

DEVICE SPECIFICATIONS

NI 6221

M Series Data Acquisition: 16-Bit, 250 kS/s, 16 AI, 24 DIO, 2 AO

The following specifications are typical at 25 °C, unless otherwise noted. For more information about the NI 6221, refer to the *M Series User Manual* available at ni.com/manuals.

Analog Input

| | |
|--|--|
| Number of channels | 8 differential or 16 single ended |
| ADC resolution | 16 bits |
| DNL | No missing codes guaranteed |
| INL | Refer to the <i>AI Absolute Accuracy</i> section |
| Sample rate | |
| Single channel maximum | 250 kS/s |
| Multichannel maximum (aggregate) | 250 kS/s |
| Minimum | No minimum |
| Timing accuracy | 50 ppm of sample rate |
| Timing resolution | 50 ns |
| Input coupling | DC |
| Input range | ±0.2 V, ±1 V, ±5 V, ±10 V |
| Maximum working voltage for analog inputs (signal + common mode) | ±11 V of AI GND |
| CMRR (DC to 60 Hz) | 92 dB |
| Input impedance | |
| Device on | |
| AI+ to AI GND | >10 GΩ in parallel with 100 pF |
| AI- to AI GND | >10 GΩ in parallel with 100 pF |

| | |
|--|--|
| Device off | |
| AI+ to AI GND | 820 Ω |
| AI- to AI GND | 820 Ω |
| Input bias current | ± 100 pA |
| Crosstalk (at 100 kHz) | |
| Adjacent channels | -75 dB |
| Non-adjacent channels | -90 dB |
| Small signal bandwidth (-3 dB) | 700 kHz |
| Input FIFO size | 4,095 samples |
| Scan list memory | 4,095 entries |
| Data Transfers | |
| PCI/PXI | DMA (scatter-gather), interrupts, programmed I/O |
| USB | USB Signal Stream, programmed I/O |
| Overvoltage protection for all analog input and sense channels | |
| Device on | ± 25 V for up to two AI pins |
| Device off | ± 15 V for up to two AI pins |
| Input current during overvoltage condition | ± 20 mA maximum/AI pin |

Settling Time for Multichannel Measurements

Accuracy, full-scale step, all ranges

| | |
|-------------------------------------|----------------------------|
| ± 90 ppm of step (± 6 LSB) | 4 μ s convert interval |
| ± 30 ppm of step (± 2 LSB) | 5 μ s convert interval |
| ± 15 ppm of step (± 1 LSB) | 7 μ s convert interval |

Typical Performance Graphs

Figure 1. Settling Error versus Time for Different Source Impedances

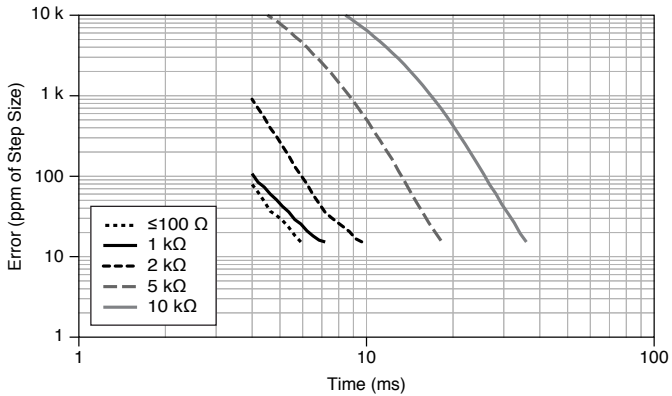


Figure 2. AI Small Signal Bandwidth

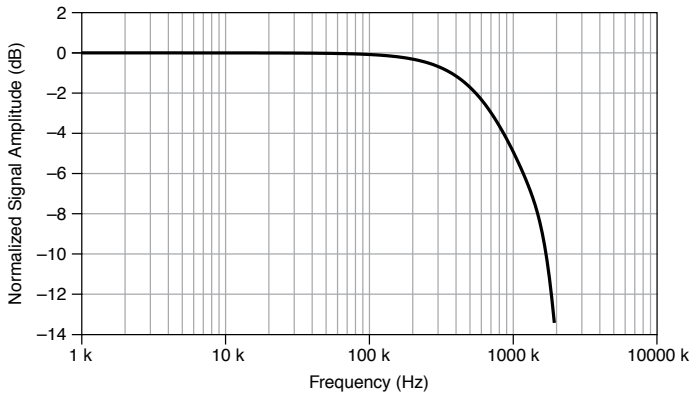
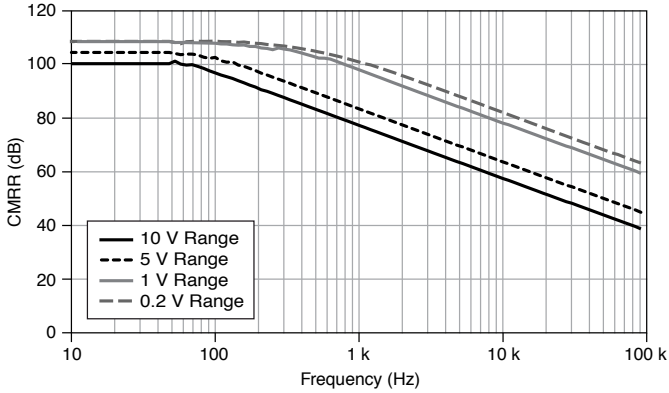


Figure 3. AI CMRR



AI Absolute Accuracy



Note Accuracies listed are valid for up to one year from the device external calibration.

Table 1. AI Absolute Accuracy

| Nominal Range Positive Full Scale | Nominal Range Negative Full Scale | Residual Gain Error (ppm of Reading) | Residual Offset Error (ppm of Range) | Offset Tempco (ppm of Range/°C) | Random Noise, σ (μ Vrms) | Absolute Accuracy at Full Scale (μ V) | Sensitivity (μ V) |
|-----------------------------------|-----------------------------------|--------------------------------------|--------------------------------------|---------------------------------|--------------------------------------|--|------------------------|
| 10 | -10 | 75 | 20 | 57 | 244 | 3,100 | 97.6 |
| 5 | -5 | 85 | 20 | 60 | 122 | 1,620 | 48.8 |
| 1 | -1 | 95 | 25 | 79 | 30 | 360 | 12.0 |
| 0.2 | -0.2 | 135 | 80 | 175 | 13 | 112 | 5.2 |



Note Sensitivity is the smallest voltage change that can be detected. It is a function of noise.

Gain tempco 25 ppm/°C

Reference tempco 5 ppm/°C

INL error 76 ppm of range

AI Absolute Accuracy Equation

$$\text{AbsoluteAccuracy} = \text{Reading} \cdot (\text{GainError}) + \text{Range} \cdot (\text{OffsetError}) + \text{NoiseUncertainty}$$

$$\text{GainError} = \text{ResidualAIGainError} + \text{GainTempco} \cdot (\text{TempChangeFromLastInternalCal}) + \text{ReferenceTempco} \cdot (\text{TempChangeFromLastExternalCal})$$

$$\text{OffsetError} = \text{ResidualAIOffsetError} + \text{OffsetTempco} \cdot (\text{TempChangeFromLastInternalCal}) + \text{INLError}$$

$$\text{NoiseUncertainty} = \frac{\text{Random Noise} \cdot 3}{\sqrt{100}} \text{ for a coverage factor of } 3 \sigma \text{ and averaging } 100 \text{ points.}$$

AI Absolute Accuracy Example

Absolute accuracy at full scale on the analog input channels is determined using the following assumptions:

- TempChangeFromLastExternalCal = 10 °C
- TempChangeFromLastInternalCal = 1 °C
- number_of_readings = 100
- CoverageFactor = 3 σ

For example, on the 10 V range, the absolute accuracy at full scale is as follows:

$$\text{GainError} = 75 \text{ ppm} + 25 \text{ ppm} \cdot 1 + 5 \text{ ppm} \cdot 10 = 150 \text{ ppm}$$

$$\text{OffsetError} = 20 \text{ ppm} + 57 \text{ ppm} \cdot 1 + 76 \text{ ppm} = 153 \text{ ppm}$$

$$\text{NoiseUncertainty} = \frac{244 \mu\text{V} \cdot 3}{\sqrt{100}} = 73 \mu\text{V}$$

$$\text{AbsoluteAccuracy} = 10 \text{ V} \cdot (\text{GainError}) + 10 \text{ V} \cdot (\text{OffsetError}) + \text{NoiseUncertainty} = 3,100 \mu\text{V}$$

Analog Output

| | |
|---------------------|-----------------------|
| Number of channels | 2 |
| DAC resolution | 16 bits |
| DNL | ± 1 LSB |
| Monotonicity | 16 bit guaranteed |
| Maximum update rate | |
| 1 channel | 833 kS/s |
| 2 channels | 740 kS/s per channel |
| Timing accuracy | 50 ppm of sample rate |
| Timing resolution | 50 ns |
| Output range | ± 10 V |

| | |
|--|--|
| Output coupling | DC |
| Output impedance | 0.2 Ω |
| Output current drive | ± 5 mA |
| Overdrive protection | ± 25 V |
| Overdrive current | 10 mA |
| Power-on state | ± 20 mV ¹ |
| Power-off glitch | 400 mV for 200 ms |
| Output FIFO size | 8,191 samples shared among channels used |
| Data transfers | |
| PCI/PXI | DMA (scatter-gather), interrupts, programmed I/O |
| USB | USB Signal Stream, programmed I/O |
| AO waveform modes | Non-periodic waveform, periodic waveform regeneration mode from onboard FIFO, periodic waveform regeneration from host buffer including dynamic update |
| Settling time, full-scale step, 15 ppm (1 LSB) | 6 μ s |
| Slew rate | 15 V/ μ s |
| Glitch energy | |
| Magnitude | 100 mV |
| Duration | 2.6 μ s |

AO Absolute Accuracy

Absolute accuracy at full-scale numbers is valid immediately following internal calibration and assumes the device is operating within 10 °C of the last external calibration.



Note Accuracies listed are valid for up to one year from the device external calibration.

¹ When the USB Screw Terminal device is powered on, the analog output signal is not defined until after USB configuration is complete.

Table 2. AO Absolute Accuracy

| Nominal Range Positive Full Scale | Nominal Range Negative Full Scale | Residual Gain Error (ppm of Reading) | Gain Tempco (ppm/°C) | Residual Offset Error (ppm of Range) | Offset Tempco (ppm of Range/°C) | Absolute Accuracy at Full Scale (µV) |
|-----------------------------------|-----------------------------------|--------------------------------------|----------------------|--------------------------------------|---------------------------------|--------------------------------------|
| 10 | -10 | 90 | 10 | 40 | 5 | 3,230 |

Reference tempco 5 ppm/°C

INL error 128 ppm of range

AO Absolute Accuracy Equation

$$AbsoluteAccuracy = OutputValue \cdot (GainError) + Range \cdot (OffsetError)$$

$$GainError = ResidualGainError + GainTempco \cdot (TempChangeFromLastInternalCal) + ReferenceTempco \cdot (TempChangeFromLastExternalCal)$$

$$OffsetError = ResidualOffsetError + AOffsetTempco \cdot (TempChangeFromLastInternalCal) + INLError$$

Digital I/O/PFI

Static Characteristics

Number of channels 24 total, 8 (P0.<0..7>),
16 (PFI <0..7>/P1, PFI <8..15>/P2)

Ground reference D GND

Direction control Each terminal individually programmable as input or output

Pull-down resistor 50 kΩ typical, 20 kΩ minimum

Input voltage protection ±20 V on up to two pins²

Waveform Characteristics (Port 0 Only)

Terminals used Port 0 (P0.<0..7>)

Port/sample size Up to 8 bits

Waveform generation (DO) FIFO 2,047 samples

Waveform acquisition (DI) FIFO 2,047 samples

² Stresses beyond those listed under *Input voltage protection* may cause permanent damage to the device.

| | |
|---|--|
| DI or DO Sample Clock frequency | 0 MHz to 1 MHz, system and bus activity dependent |
| Data transfers | |
| PCI/PXI | DMA (scatter-gather), interrupts, programmed I/O |
| USB | USB Signal Stream, programmed I/O |
| DI or DO Sample Clock source ³ | Any PFI, RTSI, AI Sample or Convert Clock, AO Sample Clock, Ctr <i>n</i> Internal Output, and many other signals |

PFI/Port 1/Port 2 Functionality

| | |
|--------------------------|---|
| Functionality | Static digital input, static digital output, timing input, timing output |
| Timing output sources | Many AI, AO, counter, DI, DO timing signals |
| Debounce filter settings | 125 ns, 6.425 μ s, 2.56 ms, disable; high and low transitions; selectable per input |

Recommended Operating Conditions

| Level | Minimum | Maximum |
|--|---------|---------|
| Input high voltage (V_{IH}) | 2.2 V | 5.25 V |
| Input low voltage (V_{IL}) | 0 V | 0.8 V |
| Output high current (I_{OH}) P0.<0..7> | — | -24 mA |
| Output high current (I_{OH}) PFI <0..15>/P1/P2 | — | -16 mA |
| Output low current (I_{OL}) P0.<0..7> | — | 24 mA |
| Output low current (I_{OL}) PFI <0..15>/P1/P2 | — | 16 mA |

Electrical Characteristics

| Level | Minimum | Maximum |
|---------------------------------------|---------|---------|
| Positive-going threshold (V_{T+}) | — | 2.2 V |
| Negative-going threshold (V_{T-}) | 0.8 V | — |

³ The digital subsystem does not have its own dedicated internal timing engine. Therefore, a sample clock must be provided from another subsystem on the device or an external source.

| Level | Minimum | Maximum |
|---|---------|-------------|
| Delta VT hysteresis ($V_{T+} - V_{T-}$) | 0.2 V | — |
| I_{IL} input low current ($V_{in} = 0$ V) | — | -10 μ A |
| I_{IH} input high current ($V_{in} = 5$ V) | — | 250 μ A |

Digital I/O Characteristics

Figure 4. DIO Port 0: I_{oh} versus V_{oh}

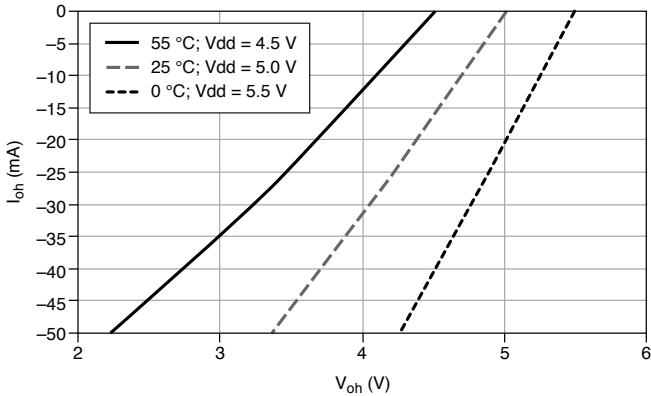


Figure 5. DIO PFI/Port 1/Port 2: I_{oh} versus V_{oh}

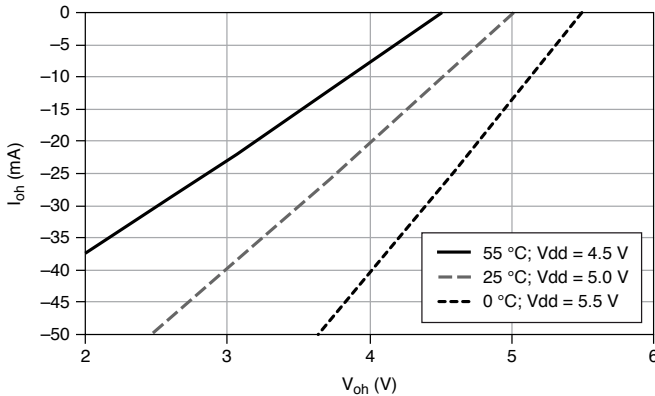


Figure 6. DIO Port 0: I_{ol} versus V_{ol}

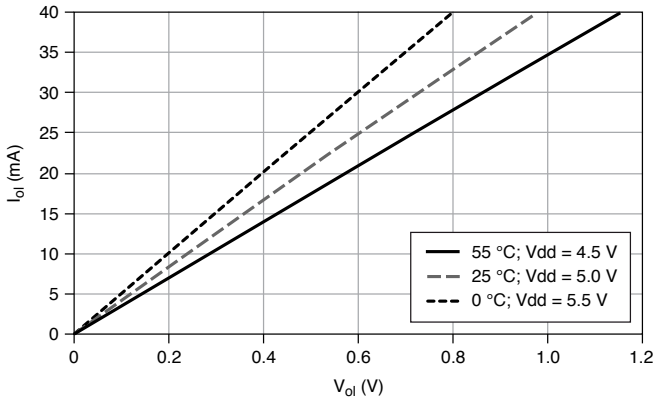
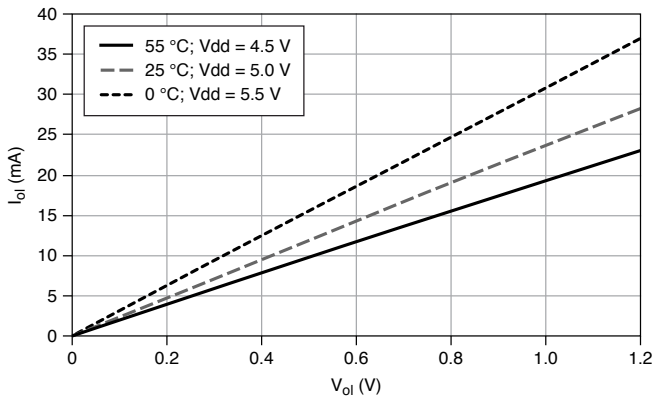


Figure 7. DIO PFI/Port 1/Port 2: I_{ol} versus V_{ol}



General-Purpose Counters/Timers

| | |
|--------------------------|---|
| Number of counter/timers | 2 |
| Resolution | 32 bits |
| Counter measurements | Edge counting, pulse, semi-period, period, two-edge separation |
| Position measurements | X1, X2, X4 quadrature encoding with Channel Z reloading; two-pulse encoding |
| Output applications | Pulse, pulse train with dynamic updates, frequency division, equivalent time sampling |

| | |
|-------------------------------|--|
| Internal base clocks | 80 MHz, 20 MHz, 0.1 MHz |
| External base clock frequency | 0 MHz to 20 MHz |
| Base clock accuracy | 50 ppm |
| Inputs | Gate, Source, HW_Arm, Aux, A, B, Z, Up_Down |
| Routing options for inputs | Any PFI, RTSI, PXI_TRIG, PXI_STAR, analog trigger, many internal signals |
| FIFO | 2 samples |
| Data transfers | |
| PCI/PXI | Dedicated scatter-gather DMA controller for each counter/timer; interrupts, programmed I/O |
| USB | USB Signal Stream, programmed I/O |

Frequency Generator

| | |
|---------------------|-----------------|
| Number of channels | 1 |
| Base clocks | 10 MHz, 100 kHz |
| Divisors | 1 to 16 |
| Base clock accuracy | 50 ppm |

Output can be available on any output PFI or RTSI terminal.

Phase-Locked Loop (PLL)



Note PCI/PXI devices only.

| | |
|------------------|--|
| Number of PLLs | 1 |
| Reference signal | PXI_STAR, PXI_CLK10, RTSI <0..7> |
| Output of PLL | 80 MHz Timebase; other signals derived from 80 MHz Timebase including 20 MHz and 100 kHz Timebases |

External Digital Triggers

| | |
|----------|--------------------------------------|
| Source | Any PFI, RTSI, PXI_TRIG, PXI_STAR |
| Polarity | Software-selectable for most signals |

| | |
|--|---|
| Analog input function | Start Trigger, Reference Trigger, Pause Trigger, Sample Clock, Convert Clock, Sample Clock Timebase |
| Analog output function | Start Trigger, Pause Trigger, Sample Clock, Sample Clock Timebase |
| Counter/timer function | Gate, Source, HW_Arm, Aux, A, B, Z, Up_Down |
| Digital waveform generation (DO) function | Sample Clock |
| Digital waveform acquisition (DI) function | Sample Clock |

Device-to-Device Trigger Bus

| | |
|--------------------------|--|
| PCI | RTSI <0..7> ⁴ |
| PXI | PXI_TRIG <0..7>, PXI_STAR |
| USB source | None |
| Output selections | 10 MHz Clock, frequency generator output, many internal signals |
| Debounce filter settings | 125 ns, 6.425 µs, 2.56 ms, disable; high and low transitions; selectable per input |

Bus Interface

| | |
|------------------------|---|
| PCI/PXI | 3.3 V or 5 V signal environment |
| USB | USB 2.0 Hi-Speed or full-speed ^{5, 6} |
| DMA channels (PCI/PXI) | 6, can be used for analog input, analog output, digital input, digital output, counter/timer 0, counter/timer 1 |
| USB Signal Stream | 4, can be used for analog input, analog output, counter/timer 0, counter/timer 1 |

The PXI device supports one of the following features:

- May be installed in PXI Express hybrid slots
- Or, may be used to control SCXI in PXI/SCXI combo chassis

⁴ In other sections of this document, RTSI refers to RTSI <0..7> for the PCI devices or PXI_TRIG <0..7> for PXI devices.

⁵ If you are using a USB M Series device in full-speed mode, device performance will be lower and you will not be able to achieve maximum sample/update rates.

⁶ Operating on a full-speed bus may result in lower performance.

Table 3. PXI/SCXI Combo and PXI Express Chassis Compatibility

| M Series Part Number | SCXI Control in PXI/SCXI Combo Chassis | PXI Express Hybrid Slot Compatible |
|----------------------|--|------------------------------------|
| 191332B-03 | No | Yes |
| 191332B-13 | Yes | No |
| 191322A-0x | Yes | No |

Power Requirements

Current draw from bus during no-load condition⁷

| | |
|--------|--------|
| +5 V | 0.02 A |
| +3.3 V | 0.25 A |
| +12 V | 0.15 A |

Current draw from bus during AI and AO overvoltage condition⁷

| | |
|--------|--------|
| +5 V | 0.02 A |
| +3.3 V | 0.25 A |
| +12 V | 0.25 A |



Caution USB devices must be powered with an NI offered AC adapter or a National Electric Code (NEC) Class 2 DC source that meets the power requirements for the device and has appropriate safety certification marks for country of use.

USB power supply requirements

11 to 30 VDC, 20 W, locking or non-locking power jack with 0.080 in. diameter center pin, 5/16-32 thread for locking collars

Current Limits



Caution Exceeding the current limits may cause unpredictable behavior by the device and/or PC/chassis.

PCI, +5 V terminal

1 A maximum⁸

⁷ Does not include P0/PFI/P1/P2 and +5 V terminals.

⁸ Older revisions have a self-resetting fuse that opens when current exceeds this specification. Newer revisions have a traditional fuse that opens when current exceeds this specification. This fuse is not customer-replaceable; if the fuse permanently opens, return the device to NI for repair.

PXI

| | |
|--|--------------------------|
| +5 V terminal | 1 A maximum |
| P0/PFI/P1/P2 and +5 V terminals combined | 2 A maximum ⁸ |

USB

| | |
|--|--------------------------|
| +5 V terminal | 1 A maximum ⁸ |
| P0/PFI/P1/P2 and +5 V terminals combined | 2 A maximum |
| Power supply fuse | 2 A, 250 V |

Physical Characteristics

Dimensions

| | |
|--|--|
| PCI printed circuit board | 10.6 cm × 15.5 cm (4.2 in. × 6.1 in.) |
| PXI printed circuit board | Standard 3U PXI |
| USB Screw Terminal enclosure (includes connectors) | 26.67 cm × 17.09 cm × 4.45 cm (10.5 in. × 6.73 in. × 1.75 in.) |
| USB BNC enclosure (includes connectors) | 28.6 cm × 17 cm × 6.9 cm (11.25 in. × 6.7 in. × 2.7 in.) |
| USB OEM | Refer to the <i>NI USB-622x/625x/628x OEM User Guide</i> |

Weight

| | |
|--------------------|---------------------|
| PCI | 92 g (3.2 oz) |
| PXI | 162 g (5.7 oz) |
| USB Screw Terminal | 1.2 kg (2 lb 10 oz) |
| USB OEM | 131 g (4.6 oz) |

I/O connector

| | |
|--|--------------------------------|
| PCI/PXI | 1 68-pin VHDCI |
| USB Screw Terminal | 64 screw terminals |
| USB BNC | 20 BNCs and 30 screw terminals |
| USB Screw Terminal/BNC screw terminal wiring | 16 to 28 AWG |

Calibration

Recommended warm-up time

| | |
|----------------------|------------|
| PCI/PXI | 15 minutes |
| USB | 30 minutes |
| Calibration interval | 1 year |

Maximum Working Voltage

Maximum working voltage refers to the signal voltage plus the common-mode voltage.

| | |
|------------------|------------------------------|
| Channel-to-earth | 11 V, Measurement Category I |
|------------------|------------------------------|

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



Caution Do not use for measurements within Categories II, III, or IV.



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

Environmental

Operating temperature

| | |
|------------------------------------|---------------------------------|
| PCI/PXI | 0 °C to 55 °C |
| USB | 0 °C to 45 °C |
| Storage temperature | -20 °C to 70 °C |
| Humidity | 10% RH to 90% RH, noncondensing |
| Maximum altitude | 2,000 m |
| Pollution Degree (indoor use only) | 2 |

Indoor use only.

Shock and Vibration (PXI Only)

| | |
|-------------------|---|
| Operational shock | 30 g peak, half-sine, 11 ms pulse (Tested in accordance with IEC 60068-2-27. Test profile developed in accordance with MIL-PRF-28800F.) |
| Random vibration | |
| Operating | 5 Hz to 500 Hz, 0.3 g _{rms} |
| Nonoperating | 5 Hz to 500 Hz, 2.4 g _{rms} (Tested in accordance with IEC 60068-2-64. Nonoperating test profile exceeds the requirements of MIL-PRF-28800F, Class 3.) |

Safety

This product is designed to meet the requirements of the following electrical equipment safety standards for measurement, control, and laboratory use:

- IEC 61010-1, EN 61010-1
- UL 61010-1, CSA 61010-1



Note For UL and other safety certifications, refer to the product label or the [Online Product Certification](#) section.

Electromagnetic Compatibility

This product meets the requirements of the following EMC standards for electrical equipment for measurement, control, and laboratory use:

- EN 61326-1 (IEC 61326-1): Class A emissions; Basic immunity
- EN 55011 (CISPR 11): Group 1, Class A emissions
- EN 55022 (CISPR 22): Class A emissions
- EN 55024 (CISPR 24): Immunity
- AS/NZS CISPR 11: Group 1, Class A emissions
- AS/NZS CISPR 22: Class A emissions
- FCC 47 CFR Part 15B: Class A emissions
- ICES-001: Class A emissions



Note In the United States (per FCC 47 CFR), Class A equipment is intended for use in commercial, light-industrial, and heavy-industrial locations. In Europe, Canada, Australia and New Zealand (per CISPR 11) Class A equipment is intended for use only in heavy-industrial locations.



Note Group 1 equipment (per CISPR 11) is any industrial, scientific, or medical equipment that does not intentionally generate radio frequency energy for the treatment of material or inspection/analysis purposes.



Note For EMC declarations and certifications, and additional information, refer to the [Online Product Certification](#) section.

CE Compliance

This product meets the essential requirements of applicable European Directives, as follows:

- 2014/35/EU; Low-Voltage Directive (safety)
- 2014/30/EU; Electromagnetic Compatibility Directive (EMC)
- 2011/65/EU; Restriction of Hazardous Substances (RoHS)

Online Product Certification

Refer to the product Declaration of Conformity (DoC) for additional regulatory compliance information. To obtain product certifications and the DoC for this product, visit ni.com/certification, search by model number or product line, and click the appropriate link in the Certification column.

Environmental Management

NI is committed to designing and manufacturing products in an environmentally responsible manner. NI recognizes that eliminating certain hazardous substances from our products is beneficial to the environment and to NI customers.

For additional environmental information, refer to the *Minimize Our Environmental Impact* web page at ni.com/environment. This page contains the environmental regulations and directives with which NI complies, as well as other environmental information not included in this document.

Waste Electrical and Electronic Equipment (WEEE)



EU Customers At the end of the product life cycle, all NI products must be disposed of according to local laws and regulations. For more information about how to recycle NI products in your region, visit ni.com/environment/weee.

电子信息产品污染控制管理办法（中国 RoHS）



中国客户 National Instruments 符合中国电子信息产品中限制使用某些有害物质指令 (RoHS)。关于 National Instruments 中国 RoHS 合规性信息，请登录 ni.com/environment/rohs_china。(For information about China RoHS compliance, go to ni.com/environment/rohs_china.)

Device Pinouts

Figure 8. NI PCI/PXI-6221 Pinout

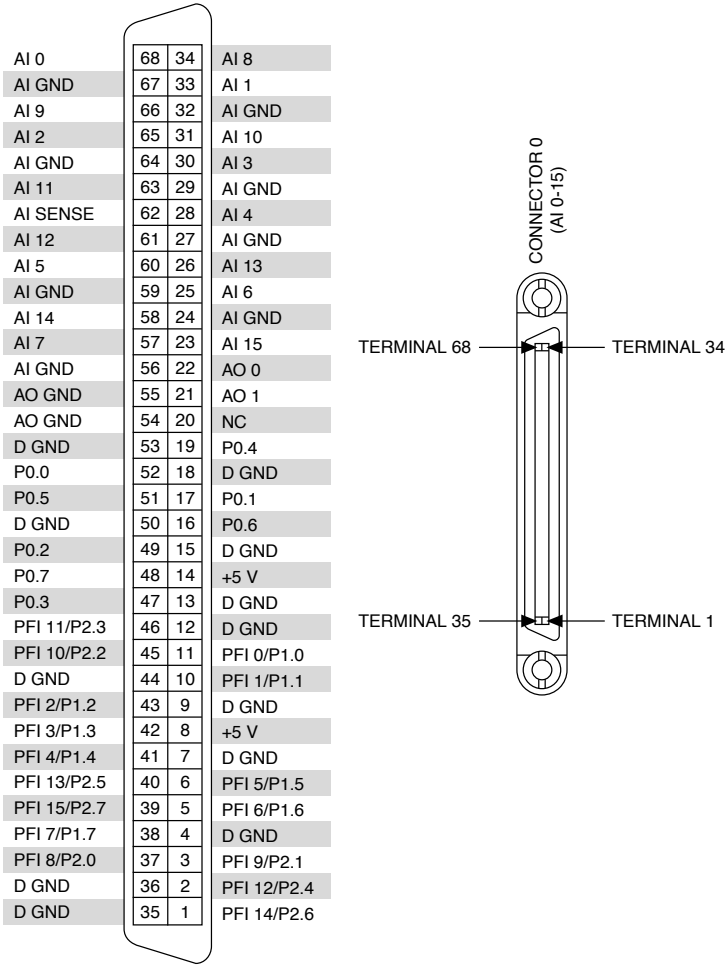
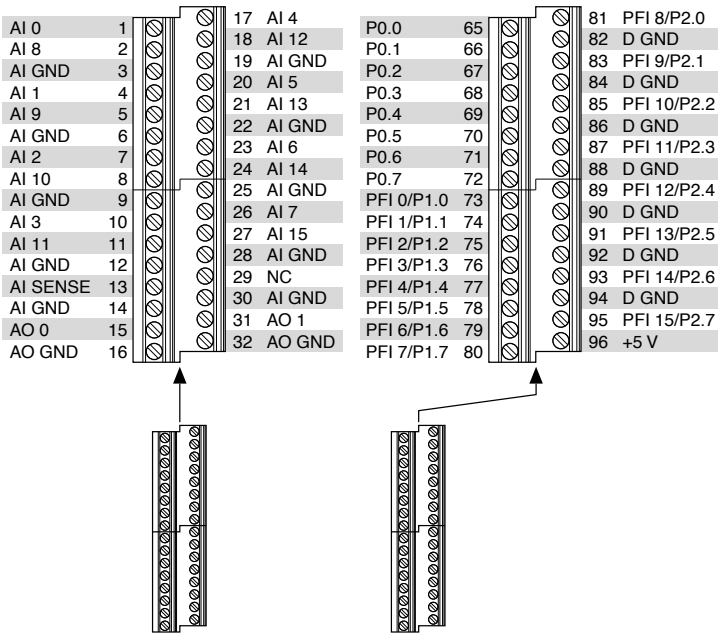
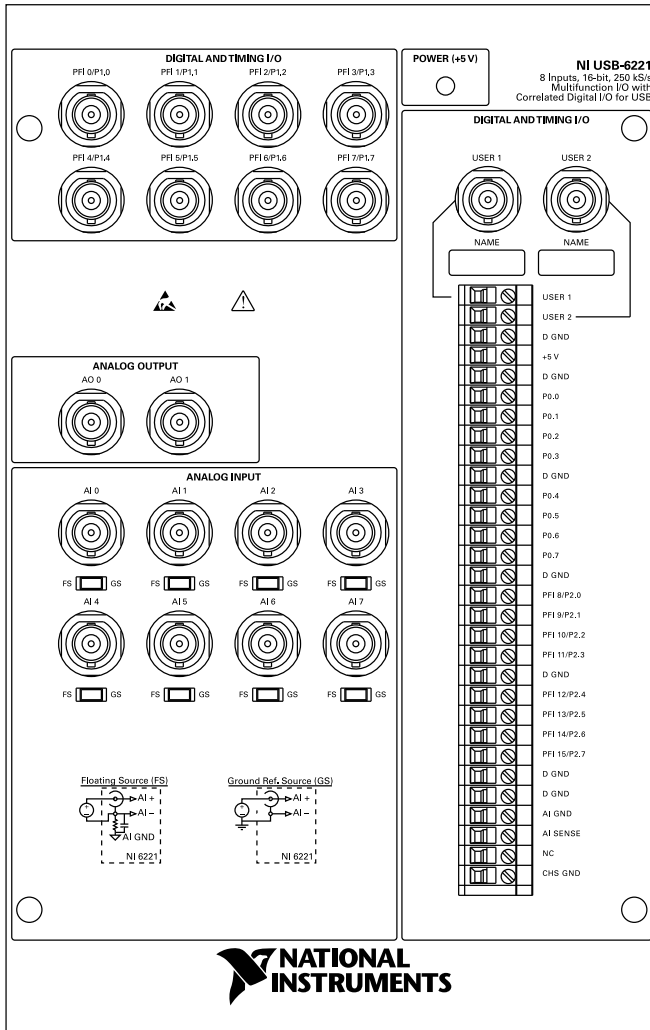


Figure 9. NI USB-6221 Screw Terminal Pinout



NC = No Connect

Figure 10. NI USB-6221 BNC Top Panel and Pinout



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