. When you enable an output, if the selected output function is DC Voltage, the programmed voltage level and current limit are applied to the channel. If the selected output function is DC Current, the programmed current level and voltage limit are applied to the channel. When you disable an output, the channel generates 0 V.

Measurements

NI DC power supplies and SMUs can measure the current and voltage they generate. This measurement capability is essential for many test applications including I-V curve tracing, where current must be measured for multiple voltage set points, and IDDQ measurements on CMOS integrated circuits, where current consumption must be characterized at fixed voltage levels. For more information about measurement resolution, accuracy, and speed, refer to your <u>device specifications</u> document.

To retrieve these measurements, use the <u>niDCPower Measure</u> or <u>niDCPower Measure Multiple</u> VI, or the <u>niDCPower_Measure</u> or <u>niDCPower_MeasureMultiple</u> function. The niDCPower Measure VI and the niDCPower_Measure function measure either the voltage or the current on a single channel. The niDCPower Measure Multiple VI and the niDCPower_MeasureMultiple function measure both the voltage and the current on multiple channels.

As with any measurement device, there is a trade-off between the speed at which measurements are performed and the amount of noise in those measurements. NI power supplies and SMUs provide flexibility in this trade-off by averaging a configurable number of samples before returning a measurement. To learn more about adjusting the number of measurement samples to average, including the trade-off between measurement speed and measurement noise, refer to the *Measurement Averaging* topic for your device.

Programming the Output

NI DC power supplies or SMUs have two possible output functions: DC Voltage and DC Current. To force a voltage, set the output function to NIDCPOWER_VAL_DC_VOLTAGE using the

niDCPower_ConfigureOutputFunction function or **DC Voltage** using the niDCPower Configure Output Function VI. To force a current, set the output function to NIDCPOWER_VAL_DC_CURRENT using the niDCPower_ConfigureOutputFunction function or **DC Current** using the niDCPower Configure Output Function VI.

When you select the DC Voltage output function, the instrument attempts to generate the desired output voltage level as long as the output current is below the current limit. You can program the voltage level with the niDCPower Configure Voltage Level VI or the niDCPower_ConfigureVoltageLevel function. You can program the current limit with the niDCPower Configure Current Limit VI or the niDCPower_ConfigureCurrentLimit function.

When the DC Current output function is selected, the instrument attempts to generate the desired output current level as long as the output voltage is below the voltage limit. You can program the current level with the niDCPower Configure Current Level VI or the niDCPower_ConfigureCurrentLevel function. You can program the voltage limit with the niDCPower Configure Voltage Limit VI or the niDCPower_ConfigureVoltageLimit function.

Simulating a Power Supply or SMU

Simulate a power supply or SMU using NI-DCPower or Measurement & Automation Explorer (MAX) to develop, modify, and/or test an application without hardware. Using a simulated device to test an application eliminates the risk of hardware damage. Additionally, you can use a simulated power supply or SMU to evaluate an NI product for which you do not have hardware.



Tip As with any installed and configured power supply or SMU, you can use the <u>NI-DCPower Soft Front Panel</u> to test the basic functionality of the device.

NI-DCPower

Complete the following steps to create and configure a simulated power supply or SMU using NI-DCPower.

- 1. Run the <u>niDCPower Initialize With Options</u> VI or the <u>niDCPower_InitWithOptions</u> function.
- 2. Set the **option string** parameter. The **option string** parameter is composed of the Simulate and Driver Setup keywords, as illustrated in the following example:

Simulate=1, DriverSetup=Model:<model number>; BoardType:<type>

The DriverSetup keyword is set using the *driver setup string*—the device model number and board type. When you specify the driver setup string, NI-DCPower ignores the **resource name** parameter. If you do not specify the driver setup string, NI-DCPower simulates the device specified in the **resource name** parameter. If you specify neither the driver setup string nor the **resource name** parameter, NI-DCPower simulates an NI PXI-4110 by default.

Example

When simulating an NI PXI-4110, use the following **option string** parameter:

Simulate=1, DriverSetup=Model:4110; BoardType:PXI

MAX

Complete the following steps to create and configure a simulated power supply in Measurement & Automation Explorer (MAX).

- 1. Launch MAX.
- 2. Right-click **Devices and Interfaces** in the MAX configuration tree, and select **Create New**. The Create New dialog box opens.
- 3. Select **NI-DAQmx Simulated Device**, and click Finish. The Choose Device dialog box opens.
- 4. Expand **Power Supplies**, and select the power supply to simulate.
- 5. Click OK. The power supply appears in the MAX configuration tree with a yellow icon to indicate that it is a simulated device.

Refer to the NI-DAQmx Simulated Devices topic in the *Measurement & Automation Explorer Help for NI-DAQmx* for more detailed information about simulating NI-DAQmx devices.

Examples

NI-DCPower examples are instructional tools that demonstrate power supply functionality. NI-DCPower examples are available for the following ADEs:

- LabVIEW 7.1 or later
- LabWindows/CVI 7.0 or later
- Visual Basic 6.0

For example locations, refer to the <u>NI-DCPower Readme</u>.

Operating System Support

For information about the supported operating system (OS) for your device, refer to the <u>NI-DCPower Readme</u>.

Glossa	ry
Prefixes	Numbers/Symbols A B C D E F G H I
LMN	O P R S T U V W

Prefixes

Prefix	Meaning	Value
f	femto	10 ⁻¹⁵
р	pico	10-12
n	nano	10 ⁻⁹
μ	micro	10-6
m	milli	10 ⁻³
k	kilo	10 ³
М	mega	106
G	giga	10 ⁹
Т	tera	1012

Numbers/Symbols

nV	nanovolts	10 ⁻⁹ volts
μV	microvolts	10 ⁻⁶ volts
μΩ	microohms	10 ⁻⁶ ohms
mV	millivolts	10 ⁻³ volts
mΩ	milliohms	10 ⁻³ ohms
MΩ	megaohms	10 ⁶ ohms
pА	picoamps	10 ⁻¹² amperes
nA	nanoamps	10 ⁻⁹ amperes
μA	microamps	10 ⁻⁶ amperes
mΑ	milliamps	10 ⁻³ amperes

Α

- AC alternating current
- ADE application development environment—A software environment incorporating the development, debug, and analysis tools for software development.

admittance The reciprocal of impedance.

- aperture The period during which the ADC is reading the input time signal.
- ATE automated test equipment—A term typically applied to computer-based systems for testing semiconductor components or circuit card assemblies.
- auxiliary Power drawn from a separate, external power source. Use an auxiliary power source to increase the output capability of a power supply that is only drawing <u>internal power</u>.
- AWG American Wire Gauge—A U.S. standard set of non-ferrous wire conductor sizes. Gauge means the diameter. Non-ferrous includes copper and also aluminum and other materials, but is most frequently applied to copper household electrical wiring and telephone wiring. Typical household wiring is AWG number 12 or 14. Telephone wire is usually 22, 24, or 26. The higher the gauge number, the smaller the diameter and the thinner the wire. Since thicker wire carries more current because it has less electrical resistance over a given length, thicker wire is better for longer distances.

В

- bandwidth The range of frequencies present in a signal, or the range of frequencies to which a measuring device can respond.
- bipolar A signal range that includes both positive and negative values (for example, -5 V to +5 V).

С

- calibration The process of determining the accuracy of an instrument. In a formal sense, calibration establishes the relationship of an instrument's measurement to the value provided by a standard. When that relationship is known, the instrument can then be adjusted (calibrated) for best accuracy.
- capacitance The ability of a capacitor to store an electrical charge, measured in Farads.
- commonmode noise present between the output common/ground and the chassis or earth ground. In this sense, the equivalent circuit is a current noise source connected across these two terminals.
- compliance A channel that is operating at the programmed limit because the requested level cannot be reached.
- connector A device that provides electrical connection.
- constant An NI-DCPower control mode in which a circuit supplies a constant current source, independent of the load placed on the current generator. When constant current mode is enabled on an output channel, the current is held constant at the value specified by the current limit, and the voltage rises or falls as the load requires more or less power.
- constant An NI-DCPower control mode in which a circuit supplies a constant voltage source. When constant voltage mode is enabled on an output channel, the voltage is held constant at the value specified by the voltage level despite load changes.
- crowbar A method of <u>overvoltage protection</u> that shunts the protection auxiliary power input to ground if excessive voltage is detected. When crowbar protection is enabled, a overvoltage condition might cause the auxiliary power input fuse to blow.
- current The rate of flow of electric charge, measured in amperes.
- current Error current that travels through undesired paths and can leakage degrade signals.

current- See <u>voltage drop</u>. resistance

loss

D

DC	direct current
DC voltage	The direct current (non-changing) component of a voltage. In practice, the DC voltage should not change over the period of observation, that is, the measurement time.
Delayed Configuration mode	An NI-DCPower configuration mode in which every configuration call is cached until the configuration is initiated.
DMM	digital multimeter
driver	Software that controls a specific hardware device such as a DAQ device or GPIB interface device.
DSP	digital signal processor
DUT	device under test

Ε

electrical A device to which power is supplied.

load

- EEPROM Electrically erasable programmable read-only memory. Read-only memory that you can erase with an electrical signal and reprogram.
- EMF electromotive force
- EXTCLK Auxiliary Clock signal.

F

- fall time The time for a signal to move from 90% to 10% of the signal value.
- frequency f—The basic unit of rate, measured in events or oscillations per second using a frequency counter or spectrum analyzer. Frequency is the reciprocal of the period of a signal.

G

GND ground—A noncurrent-carrying circuit intended for safety.

Η

- handle A unique variable you use to refer to a window or other interface element in C programming.
- Hz hertz. Cycles per second. See <u>frequency</u>

I

Immediate mode	An NI-DCPower configuration mode in which every configuration call is immediately applied to the device.
impedance	The property of a circuit or circuit element to resist both steady-state current flow (<u>resistance</u>) and changes in current or voltage (<u>reactance</u>).
inductance	The property of a circuit or circuit element to oppose a change in current flow, thus causing current changes to lag behind voltage changes. Inductance is measured in henrys (H).
inductive load	A load whose current changes lag behind its voltage changes. See inductance.
instrument driver	A set of high-level functions that control and communicate with instrument hardware in a system.
internal power	For NI DC power supplies, power drawn from the PXI chassis backplane.
inverse voltage protection	A protection circuit that prevents the power supply from being damaged in the event that an inverse voltage is applied at the input or output terminals.
I/O	input/output
isolation	Describes the electrical separation between the input and the output, measured in <u>resistance</u> .
isolated output	An output that is electrically separated from the input.
IVI	Interchangeable Virtual Instruments. A software standard for creating a common interface (API) to common test and measurement instruments.
IVI driver	A driver written according to the IVI specification. The generic driver for a class of instruments (such as voltmeters) is called a class driver, whereas the driver for a specific instrument from a specific manufacturer is called a device-specific driver.

L

LabVIEW Laboratory Virtual Instrument Engineering Workbench. LabVIEW is a graphical programming language that uses icons instead of lines of text to create programs.

leakage Error current that travels through undesired paths that can degrade signals.

LED light emitting diode—A semiconductor light source.

line The ability of the power supply to maintain its output voltage regulation given changes in the input line voltage. Line regulation is expressed as percent of change in the output voltage relative to the change in the input line voltage. For NI DC

power supplies, the line regulation specification refers to the auxiliary power input.

load See <u>electrical load</u>.

load The ability of an output channel to remain constant given changes in the load. The control mode enabled on the output channel determines the way in which load regulation is expressed.
Μ

max	maximum
Measurement & Automation Explorer	The standard National Instruments hardware configuration and diagnostic environment on Windows.
min	minutes or minimum

Ν

- NaN Not a Number—Digital display value for a floating-point representation of <Not A Number>. Typically the result of an undefined operation, such as log(–1).
- noise Analog. Unwanted signals. Noise comes from both external and internal sources. Noise corrupts signals you are trying to send or receive.
- normal- Noise present between the output HI and output LO/ground,
- mode appearing either in series (constant voltage mode) or parallel
- noise (constant current mode) with the output. Normal-mode noise can be expressed as voltage noise or current noise, depending on the control mode of the output channel.

0

- output HI The output channel terminal capable of supplying a DC potential.
- output LO The output channel terminal referenced to circuit common.
- overcurrent A power supply protection circuit that limits the output protection current in the event of an overcurrent condition.
- overvoltage A power supply protection circuit that either shuts down or crowbars the power supply in the event of an overvoltage condition.
- OVP overvoltage protection

Ρ

ppm	parts per million	
preload	A small amount of current drawn from a power supply used stabilize its operation.	
programmable power supply	An instrument providing user-adjustable power (voltage and current) for a DUT.	
pulse load	A load whose current amplitude deviates from its steady state value for short periods of time.	
PXI	PCI eXtensions for Instrumentation. A modular, computer-based instrumentation platform.	

R

time

- reactance The property of a circuit or circuit element to resist changes in voltage or current.
- remote A method of monitoring the output voltage directly at the load rather than at the power supply output terminals. Remote sensing improves regulation when in voltage mode.
- resistance The property of a material to resist or inhibit current flow.
- resonance The frequency at which capacitive reactance and inductive reactance are equal and, thus, cancel one another's effects.
- response The time a device takes to respond to a request.
- ringing A decaying <u>sinusoidal signal</u> resulting from an external perturbation (for example, a transient load, an application of a capacitive discharge, etc).
- ripple The level of the undesired frequency components on a DC power supply output. The ripple is most often the same frequency as the AC input voltage or the internal switching frequency. This is measured using a spectrum analysis.
- rise time The time for a signal to transition from 10% to 90% of the maximum signal amplitude.
- rms root mean square

S

settling time	The time required for a circuit to reach a stable mode of operation.	
shunt	An electronic component that diverts current.	
shunt resistance	A resistor connected in parallel or in shunt with a circuit or other component.	
sink	A device that can dissipate power.	
sinking	The ability to dissipate power from active circuitry.	
sinusoidal signal	A signal varying in proportion to the sine of an angle or time function.	
slew rate	The voltage rate of change as a function of time. Slew rate limitations are first seen as distortion at higher signal frequencies.	
SMU	source-measure unit. A device capable of sourcing and measuring DC voltage and current with high precision.	
source	A device that can supply power to an external device.	
sourcing	The ability to supply power for external circuitry.	

Т

tempco	temperature coefficient. Describes how much a property changes with temperature.	
thermal protection	A power supply protection circuit that shuts down the power supply in the event of an overtemperature condition.	
thermistor	Semiconductor sensor that exhibits a repeatable change in electrical resistance as a function of temperature; most thermistors exhibit a negative temperature coefficient.	
time constant	A figure of merit for system speed.	
transient response	The length of time it takes for a circuit to recover from a sudden change in an output load or an input voltage.	

U

uncertainty The total calculated error caused by calibration error, noise, nonlinearity, offsets, temperature drift, and so on.

unregulated Describes the state of an output channel that has neither mode <u>constant voltage mode</u> or <u>constant current mode</u> enabled.

V		
V	Volts.	
VAC	Volts, Alternating Current.	
VDC	Volts, Direct Current.	
VI	Virtual Instrument—Program in LabVIEW that models the appearance and function of a physical instrument.	
voltage drop	The decrease in voltage along a conductor. The amount of voltage drop is dependant on the conductor (wire gauge and length) and the amount of current flowing through the conductor.	
VXI	VME eXtensions for Instrumentation (bus)	
VXI <i>plug&play</i> SystemsAlliance	A group of VXI developers dedicated to making VXI devices as easy to use as possible, primarily by simplifying software development.	

W

wideband The maximum amount of microprocessor and power supply noise that may be present on the output voltage.

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