

Analog Output Overview

Analog Output

National Instruments analog voltage and current output devices cover a full spectrum of applications from basic software-timed output to complex high-speed waveform generation.

Analog output (AO) is accomplished using a digital-to-analog converter (DAC). In hardware, the DAC is given a binary value, which it converts to an analog level that is within a given voltage or current range. A common voltage range is ± 10 V. DACs come with set resolution – commonly 12 or 16 bits. A 12-bit DAC can produce 4,096 voltage steps within its range. A 16-bit DAC can produce 65,536. Taking advantage of the NI-DAQ device driver, the user is able to define named analog output channels and update their values based on voltage levels or other defined engineering scales.

AO capabilities can be separated into two categories – static analog output and high-speed output.

Static Outputs

All National Instruments AO devices can generate software-timed single-point values. software-timed updates are typical for control applications. NI 6704 devices, for example, are software-timed devices that feature 32 channels of 16-bit AO that are updated by software commands.

Waveform Generation

Select AO devices are capable of high-speed or waveform output. Such devices typically have a FIFO and use DMA, so they can perform waveform generation at high rates with accurately timed updates. For example, NI 671x and NI 673x devices use both FIFOs and DMA to generate dynamic signals. You can use high-speed updates to generate simple waveforms, such as sine, square, and triangle waves, or more complex user-defined waveforms.

AO devices come in several configurations. You have the options with regard to channel count, update speed, output voltage range, digital I/O lines, and counter/timers.

Applications for waveform generation AO include stimulus for circuit testing, automotive component testing, audio signal generation, stimulus for vibration testing, and much more.



Multidevice Synchronization

Each AO device offers and uses integration technologies such as RTSI bus, PXI trigger bus, and PFI pins to trigger and synchronize to a wide variety of I/O types. These I/O types range from image acquisition, motion control, and high-speed digitizers to multifunction data acquisition (DAQ) devices. These integration infrastructures enable engineers/scientists to create powerful, custom test systems with ease.

Real-Time Control

All PXI AO devices can be used with LabVIEW Real-Time to deliver real-time, deterministic control loop execution. These densely packed AO devices can be integrated with other DAQ devices to serve a wide range of control needs. See page 134 for more details about LabVIEW Real-Time as well as other DAQ devices that are compatible with LabVIEW Real-Time.

Product	Bus	Analog Outputs	Output Resolution	Update Rate	Output Range	Digital I/O	Counter/Timers	Current Source/Sink	Triggers	Page
NI 6733	PCI, PXI	8	16 bits	1 MS/s ¹	± 10 V	8 ³	2, 24-bit	–	✓	363
NI 6731	PCI	4	16 bits	1 MS/s	± 10 V	8 ³	2, 24-bit	–	✓	363
NI 6713	PCI, PXI	8	12 bits	1 MS/s ¹	± 10 V	8	2, 24-bit	–	✓	363
NI 6715	PCMCIA	8	12 bits	1 MS/s ¹	± 10 V	8	2, 24-bit	–	✓	363
NI 6711	PCI, PXI	4	12 bits	1 MS/s	± 10 V	8	2, 24-bit	–	✓	363
NI 6704	PCI, PXI	32	16 bits	Static	± 10 V, 0 to 20 mA ²	8	–	✓	–	366
NI 6703	PCI	16	16 bits	Static	± 10 V	8	–	–	–	366

¹Maximum update rate decreases when all 8 channels updating simultaneously. ²The current output varies when set between 0 and 100 μ A. ³Static, high-speed pattern generation and acquisition.

Table 1. Analog Voltage and Current Output Devices

High-Speed Voltage Output – 1 MS/s/Channel, 12 or 16-Bit, 4 or 8 Channels

High-Speed Voltage Output

NI 671x, NI 673x

- 4 or 8 channels
- 12 or 16-bit analog output resolution
- 1 MS/s maximum output update rate
- 8 (5 V TTL/CMOS) digital I/O lines
- 2 up/down, 24-bit resolution counter/timers
- Digital triggering and external clocking
- NI-DAQ driver simplifies configuration and measurements

Models

- NI PCI-6711
- NI PXI-6711
- NI PCI-6713
- NI PXI-6713
- NI DAQCard-6715
- NI PCI-6731
- NI PCI-6733
- NI PXI-6733

Operating Systems

- Windows 2000/NT/XP
- Real-Time Performance with LabVIEW (page 134)
- Others such as Linux and Mac OS X (page 187)

Recommended Software

- LabVIEW
- LabWindows/CVI
- Measurement Studio

Other Compatible Software

- Visual Basic
- C/C++

Driver Software (included)

- NI-DAQ 7

Calibration Certificate Included

See page 21.



Overview

National Instruments NI 671x and NI 673x devices are 12 or 16-bit analog output sources for PCI, PXI, and PCMCIA. You get up to 1 MS/s per channel on four or eight analog outputs. In addition, these devices feature eight digital I/O lines; two 24-bit, 20 MHz counter/timers; and digital triggering capability. NI 673x devices are capable of both static and high-speed digital pattern generation and acquisition.

Hardware

Analog Output Channels

Each channel can generate waveform voltage outputs at up to 1 MS/s (rate varies with the number of channels used). The output channels typically settle to within less than ± 1.0 LSB of full scale within 3 μ s. The output range for all channels is ± 10 V, but you can use the external reference to select other output ranges for all channels. You can refer each individual analog output to the onboard voltage reference or to the external reference.

Waveform Generation

The NI 671x and 673x devices can simultaneously generate waveforms on up to eight channels. These devices use DMA transfers (except for the NI DAQCard-6715) and onboard FIFOs to output seamless high-speed waveforms. You can control the update rate with an onboard timer, or you can supply your own update or trigger signal.

Analog Signal Connector

The analog outputs are available through a 68-pin shielded connector. AO <0..7> are the AO channels. Each is referenced to AO GND. AO_EXT_REF is the external reference input. You can update the AO signal externally by applying a pulse at the external update pin PFI 5. A fused 5 VDC power signal from the PCI or PXI bus is available at the I/O connector.

Related Products

SCC or SCXI for isolated analog output See page 251 or 270.

Data Acquisition and Signal Conditioning

Product	Bus	Analog Outputs	Output Resolution	Update Rate	Output Range	Digital I/O	Counter/Timers	Triggers
NI 6711	PCI, PXI	4	12 bits	1 MS/s	± 10 V	8	2, 24-bit	Digital
NI 6713	PCI, PXI	8	12 bits	1 MS/s ¹	± 10 V	8	2, 24-bit	Digital
NI 6715	PCMCIA	8	12 bits	1 MS/s ¹	± 10 V	8	2, 24-bit	Digital
NI 6731	PCI	4	16 bits	1 MS/s	± 10 V	8 ²	2, 24-bit	Digital
NI 6733	PCI, PXI	8	16 bits	1 MS/s ¹	± 10 V	8 ²	2, 24-bit	Digital

¹Rate varies with number of channels used. ²Static or high speed pattern generation and acquisition.

Table 1. Channel, Speed, and Resolution Specifications (See page 372 for detailed specifications.)

High-Speed Voltage Output – 1 MS/s/Channel, 12 or 16-Bit, 4 or 8 Channels

High-Speed Voltage Output

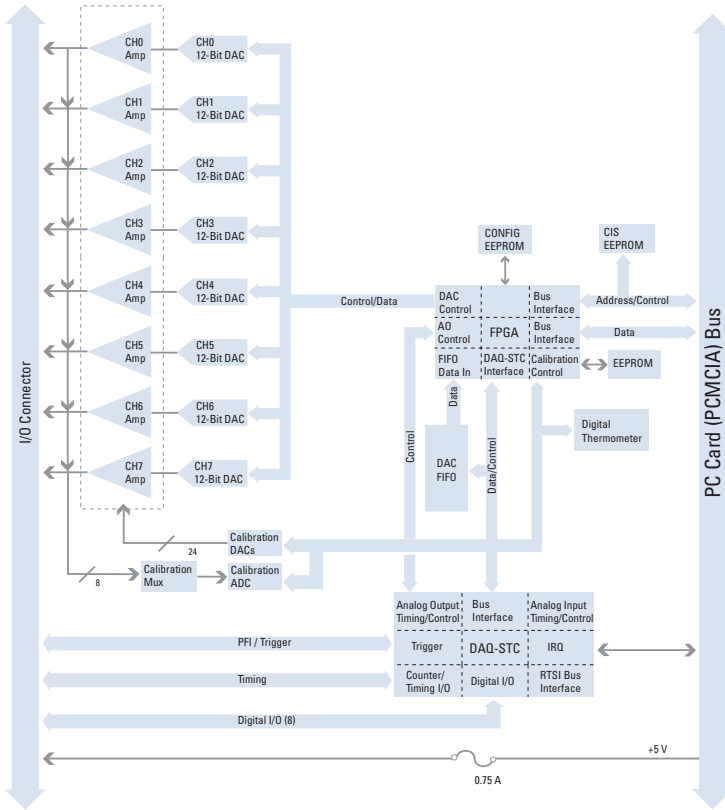


Figure 1. NI DAQcard-6715 Hardware Block Diagram

Data Acquisition and Signal Conditioning

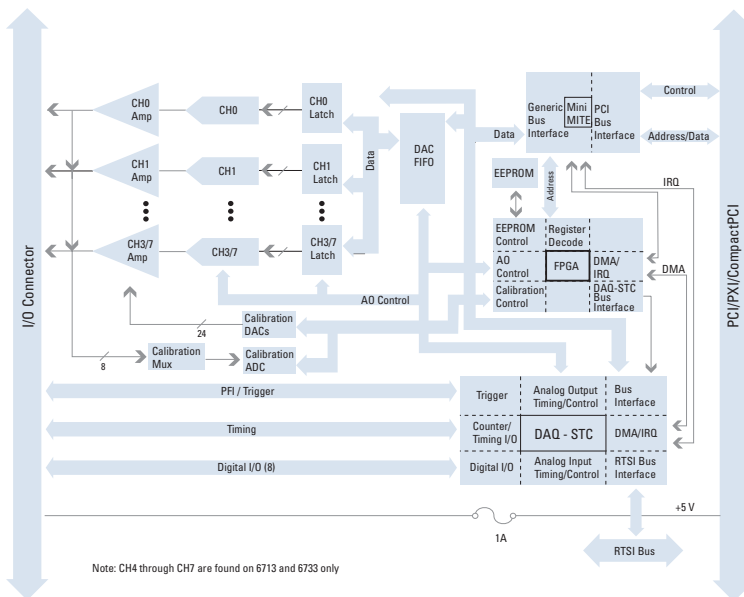


Figure 2. NI 671x and NI 673x Hardware Block Diagram

High-Speed Voltage Output – 1 MS/s/Channel, 12 or 16-Bit, 4 or 8 Channels

Product	Nominal Range (V)	Absolute Accuracy % of Reading			Offset (mV)	Temp Drift (%/°C)	Absolute Accuracy at Full Scale (mV)
		24 hrs	90 days	1 year			
NI 671x	±10	0.0177%	0.0197%	0.0219%	±5.933	0.0005%	±8.123
NI 673x	±10	0.0044%	0.0052%	0.0061%	±1.027	0.00006%	±1.637

Note: Temp Drift applies only if ambient is greater than ±10 °C of previous external calibration. Absolute Accuracy calculations assume full scale output after one year.

Table 2. NI 671x and NI 673x Analog Output Accuracy Specifications

AO_GND	34	68	NC
NC	33	67	AO_GND
AO_GND	32	66	AO_GND
AO_GND	31	65	AO_7*
AO_6*	30	64	AO_GND
AO_GND	29	63	AO_GND
AO_5*	28	62	NC
AO_GND	27	61	AO_GND
AO_GND	26	60	AO_4
AO_3	25	59	AO_GND
AO_GND	24	58	AO_GND
AO_GND	23	57	AO_2
AO_0	22	56	AO_GND
AO_1	21	55	AO_GND
EXTREF	20	54	AO_GND
PO4	19	53	D_GND
D_GND	18	52	DIO0
PO1	17	51	PO5
PO6	16	50	D_GND
D_GND	15	49	DIO2
+5 V	14	48	PO7
D_GND	13	47	PO3
D_GND	12	46	NC
PFI_0	11	45	EXTSTROBE
PFI_1	10	44	D_GND
DBND	9	43	PFI_2
+5 V	8	42	PFI_3/CTR_1_SOURCE
D_GND	7	41	PFI_4/CTR_1_GATE
PFI_5/AO_SAMP_CLK	6	40	CTR_1_OUT
PFI_6/AO_START_TRIG	5	39	D_GND
D_GND	4	38	PFI_7
PFI_9/CTR_0_GATE	3	37	PFI_8/CTR_0_SOURCE
CTR_0_OUTT	2	36	D_GND
FREQ_OUT	1	35	D_GND

* No Connect on 6711 or 6731

Figure 3. NI 671x and NI 673x I/O Connector

Ordering Information

NI PCI-6711	.....	777740-01
NI PXI-6711	.....	777794-01
NI PCI-6713	.....	777741-01
NI PXI-6713	.....	777795-01
NI DAQCard-6715	.....	778146-01
NI PCI-6731	.....	778511-01
NI PCI-6733	.....	778510-01
NI PXI-6733	.....	778512-01

Includes NI-DAQ driver software and calibration certificate.

Recommended Configurations

Family	Bus	Accessory	Cable
NI 6711	PCI, PXI	SCB-68 (776844-01)	SH68-68-EP (184749-01)
NI 6713	PCI, PXI	SCB-68 (776844-01)	SH68-68-EP (184749-01)
NI 6715	PCMCIA	SCB-68 (776844-01)	SHC68-68-EP (186838-01)
NI 6731	PCI	SCB-68 (776844-01)	SH68-68-EP (184749-01)
NI 6733	PCI, PXI	SCB-68 (776844-01)	SH68-68-EP (184749-01)

BUY ONLINE!

Visit ni.com/info and enter *pci6711*, *pxi6711*, *pci6713*, *pxi6713*, *daqcard6715*, *pci6731*, *pci6733*, or *pxl6733*.

Analog Output Specifications

Specifications – NI 671x and NI 673x

These specifications are typical at 25 °C unless otherwise stated.

Analog Output

Output Characteristics

Number of channels

NI 6715/6713/6733 8 voltage outputs

NI 6711/6731 4 voltage outputs

Resolution 12 bits, 1 in 4,096 (NI 671x),
16 bits, 1 in 65,536 (NI 673x)

Number of Channels	Maximum Update Rate (NI 671x/673x)		Max Update Rate (NI 6715)	
	Using Local FIFO (kS/s) ¹	Using Host Memory (kS/s) ²	Using Local FIFO (kS/s) ¹	Using Host Memory (kS/s) ²
1	1,000	1,000	1,000	800
2	1,000	1,000	850	400
3	1,000	1,000	750	266
4	1,000	1,000	650	200
5	1,000	1,000	600	160
6	952	1,000	550	133
7	833	869	510	114
8	740	769	480	100

¹ These numbers apply to continuous waveform generation, and will not change irrespective of the number of devices in the system. ² These numbers may change when using more devices or when other CPU or bus activity is taking place.

FIFO buffer size

NI 6713/6733 16,384 samples

NI 6711/6715/6731 8,192 samples

Data transfers DMA, interrupts, programmed I/O

DMA modes (PXI/PCI only) Scatter-gather

Transfer Characteristics

NI 671x

Relative accuracy ±0.5 LSB maximum

DNL ±1.0 LSB maximum

Monotonicity 12 bits, guaranteed after calibration

Gain error (relative to internal reference)

After calibration ±0.01% of output maximum

Before calibration ±0.5% of output maximum

Gain error (relative to external reference) at >4 V to +0.67% of output maximum, not adjustable

NI 673x

Relative accuracy ±2.2 LSB maximum

DNL ±1.0 LSB maximum

Monotonicity 16 bits, guaranteed after calibration

Gain error (relative to internal reference)

After calibration ±0.003% of output maximum

Before calibration ±0.9% of output maximum

Gain error (relative to external reference) ±0.1% of output maximum, not adjustable

Voltage Output (NI 671x and 673x)

Ranges ±10.0 V, ±AO EXT REF

Output coupling DC

Output impedance 0.1 Ω maximum

Current drive ±5 mA maximum (total not to exceed 20 mA for all

8 outputs combined on NI DAQCard 6715)

Output stability Any passive load, up to 1,500 pF

Protection Short-circuit to ground

Power-on state 0 V (±200 mV)

External reference input

Range ±11 V

Overvoltage protection

Powered on ±25 V

Powered off ±15 V

Input impedance 10 kΩ (NI 671x) 1mΩ (NI 673x)

Bandwidth (-3 dB) 1 MHz

Dynamic Characteristics

Settling time 3 μs to ±0.5 LSB accuracy (NI 671x)

5.0 μs to 0.5 LSB accuracy (NI 6715)

2.8 μs to ±1 LSB accuracy (NI 673x)

Slew rate 20 V/μs (NI 671x)

15 V/μs (NI 673x)

Noise 200 μV_{rms}, DC to 1 MHz (NI 671x)
80 μV_{rms}, DC to 1 MHz (NI 673x)
400 μV_{rms}, DC to 1 MHz (NI 6715)

Glitch energy (at mid-scale transition) (NI 671x only)

Magnitude

Reglitching disabled ±20 mV

Reglitching enabled ±4 mV

Duration 1.5 μs

Stability

Gain temperature coefficient

Internal reference ±25 ppm/°C (NI 671x), ±6.5 ppm/°C (NI 673x)

External reference ±25 ppm/°C (NI 671x), ±5 ppm/°C (NI 673x)

Digital I/O

Number of channels 8 input/output

Compatibility 5 V TTL/CMOS

Power-on state Input (high-impedance)

Data transfers Programmed I/O, DMA (NI 673x), interrupts (NI 673x)

Input buffer 2048 bytes (NI 673x)

Output buffer 2048 bytes (NI 673x)

Transfer rate 10 Mwords/s (NI 673x)

Digital logic levels

Level	Minimum	Maximum
Input low voltage	0 V	0.8 V
Input high voltage	2 V	5 V
Output low voltage (I _{out} = 24 mA)	–	0.4 V
Output high voltage (I _{out} = 13 mA)	4.35 V	–

Timing I/O

General-Purpose Up/Down Counter/Timers

Number of channels 2

Resolution 24 bits

Compatibility 5 V TTL/CMOS

Digital logic levels

Level	Minimum	Maximum
Input low voltage	0 V	0.8 V
Input high voltage	2 V	5 V
Output low voltage (I _{out} = 5 mA)	–	0.4 V
Output high voltage (I _{out} = 3.5 mA)	4.35 V	–

Base clocks available 20 MHz and 100 kHz

Base clock accuracy ±0.01% over operating temperature

Maximum source frequency 20 MHz

External source selections PFI <0..9>, RTSI <0..6> (except NI 6715)

software-selectable

External gate selections PFI <0..9>, RTSI <0..6> (except NI 6715)

software-selectable

Minimum source pulse duration 10 ns; edge-detect mode

Minimum gate pulse duration 10 ns; edge-detect mode

Data transfers DMA (except NI 6715), interrupts, programmed I/O

DMA modes (PCI/PXI only) Scatter-gather

Frequency Scaler

Number of channels 1

Resolution 4 bits

Compatibility 5 V TTL/CMOS

Base clocks available 10 MHz, 100 kHz

Base clock accuracy ±0.01%

Triggers

Digital

Purpose

Analog output Start trigger, gate, clock

General-purpose counter/timers Source, gate

Source PFI <0..9>, RTSI <0..6> (except NI 6715)

Slope Positive or negative; software selectable

Compatibility 5 V TTL/CMOS

Pulse width 10 ns minimum

Analog Output Specifications

Specifications – NI 671x and NI 673x (continued)

Calibration

Recommended warm-up time.....	15 minutes
Calibration interval.....	1 year
Onboard calibration reference	
DC Level.....	5,000 V (±2.5 mV); actual value stored in EEPROM
Temperature coefficient.....	±5 ppm/°C maximum (NI 671x) ±0.6 ppm/°C maximum (NI 673x)
Long-term stability.....	±15 ppm/√1,000 h (NI 671x) ±6 ppm/√1,000 h (NI 673x)

RTSI Bus (PCI Only)

Trigger lines.....	7
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PXI Trigger Bus (PXI Only)

Trigger lines.....	6
Star trigger.....	1

Bus Interface

PCI, PXI.....	Master, Slave
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Power Requirements

+5 VDC (±5%).....	1.0 A max for NI 6711 1.5 A max for NI 6713 250 mA max for NI 6715 1.8 A max for NI 6733 1.25 A max for NI 6731
+3.3 VDC (±5%).....	250 mA max for NI 6731/6733
Power available at I/O connector.....	+4.65 to +5.25 VDC, 1 A

Physical

Dimensions	
PCI.....	17.5 by 10.7 cm (6.9 by 4.2 in.)
PXI.....	16 by 10 cm (6.3 by 3.9 in.)
PCMCIA.....	Type II PC Card
I/O connectors	
PCI, PXI.....	68-pin male SCSI II
PCMCIA.....	68-pin female Honda connector

Environment

PCI, PXI	
Operating temperature.....	0 to 55 °C
Storage temperature.....	-20 to 70 °C
Relative humidity.....	10 to 90%, noncondensing
PCMCIA	
Operating temperature.....	0 to 50 °C
Storage temperature.....	-20 to 70 °C
Relative humidity.....	10 to 90%, noncondensing

Certifications and Compliances

CE Mark Compliance **CE**

Specifications – NI 6703, NI 6704

These specifications are typical at 25 °C unless otherwise stated.

Analog Output

Output Characteristics

Device	Channels		
	Voltage	Current	Total
NI 6703	16	0	16
NI 6704	16	16	32

Resolution.....	16 bits, 1 in 65,536
Type of DAC.....	Enhanced R-2R
Data transfers.....	Programmed I/O

Transfer Characteristics

Relative accuracy (INL).....	±1.0 LSB maximum
DNL.....	±1.0 LSB maximum
Monotonicity.....	16 bits, guaranteed after calibration

Voltage Output

Ranges.....	±10.1 V
Output coupling.....	DC

Output impedance.....	0.1 Ω maximum
Current drive.....	±10 mA maximum
Load capacitance.....	10,000 pF maximum
Protection.....	Short-circuit to ground
Absolute accuracy.....	±1 mV maximum
Power-on state.....	Independent, user-defined

Current Output (NI 6704 Only)

Range.....	0.0; 0.1 to 20.2 mA
Type.....	Source, does not require external excitation source
Output impedance.....	1 GΩ minimum
Output compliance.....	0 to 10 V
Protection.....	Short circuit and open circuit
Absolute accuracy.....	±2 μA maximum
Power-on state.....	Independent, user-defined

Dynamic Characteristics

Settling time	
NI 6703.....	7.2 ms to ± 0.001% typ.
NI 6704.....	14.4 ms to ± 0.001% typ.

Stability

Offset temperature coefficient	
Voltage.....	5 μV/°C
Current.....	10 nA/°C
Gain temperature coefficient	
Voltage.....	±1 ppm/°C
Current.....	±2 ppm/°C

Digital I/O

Digital logic levels

Level	Minimum	Maximum
Input low voltage	0V	0.8 V
Input high voltage	2 V	5 V
Output low voltage (I _{out} = 16 mA)	–	0.45 V
Output high voltage (I _{out} = 16 mA)	2.4 V	–

Number of channels.....	8 input/output
Compatibility.....	5 V TTL/CMOS
Power-on state.....	Input (high impedance)

Calibration

Recommended warm-up time.....	15 minutes
Calibration interval.....	1 year
Onboard calibration reference	
DC Level.....	10,000 V (±1 mV, actual value stored in EEPROM)
Temperature coefficient.....	±0.6 ppm/°C max
Long-term stability.....	±6 ppm/√1,000 h

Bus Interface

PCI, PXI.....	Slave
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Power Requirements

+5 VDC (±5%).....	NI 6703..... 1.1 A maximum NI 6704..... 1.8 A maximum
+12 VDC (±5%).....	70 mA maximum
-12 VDC (±5%).....	70 mA maximum
Power available at I/O connector.....	+4.65 to +5.25 VDC, 0.75 A

Physical

Dimensions (not including connectors)	
PCI.....	17.5 by 10.7 cm (6.9 by 4.2 in.)
PXI.....	16.0 by 10.0 cm (6.3 by 3.9 in.)
I/O connector.....	68-pin male SCSI-II type

Environment

Operating temperature.....	0 to 55 °C
Storage temperature.....	-20 to 70 °C
Relative humidity.....	10 to 90%, noncondensing

Certifications and Compliances

CE Mark Compliance **CE**

Analog Output Accessories and Cables



Figure 1. BNC-2110 I/O Connector Block



Figure 2. SCB-68 Shielded I/O Connector Blocks



Figure 3. CA-1000 Custom Connectivity Enclosure



Figure 4. TBX-68 I/O Connector Block

Device	Cables	Accessories
NI 6711	SH68-68-EP	SCB-68, TBX-68
NI 6713	SH68-68R1-EP	CB-68LP, CB-68LPR
NI 6731	R6868	BNC-2110
NI 6733		CA-1000
	SH68-50	CB-50LP
	N/A	TB-2705 (PXI only)
NI 6715	SHC68-68-EP	SCB-68, TBX-68
	SHC68U-68-EP	CB-68LP, CB-68LPR
	RC68-68	BNC-2110
	Above cables plus 68M-50F	CA-1000 CB-50LP
NI 6703	SH68-68-D1	SCB-68, TBX-68
NI 6704	R6868	CB-68LP, CB-68LPR
		CA-1000

Table 1. Accessory and Cable Selection Guide

I/O Connector Blocks

BNC-2110 I/O Connector Block (See Figure 1)

The BNC-2110 is a shielded connector block with signal-labeled BNC connectors for easy connectivity of your analog output (AO), digital I/O (DIO), and counter/timer signals.

BNC-2110777643-01

Dimensions – 20.3 by 11.2 by 5.5 cm (8.0 by 4.4 by 2.2 in.)

SCB-68 Shielded I/O Connector Blocks (See Figure 2)

The SCB-68 is a shielded I/O connector block giving you rugged, very low-noise signal termination. The SCB-68 also houses silk-screened component locations for easy addition of simple signal conditioning circuitry for your AO channels.

SCB-68776844-01

Dimensions – 19.5 by 15.2 by 4.5 cm (7.7 by 6.0 by 1.8 in.)

CA-1000 Custom Connectivity Enclosure (See Figure 3)

The CA-1000 is a configurable enclosure that gives you user-defined connectivity and flexibility through customized panelettes.

CA-1000See page 351

Dimensions – 30.7 by 25.4 by 4.3 cm (12.1 by 10 by 1.7 in.)

TBX-68 I/O Connector Block with DIN-Rail Mounting (See Figure 4)

The TBX-68 is a termination accessory with 68 screw terminals for easy connection of field signals to 68-pin DAQ devices. It includes one 68-pin male connector for direct connection to 68-pin cables. The TBX-68 is mounted in a protective plastic base with hardware for mounting on a standard DIN rail.

TBX-68777141-01

Dimensions – 12.50 by 10.74 cm (4.92 by 4.23 in.)