

# ***Motion Control***

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## **NI 7350 User Manual**

## **Worldwide Technical Support and Product Information**

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## Compliance with FCC/Canada Radio Frequency Interference Regulations

### Determining FCC Class

The Federal Communications Commission (FCC) has rules to protect wireless communications from interference. The FCC places digital electronics into two classes. These classes are known as Class A (for use in industrial-commercial locations only) or Class B (for use in residential or commercial locations). All National Instruments (NI) products are FCC Class A products.

Depending on where it is operated, this Class A product could be subject to restrictions in the FCC rules. (In Canada, the Department of Communications (DOC), of Industry Canada, regulates wireless interference in much the same way.) Digital electronics emit weak signals during normal operation that can affect radio, television, or other wireless products.

All Class A products display a simple warning statement of one paragraph in length regarding interference and undesired operation. The FCC rules have restrictions regarding the locations where FCC Class A products can be operated.

Consult the FCC Web site at [www.fcc.gov](http://www.fcc.gov) for more information.

### FCC/DOC Warnings

This equipment generates and uses radio frequency energy and, if not installed and used in strict accordance with the instructions in this manual and the CE marking Declaration of Conformity\*, may cause interference to radio and television reception. Classification requirements are the same for the Federal Communications Commission (FCC) and the Canadian Department of Communications (DOC).

Changes or modifications not expressly approved by NI could void the user's authority to operate the equipment under the FCC Rules.

### Class A

#### Federal Communications Commission

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user is required to correct the interference at their own expense.

#### Canadian Department of Communications

This Class A digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

Cet appareil numérique de la classe A respecte toutes les exigences du Règlement sur le matériel brouilleur du Canada.

### Compliance with EU Directives

Users in the European Union (EU) should refer to the Declaration of Conformity (DoC) for information pertaining to the CE marking. Refer to the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, visit [ni.com/hardref.nsf](http://ni.com/hardref.nsf), search by model number or product line, and click the appropriate link in the Certification column.

\* The CE marking Declaration of Conformity contains important supplementary information and instructions for the user or installer.

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# About This Manual

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This manual describes the electrical and mechanical aspects of the PXI/PCI-7350 controller and contains information concerning its installation and operation.

The 7350 controller is designed for PXI, CompactPCI, and PCI bus computers.

## Conventions

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This manual uses the following conventions:

- <> Angle brackets that contain numbers separated by an ellipsis represent a range of values associated with a bit or signal name—for example, DIO<3..0>.
- » 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.
- ◆ The ◆ symbol indicates that the following text applies only to a specific product, a specific operating system, or a specific software version.
-  This icon denotes a tip, which alerts you to advisory information.
-  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 in the software, such as menu items and dialog box options. Bold text also denotes parameter names.
- italic* Italic text denotes variables, emphasis, a cross reference, or an introduction to a key concept. This font 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.

## Related Documentation

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The following documents contain information you might find helpful as you read this manual:

- *NI-Motion Function Help*
- *NI-Motion VI Help*
- *NI-Motion User Manual*
- *Getting Started With NI-Motion Control*
- *PXI Specification, Revision 2.1*
- *PCI Local Bus Specification, Revision 2.2*
- The technical reference manual for the computer you are using

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# Introduction

This chapter describes the PXI/PCI-7350 controller and its operation.

## About the 7350 Controller

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The 7350 controller features advanced motion control with easy-to-use software tools and add-on motion VI libraries for use with LabVIEW.

### Features

The 7350 controller is a combination servo and stepper motor controller for PXI, CompactPCI, and PCI bus computers. It provides fully-programmable motion control for up to eight independent axes of motion. Coordinated motion is supported through multi-dimensional coordinate spaces. Each axis provides dedicated motion I/O for limit and home switches and additional I/O for general-purpose functions.

You can use the 7350 controller for point-to-point and straight-line vector moves. The 7350 also performs arbitrary and complex motion trajectories through circular interpolation and contouring.

Servo axes can control DC brushed or brushless servo motors, servo hydraulics, servo valves, and other servo devices, such as closed-loop piezo motor systems. Servo axes always operate in closed-loop mode. These axes use quadrature encoders or analog inputs for position and velocity feedback and provide analog command outputs with an industry-standard range of  $\pm 10$  V.

Stepper axes control stepper motors in either open or closed-loop mode. They use quadrature encoders or analog inputs for position feedback (closed-loop only), and provide step/direction or clockwise (CW)/counter-clockwise (CCW) digital command outputs. All stepper axes support full, half, and microstepping applications.

### Hardware

Because of its advanced dual-processor architecture for embedded real-time control, the 7350 controller has high-performance capabilities.

This powerful functionality provides high-speed communications while off-loading complex motion functions from the host PC for maximum command throughput and system performance.

The 7350 features motion profiles that are controlled with enhanced *PID/PIVff* high-speed servo update rates. The update rate depends on the number of axes enabled. Refer to Appendix A, *Specifications*, for more information.

Each axis has motion I/O for end-of-travel limit and home switch inputs, breakpoint output, trigger input, hall effect sensor input, and encoder feedback. The 7350 controller also has non-dedicated user I/O including 64 bits of digital I/O and eight analog inputs for  $\pm 10$  V signals, joystick inputs, or analog sensor monitoring. Additionally, the 7350 analog inputs can provide feedback for loop closure.

## RTSI

The 7350 controller supports the National Instruments Real-Time System Integration (RTSI) bus. The RTSI bus provides high-speed connectivity between National Instruments products, including image acquisition (IMAQ) and data acquisition (DAQ) products. Using the RTSI bus, you can easily synchronize several functions to a common trigger or timing event across multiple motion, IMAQ, or DAQ devices.

## What You Need to Get Started

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To set up and use the 7350 controller, you must have the following items:

- NI PXI-7350 controller or PCI-7350 controller
- NI-Motion 6.1 or later driver software and documentation
- One of the following software packages and documentation:
  - LabVIEW 6.0 or later
  - LabWindows™/CVI™
  - Measurement Studio
  - C/C++
  - Microsoft Visual Basic
- A computer with an available PXI, CompactPCI, or PCI slot

# Software Programming Choices

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The 7350 controller comes with a simple but powerful high-level application programming interface (API) that makes it easy to program. You can execute all setup and motion control functions by calling into a dynamically-linked library (DLL). You can use the full function set implementations for LabVIEW, LabWindows/CVI, and other industry-standard software programs, or call the NI-Motion libraries from C, Visual Basic, and other high-level languages.

## National Instruments Application Software

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LabVIEW is based on the graphical programming language, G, and features interactive graphics and a state-of-the-art user interface. In LabVIEW, you can create 32-bit compiled programs and stand-alone executables for custom automation, data acquisition, test, measurement, and control solutions. National Instruments offers the NI-Motion VI Library, which is a series of virtual instruments (VIs) for using LabVIEW with National Instruments motion control hardware. The NI-Motion VI library implements the full API, along with a useful set of example programs.

ANSI C-based LabWindows/CVI also features interactive graphics and a state-of-the-art user interface. Using LabWindows/CVI, you can generate C code for custom data acquisition, test, measurement, and automation solutions. The NI-Motion software includes a series of example programs for using LabWindows/CVI with National Instruments motion control hardware.

NI Motion Assistant offers a point-and-click interface for creating motion control sequences quickly and easily. When you have created a motion task, you can use Motion Assistant to output the task in LabVIEW code or code recipes.

## Optional Equipment

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National Instruments offers a variety of products for use with the 7350 controller, including the following accessories:

- Cables and cable assemblies for motion and digital I/O
- Universal Motion Interface (UMI) wiring connectivity blocks with integrated motion signal conditioning and motion inhibit functionality
- Stepper and servo motor compatible drive amplifier units with integrated power supply and wiring connectivity
- Connector blocks and shielded and unshielded 68-pin screw terminal wiring aids
- RTSI bus cables

For more specific information about these products, refer to the National Instruments catalog, the National Instruments Web site at [ni.com](http://ni.com), or call your National Instruments sales representative.

## Motion I/O Connections

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The external motion and digital I/O connectors on the 7350 controller are high-density, 68-pin female VHDCI connectors.

For custom cables, use the AMP mating connector (part number 787801-01).

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# Configuration and Installation

This chapter describes how to configure and install the PXI/PCI-7350 controller.

## Software Installation

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Before installing the 7350 controller, install the NI-Motion software and, if appropriate, the NI-Motion VI libraries. Refer to the release notes included with the controller for specific instructions for the software installation sequence for the host PC.

## Controller Configuration

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Because the motion I/O-related configuration of 7350 controller is performed entirely with software, it is not necessary to set jumpers for motion I/O configuration.

The PXI-7350 and PCI-7350 controllers are fully compatible with the industry standard *PXI Specification*, Revision 2.1 and the *PCI Local Bus Specification*, Revision 2.2, respectively. This compatibility allows you to configure the computer to automatically perform all bus-related configuration without user interaction. It is not necessary to configure jumpers for bus-related configuration.



**Note** When adding or removing a controller from a Windows 2000/NT/XP system, you must be logged on with administrator-level access. After you have restarted the system, you may need to refresh Measurement & Automation Explorer (MAX) to view the new controller.

# Safety Information

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**Caution** The following section contains important safety information that you *must* follow when installing and using the device.

Do *not* operate the device in a manner not specified in this document. Misuse of the device can result in a hazard. You can compromise the safety protection built into the device if the device is damaged in any way. If the device is damaged, return it to National Instruments (NI) for repair.

Do *not* substitute parts or modify the device except as described in this document. Use the device only with the chassis, modules, accessories, and cables specified in the installation instructions. You *must* have all covers and filler panels installed during operation of the device.

Do *not* operate the device in an explosive atmosphere or where there may be flammable gases or fumes. If you must operate the device in such an environment, it must be in a suitably rated enclosure.

If you need to clean the device, use a soft, nonmetallic brush. Make sure that the device is completely dry and free from contaminants before returning it to service.

Operate the device only at or below Pollution Degree 2. Pollution is foreign matter in a solid, liquid, or gaseous state that can reduce dielectric strength or surface resistivity. The following is a description of pollution degrees:

- Pollution Degree 1 means no pollution or only dry, nonconductive pollution occurs. The pollution has no influence.
- Pollution Degree 2 means that only nonconductive pollution occurs in most cases. Occasionally, however, a temporary conductivity caused by condensation must be expected.
- Pollution Degree 3 means that conductive pollution occurs, or dry, nonconductive pollution occurs that becomes conductive due to condensation.



**Note** The 7350 is intended for indoor use only.

You *must* insulate signal connections for the maximum voltage for which the device is rated. Do *not* exceed the maximum ratings for the device. Do *not* install wiring while the device is live with electrical signals. Do not remove or add connector blocks when power is connected to the system.

Remove power from signal lines before connecting them to or disconnecting them from the device.

Operate the device at or below the installation category<sup>1</sup> marked on the hardware label. Measurement circuits are subjected to working voltages<sup>2</sup> and transient stresses (overvoltage) from the circuit to which they are connected during measurement or test. Installation categories establish standard impulse withstand voltage levels that commonly occur in electrical distribution systems. The following is a description of installation categories:

- Installation Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS<sup>3</sup> voltage. 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.
- Installation Category II is for measurements performed on circuits directly connected to the electrical distribution system. This category refers to local-level electrical distribution, such as that provided by a standard wall outlet (for example, 115 AC voltage for U.S. or 230 AC voltage for Europe). Examples of Installation Category II are measurements performed on household appliances, portable tools, and similar devices/modules.
- Installation Category III is for measurements performed in the building installation at the distribution level. This category refers to measurements on hard-wired equipment such as equipment in fixed installations, distribution boards, and circuit breakers. Other examples are wiring, including cables, bus bars, junction boxes, switches, socket outlets in the fixed installation, and stationary motors with permanent connections to fixed installations.
- Installation Category IV is for measurements performed at the primary electrical supply installation (<1,000 V). Examples include electricity meters and measurements on primary overcurrent protection devices and on ripple control units.

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<sup>1</sup> Installation categories, also referred to as *measurement categories*, are defined in electrical safety standard IEC 61010-1.

<sup>2</sup> Working voltage is the highest rms value of an AC or DC voltage that can occur across any particular insulation.

<sup>3</sup> MAINS is defined as a hazardous live electrical supply system that powers equipment. Suitably rated measuring circuits may be connected to the MAINS for measuring purposes.



# Hardware Installation

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You can install the 7350 controller in any open compatible expansion slot in the computer. Appendix A, *Specifications*, lists the maximum power required for the 7350 controller.

The following instructions are for general installation. Refer to the computer user manual or technical reference manual for specific instructions and warnings.



**Caution** The 7350 controller is a sensitive electronic device shipped in an antistatic bag. Open only at an approved workstation and observe precautions for handling electrostatic-sensitive devices.

◆ PXI-7350

1. Power off and unplug the chassis.



**Caution** To protect yourself and the chassis from electrical hazards, the computer should remain unplugged until the installation is complete.

2. Choose an unused +3.3 V or +5 V peripheral slot and remove the filler panel.
  3. Touch a metal part on the chassis to discharge any static electricity that might be on your clothes or body. Static electricity can damage the controller.
  4. Insert the PXI controller into the chosen slot. Use the injector/ejector handle to fully inject the device into place.
  5. Screw the front panel of the PXI controller to the front panel mounting rails of the chassis.
  6. Visually verify the installation.
  7. Plug in and power on the chassis.
- ◆ PCI-7350
1. Power off and unplug the computer.



**Caution** To protect yourself and the computer from electrical hazards, the computer should remain unplugged until the installation is complete.

2. Remove the cover to expose access to the PCI expansion slots.

3. Choose an unused +3.3 V or +5 V PCI slot, and remove the corresponding expansion slot cover on the back panel of the computer.
4. Touch a metal part on the computer case to discharge any static electricity that might be on your clothes or body before handling the controller. Static electricity can damage the controller.
5. Gently rock the controller into the slot. The connection may be tight, but do *not* force the controller into place.
6. If required, screw the mounting bracket of the controller to the back panel rail of the computer.
7. Replace the cover.
8. Plug in and power on the computer.



**Caution** Make sure you have correctly connected all safety devices before you power on the motion system. Safety devices include inhibits, limit switches, and emergency shut down circuits.



**Caution** Always power on the 7350 controller before you power on the rest of the motion system. Power off in the reverse order, leaving the 7350 controller until last.



**Note** When adding or removing a controller from a Windows 2000/NT/XP system, you must be logged on with administrator-level access. After you have restarted the system, you may need to refresh MAX to view the new controller.

## Connecting Brushless Servo Motors

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The 7350 controller can connect to brushless servo drives that perform sinusoidal commutation or to drives that do not. When connecting to a drive that performs the sinusoidal commutation, only one DAC output is required per axis. For information about configuring the NI-Motion software to work with this type of system, refer to the *NI-Motion User Manual*.

When connected to a drive that does not perform the sinusoidal commutation, the 7350 commutates the first two phases and the servo drive determines the third. Therefore, two DAC outputs are required per axis. Refer to the *Measurement & Automation Explorer Help for Motion* for information about configuring the NI-Motion software for brushless servo motors.

## Connecting the Hall Effect Sensors

Before the 7350 can calculate the commutation values, some form of initialization is necessary to determine the initial commutation phase angle of the brushless motor each time the controller is powered on, reset, or reconfigured.

One method of initialization is to connect Hall effect sensors to detect the commutation phase angle of the motor. You can specify how the system is configured in MAX.



**Tip** If you do not connect Hall effect sensors, you can set the commutation phase angle directly, or through a process called *shake and wake*. Shake and wake requires moving the motors to the 0° angle and setting the commutation phase angle to match.

It is important to correctly connect the Hall effect sensors to the controller so that the sensors accurately determine the commutation phase angle. Complete the following steps to connect the Hall effect sensors.

1. Locate the Hall effect sensor phase sequence diagram that applies to the motor you are using. The manufacturer of the motor should provide this diagram with the motor documentation.



**Note** The 7350 controller can use Hall effect sensors having three sensor outputs per motor. Each output is 120 degrees out of phase from the previous output.

2. Wire the Hall sensors based on the Hall effect sensor phase sequence diagram for the motor and Figures 2-1 and 2-2.

Match the Hall effect sensor phase sequence diagram for the motor with one of the diagrams in Figures 2-1 and 2-2. The diagrams on the left represent the diagram supplied with the motor. The diagrams on the right represent the expected inputs to the UMI or 7350. The arrows in the middle show the correct path to wire the Hall effect sensor outputs into the UMI or 7350 inputs.

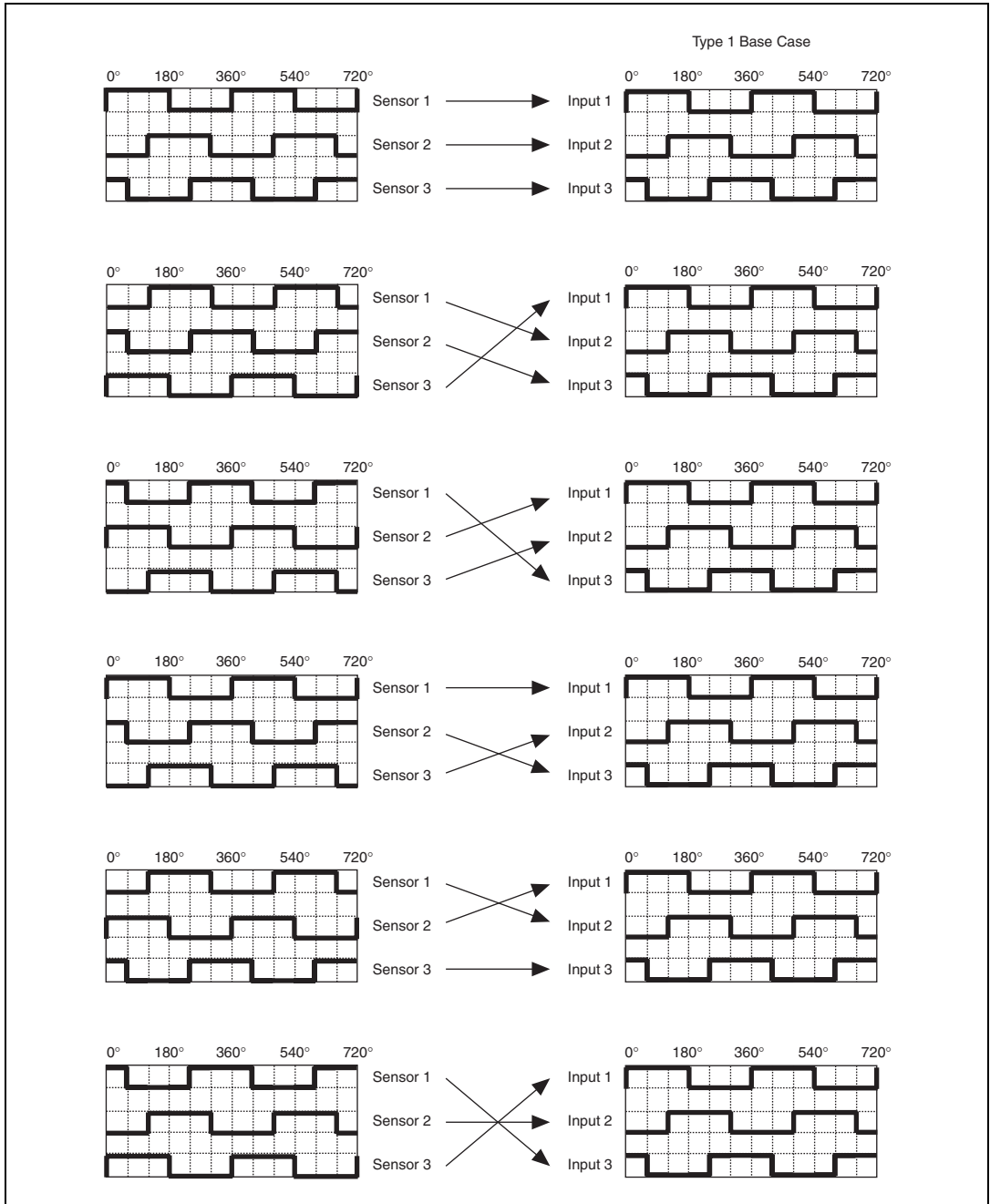


Figure 2-1. Type 1 Hall Sensor Wiring Diagrams

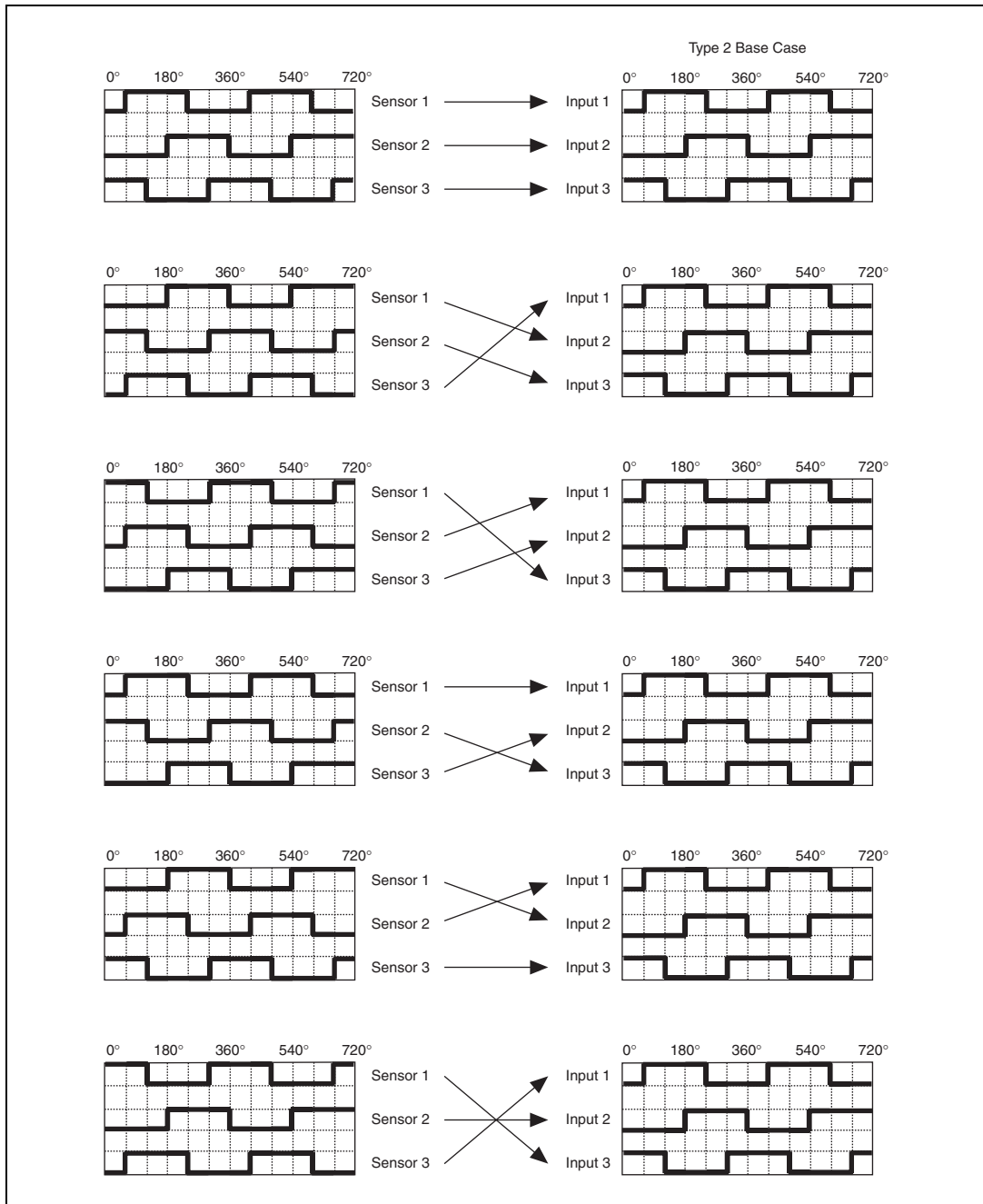


Figure 2-2. Type 2 Hall Sensor Wiring Diagrams

For example, if the diagram supplied with the motor matches the third Type 2 diagram, wire Hall effect sensor 1 to input 3 on the UMI or 7350, and then wire sensor 2 to input 1 and sensor 3 to input 2.

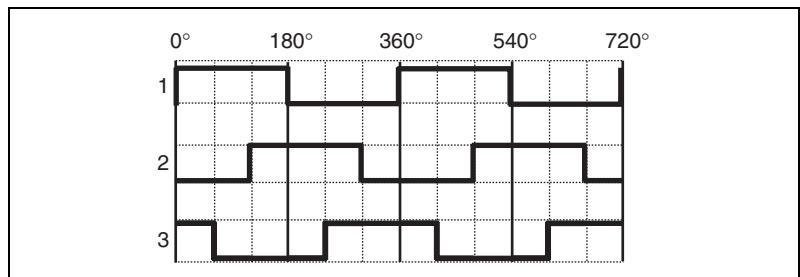
The Hall effect sensor inputs for Axes 1, 2, 5, and 6 are defined as follows:

- Axis 1 uses digital port 4, bits 2–4, with bit 2 as input 1.
- Axis 2 uses digital port 4, bits 5–7, with bit 5 as input 1.
- Axis 5 uses digital port 8, bits 2–4, with bit 2 as input 1.
- Axis 6 uses digital port 8, bits 5–7, with bit 5 as input 1.

Refer to Figure 5-6, *68-Pin Digital I/O Connector Pin Assignments (Ports 1–4)*, and Figure 5-7, *68-Pin Digital I/O Connector Pin Assignments (Ports 5–8)*, for detailed pinouts of the digital I/O connectors.

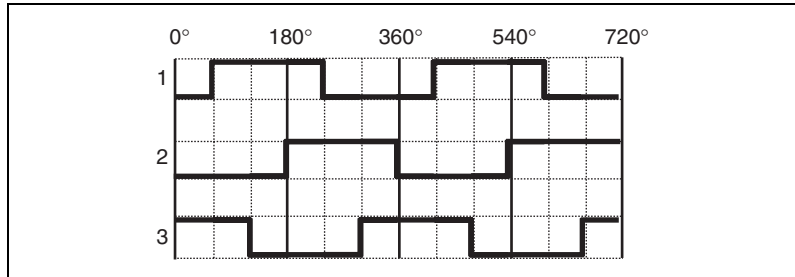
3. Configure the system in MAX. There are two base types of Hall effect sensor inputs. Set the NI-Motion software to the base sensor type you are using.

If the motor documentation matches any of the patterns in Figure 2-1, you are using Type 1, which matches the graph in Figure 2-3.



**Figure 2-3.** Type 1 Hall Sensor Phasing Sequence Diagram

If the motor documentation matches any of the patterns in Figure 2-2, you are using Type 2, which matches the graph in Figure 2-4.



**Figure 2-4.** Type 2 Hall Sensor Phasing Sequence Diagram

Refer to the *Measurement & Automation Explorer Help for Motion* for information about configuring the NI-Motion software for brushless servo motors.

## Connecting the Motor Leads

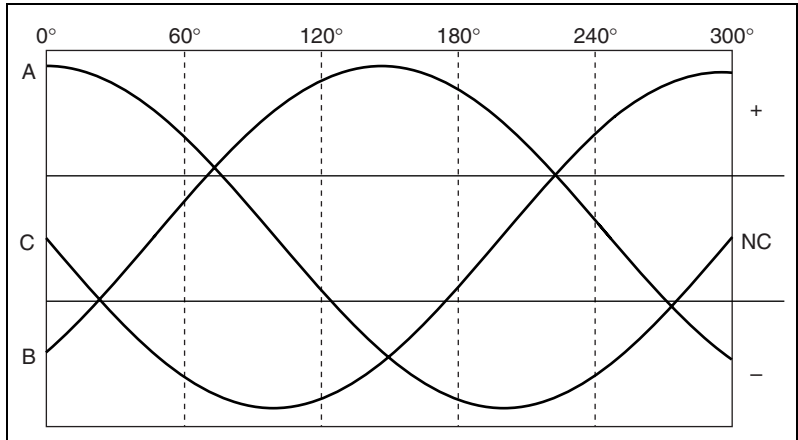
For the brushless motor to generate maximum torque, the motion system must output the commutation on the three motor phases correctly. Two of the phases are controlled by the 7350 controller, and the third phase is generated by the drive.

The primary output of the 7350 wires into the primary input of the drive. The secondary output wires into the secondary input of the drive. Use MAX to set the primary and secondary outputs of the 7350.

When you wire the brushless motor to the drive, use the commutation diagram for the motor as a reference. The manufacturer of the motor typically provides this diagram with the motor documentation. The commutation diagram shows the expected value on each of the motor leads at each angle in the commutation phase, typically in 60-degree increments. Table 2-1 shows an example of a motor phasing commutation diagram, and Figure 2-5 shows the corresponding graphical representation.

**Table 2-1.** Motor Phasing Diagram

Motor Lead	0°	60°	120°	180°	240°	300°
A	+	+	NC	-	-	NC
B	-	NC	+	+	NC	-
C	NC	-	-	NC	+	+



**Figure 2-5.** Sine Wave Motor Phasing Diagram

Table 2-2 shows the correct method of wiring a brushless motor to the drive.

**Table 2-2.** Correct Wiring Diagram At 0° Commutation Phase

Drive Motor Output	Brushless Motor Lead State
1	No Current (NC)
2	Positive Current
3	Negative Current

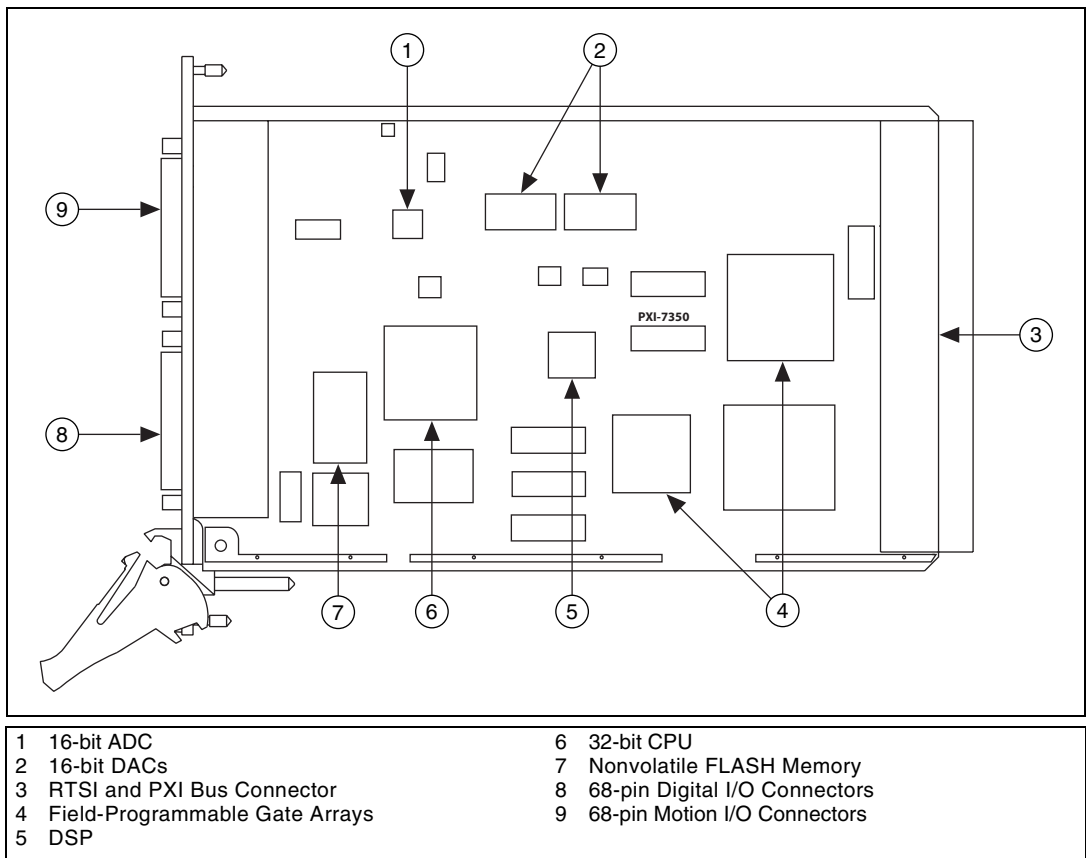
For example, if the motor has the phasing characteristics described in Table 2-1, wire the motor lead C to the motor output 1 on the drive. You wire the lead this way because the motor lead C calls for No Current at 0° Commutation Phase, and drive motor output 1 matches the No Current requirement. Similarly, wire motor lead A to motor output 2 and motor lead B to motor output 3 on the drive.



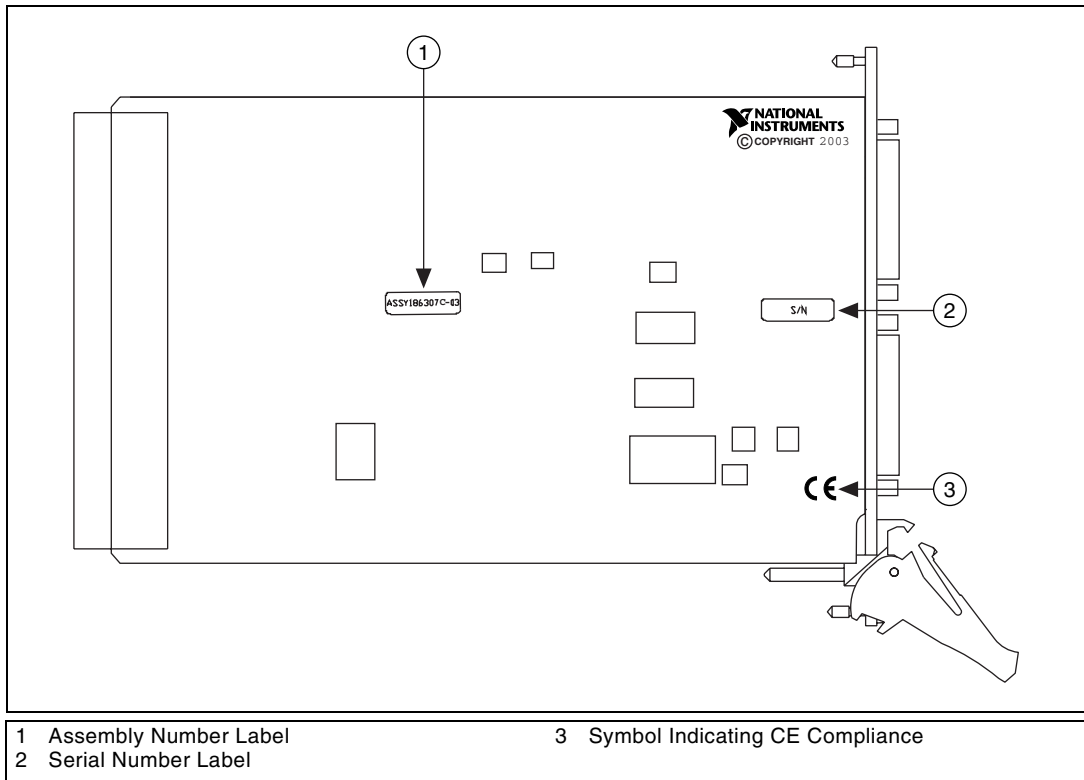
## Hardware Overview

This chapter presents an overview of the PXI/PCI-7350 controller hardware functionality.

Figures 3-1 and 3-2 show the PXI-7350 parts locator diagrams.

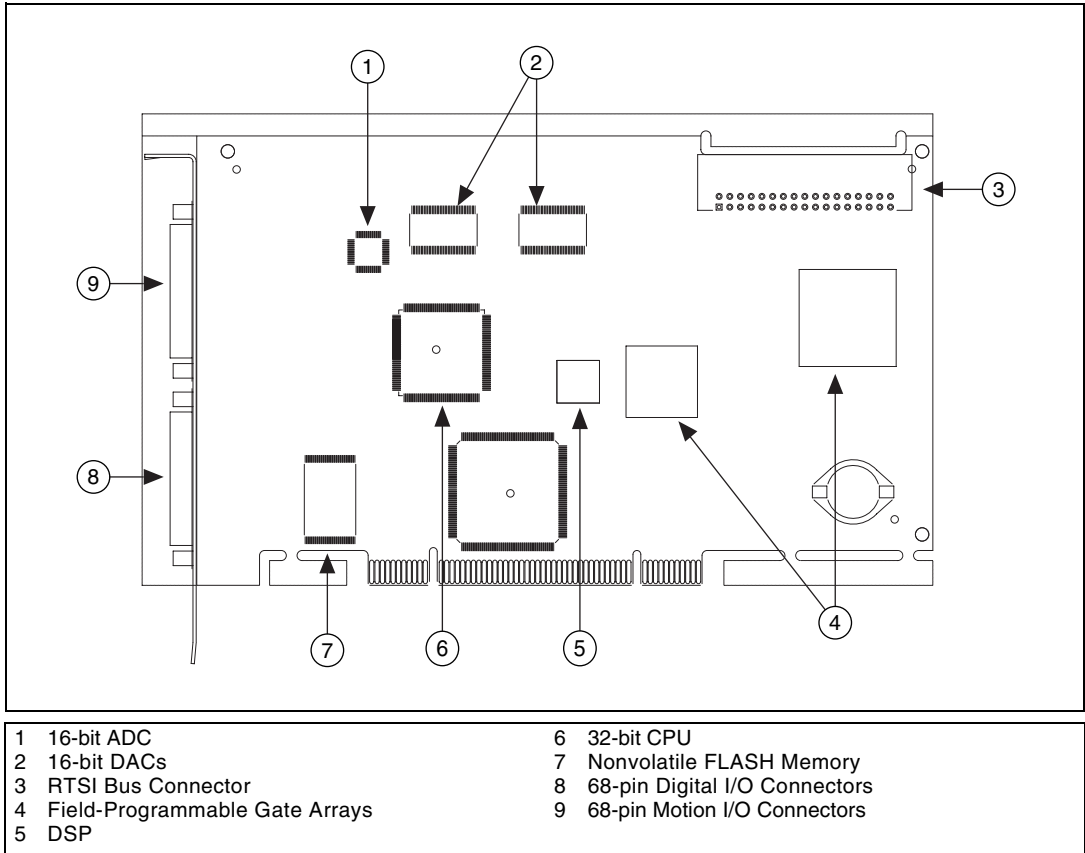


**Figure 3-1.** PXI-7350 Parts Locator Diagram (Front Panel)

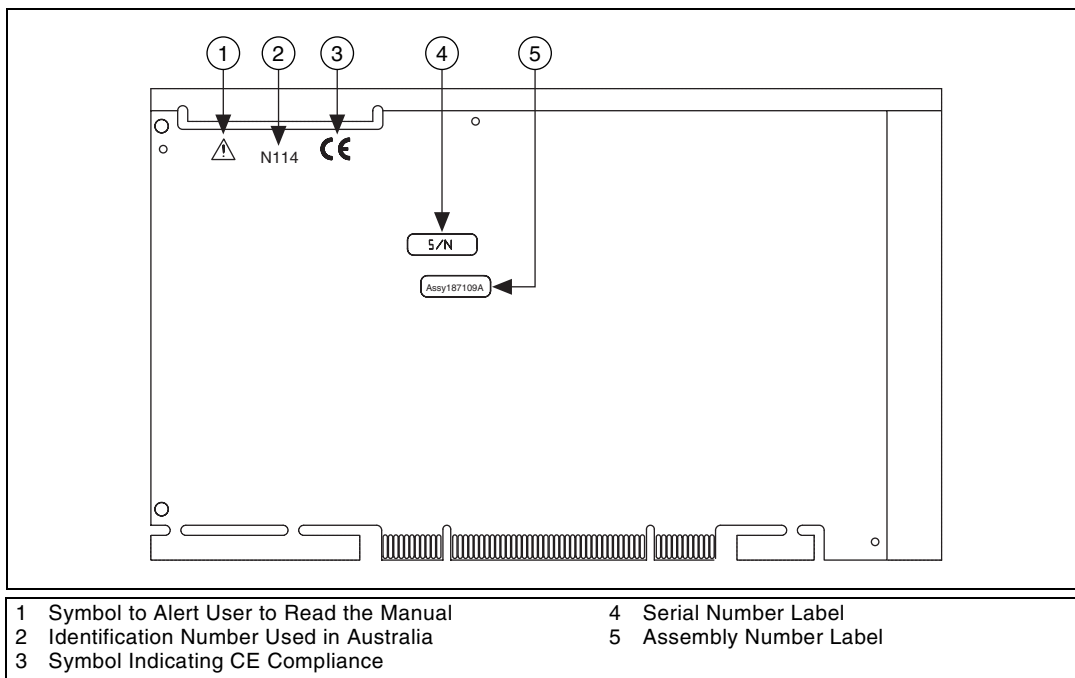


**Figure 3-2.** PXI-7350 Parts Locator Diagram (Back Panel)

Figures 3-3 and 3-4 show the PCI-7350 parts locator diagrams.



**Figure 3-3.** PCI-7350 Parts Locator Diagram (Front Panel)



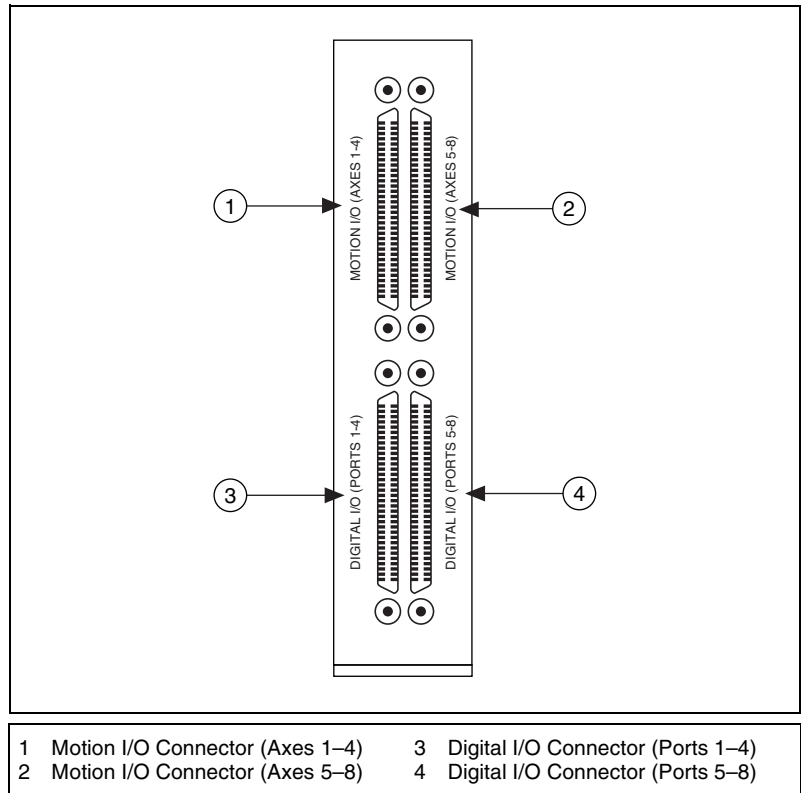
**Figure 3-4.** PCI-7350 Parts Locator Diagram (Back Panel)

## User Connectors

The two 68-pin motion I/O connectors provide all the signals for up to eight axes of closed-loop motion control, including encoder feedback, limit and home inputs, breakpoint outputs, trigger inputs, and analog-to-digital (A/D) converter signals. Refer to Chapter 5, *Signal Connections*, for details about the signals in the motion I/O connectors.

The two 68-pin digital I/O connectors provide 64 bits of user-configurable digital I/O, including 12 inputs for four Hall effect sensors. Refer to Chapter 5, *Signal Connections*, for details about the signals in the digital I/O connectors.

Figure 3-5 shows the four 68-pin I/O connectors on the 7350 motion controller.



**Figure 3-5.** PXI/PCI-7350 68-pin Connectors

The RTSI connection provides up to eight triggers and one PXI star trigger (PXI-7350 only) to facilitate synchronization between multiple RTSI-enabled National Instruments products. Typical applications of the RTSI bus include triggering an image acquisition or DAQ measurement based on motion events, or capturing current motion positions based on events external to the motion controller. You also can use the RTSI bus for general hardware-based communication between RTSI devices.

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# Functional Overview

This chapter provides an overview of the PXI/PCI-7350 controller architecture and its capabilities.

## Dual Processor Architecture

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The 7350 controller can perform up to eight axes of simultaneous motion control in a preemptive, multitasking, real-time environment.

An advanced dual-processor architecture, 32-bit CPU, digital signal processor (DSP) for embedded real-time control, and custom FPGAs give the 7350 controller high-performance capabilities. The powerful function set provides high-speed communications while off-loading complex motion functions from the host PC for optimized system performance.

The 7350 controller uses the DSP for all closed-loop control, including position tracking, PID control closed-loop computation, and motion trajectory generation. The DSP chip is supported by a custom FPGA that performs the high-speed encoder interfacing, position capture and breakpoint functions, motion I/O processing, and stepper pulse generation for hard real-time functionality.

The embedded CPU runs a multitasking real-time operating system and handles host communications, command processing, multi-axis interpolation, onboard program execution, error handling, general-purpose digital I/O, and overall motion system integration functions.

## Embedded Real-Time Operating System (RTOS)

The embedded firmware is based upon an embedded RTOS kernel and provides optimum system performance in varying motion applications. Motion tasks are prioritized. Task execution order depends on the priority of each task, the state of the entire motion system, I/O or other system events, and the real-time clock.

The DSP chip is a separate processor that operates independently from the CPU but is closely synchronized through interprocessor communication. The 7350 is a true multiprocessing and multitasking embedded controller.

The architecture of the 7350 controller enables advanced motion features, such as enhanced PID functions. Refer to the *NI-Motion User Manual* for more information about using the advanced motion features available on the 7350 controller.

## Trajectory Generators

The controller trajectory generators on the 7350 calculate the instantaneous position command that controls acceleration and velocity while it moves the axis to its target position. Depending on how you configure the axis, this command is then sent to the PID servo loop or stepper pulse generator.

To implement infinite trajectory control, the 7350 controller has 16 trajectory generators implemented in the DSP chip (two per axis). Each generator calculates an instantaneous position each PID update period. While simple point-to-point moves require only one trajectory generator, two simultaneous generators are required for blended moves and infinite trajectory control processing.

## Analog Input and Output

The 7350 controller has an 8-channel multiplexed, 16-bit ADC. The converted analog values are broadcast to both the DSP and CPU using a dedicated internal high-speed serial bus. The multiplexer scan rate provides high sampling rates required for feedback loop closure, joystick inputs, or monitoring analog sensors.

For analog output, the 7350 uses two four-channel 16-bit DACs that are updated each PID loop.

Both the analog input and output circuitry are factory-adjusted for excellent accuracy and performance. You can readjust the 7350 analog input and output circuitry in the field using a routine included in MAX. You may need to make these readjustments if you operate the 7350 at temperatures other than those that the device was factory-adjusted to operate in. You can use MAX to view the factory-adjusted temperatures for the 7350, and you can use an NI-Motion software routine to read the current temperature of the 7350. Refer to either the *NI-Motion C Reference Help* or the *NI-Motion VI Reference Help* for information about the functions and/or VIs you use to read the current temperature of the 7350.

## Onboard Sinusoidal Commutation

The 7350 controller provides onboard sinusoidal commutation for axes controlling brushless DC servo motors. This feature reduces overall system cost by allowing you to use less complex, and therefore less expensive, motor drives.

## Flash Memory

Nonvolatile memory on the 7350 controller is implemented with flash ROM, which means the controller can electrically erase and reprogram its own ROM. Because all of the embedded firmware, including the RTOS and DSP code, of the 7350 is stored in flash memory, you can upgrade the onboard firmware contents in the field for support and new-feature enhancement.

Flash memory also allows objects, such as programs and data arrays, to be stored in non-volatile memory.

It is possible to save the entire configuration state of the controller to the flash memory. On the next power cycle, the controller automatically loads and returns the configuration to these new saved default values.

Use MAX to download new firmware or save configuration defaults to flash memory.

## Axes and Motion Resources

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The 7350 controller can control up to eight axes of motion that can be completely independent, simultaneously started, or mapped in multidimensional groups called coordinate spaces. You also can simultaneously start coordinate spaces for multi-vector space coordinated motion control.

### Axes

At a minimum, an axis consists of a trajectory generator, a PID (for servo axes) or stepper control block, and at least one output resource—either a DAC output (for servo axes) or a stepper pulse generator output. Servo axes must also have either an encoder or ADC channel feedback resource. In addition to an encoder feedback, brushless DC servo axes also can use Hall effect sensors for initial position feedback. Closed-loop stepper axes also require a feedback resource, while open-loop stepper axes do not. Figures 4-1 and 4-2 show these axis configurations.



With the 7350 controller, you can map one or two feedback resources and one or two output resources to the axis.

A stepper axis has its primary output resource mapped to a stepper output. A servo axis has its primary output resource mapped to a DAC.

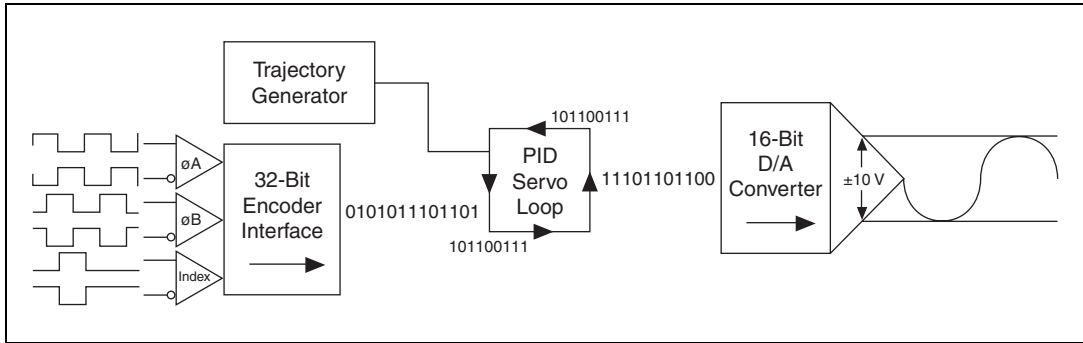


Figure 4-1. Servo Axis Resources

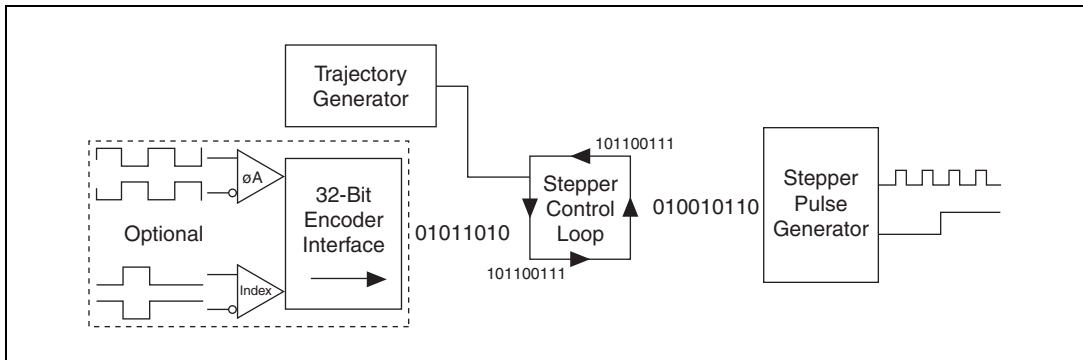


Figure 4-2. Stepper Axis Resources

The 7350 controller supports axes with secondary output resources. Defining two output resources is useful when controlling axes with multiple motors, such as gantry systems in which two DAC outputs can be configured with different torque limits and/or offsets. The 7350 controller also can use two DAC output resources when controlling a brushless DC servo axis for sinusoidal commutation.

The 7350 controller also supports secondary feedback resources, or encoders, for axes defined as servo. Two feedback resources are used when implementing dual-loop control, such as in backlash compensation, which reduces the number of encoders available for other axes.



**Note** Refer to the *NI-Motion User Manual* for more information about configuring axes.

## Motion Resources

Encoder, DAC, ADC, and motion I/O resources that are not used by an axis are available for non-axis or non-motion-specific applications. You can directly control an unmapped DAC as a general-purpose analog output ( $\pm 10$  V). Similarly, you can use any ADC channel to measure potentiometers or other analog sensors.

If an encoder resource is not needed for axis control, you can use it for any number of other functions, including position monitoring, as a digital potentiometer encoder input, or as a master encoder input for master/slave (electronic gearing) applications.

Each axis also has an associated forward and reverse limit input, a home input, a high-speed capture trigger input, a position breakpoint output, and an inhibit output. These signals can be used for general-purpose digital I/O when they are not being used for their motion-specific purpose.



**Note** When a resource is mapped to an axis, all features and functions of the resource are available as part of the axis. Because resources are referenced by axis number after they are assigned to that axis, it is not necessary to remember or use the resource number directly when accessing these features.

## Onboard Programs and Buffers

---

The 7350 controller has full onboard programmability capable of executing up to 10 simultaneous motion programs.

You can execute the NI-Motion function set from onboard programs. In addition, the onboard programs support basic math and data operation functions for up to 120 general-purpose variables.

The 7350 also features buffered operations for contouring, high-speed position captures, and breakpoints.

You can store and run onboard programs and buffers from RAM or save them to flash ROM. The 7350 controller has 64 KB of RAM and 128 KB of ROM that is divided into two 64 KB sectors for program and buffer storage. You can store and run programs and buffers from either RAM or ROM, but you cannot split programs between the two, and you cannot split programs or buffers between the two 64 KB ROM sectors.



**Note** Refer to the *NI-Motion User Manual* for detailed information about all of these onboard programming and buffer features.

## Host Communications

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The host computer communicates with the controller through a number of memory port addresses on the host bus. The host bus can be either PXI or PCI.

The primary bidirectional data transfer port supports FIFO data passing in both send and readback directions. The 7350 controller has both a command buffer for incoming commands and a return data buffer (RDB) for returning data.

The communications status register (CSR) provides bits for communications handshaking as well as real-time error reporting and general status feedback to the host PC. The move complete status (MCS) register provides instantaneous motion status of all axes.

The host computer also has a read-only register for reading position and velocity. This feature allows you to read the position and velocity without burdening the onboard CPU.

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# Signal Connections

This chapter describes how to make input and output signal connections directly to the PXI/PCI-7350 controller and briefly describes the associated I/O circuitry.

The 7350 controller has the following four connectors that handle all signals to and from the external motion system.

- Two 68-pin motion I/O connectors
- Two 68-pin digital I/O connectors

You can connect to the motion system with cables and accessories, varying from simple screw terminal blocks to enhanced UMI units and drives.



**Caution** The 7350 does not provide isolation between circuits.



**Caution** Power off all devices when connecting or disconnecting the 7350 controller motion I/O and auxiliary digital I/O cables. Failure to do so may damage the controller.

---

## Motion I/O Connectors

The motion I/O connectors contain all the signals required to control up to eight axes of servo and stepper motion, including the following features:

- Motor command analog and stepper outputs
- Encoder feedback inputs
- Forward, home, and reverse limit inputs
- Breakpoint outputs
- Trigger inputs
- Inhibit outputs
- Controller shutdown input

The motion I/O connectors also contain up to eight channels of 16-bit A/D inputs for analog feedback or general-purpose analog input.

Figures 5-1 and 5-2 show the pin assignments for the two 68-pin motion I/O connectors on the 7350 controller. A signal description follows the connector pinout. In this chapter, lines above signal names indicate that the signal is active-low.

Axis 1 Dir (CCW)	1	35	Axis 1 Step (CW)
Digital Ground	2	36	Axis 1 Encoder Phase A
Digital Ground	3	37	Axis 1 Encoder Phase B
Axis 1 Home Switch	4	38	Axis 1 Encoder Index
Trigger 1	5	39	Axis 1 Forward Limit Switch
Axis 1 Inhibit	6	40	Axis 1 Reverse Limit Switch
Axis 2 Dir (CCW)	7	41	Axis 2 Step (CW)
Digital Ground	8	42	Axis 2 Encoder Phase A
Digital Ground	9	43	Axis 2 Encoder Phase B
Axis 2 Home Switch	10	44	Axis 2 Encoder Index
Trigger 2	11	45	Axis 2 Forward Limit Switch
Axis 2 Inhibit	12	46	Axis 2 Reverse Limit Switch
Axis 3 Dir (CCW)	13	47	Axis 3 Step (CW)
Digital Ground	14	48	Axis 3 Encoder Phase A
Digital Ground	15	49	Axis 3 Encoder Phase B
Axis 3 Home Switch	16	50	Axis 3 Encoder Index
Trigger 3	17	51	Axis 3 Forward Limit Switch
Axis 3 Inhibit	18	52	Axis 3 Reverse Limit Switch
Axis 4 Dir (CCW)	19	53	Axis 4 Step (CW)
Digital Ground	20	54	Axis 4 Encoder Phase A
Digital Ground	21	55	Axis 4 Encoder Phase B
Axis 4 Home Switch	22	56	Axis 4 Encoder Index
Trigger 4	23	57	Axis 4 Forward Limit Switch
Axis 4 Inhibit	24	58	Axis 4 Reverse Limit Switch
Digital Ground	25	59	Host +5 V
Breakpoint 1	26	60	Breakpoint 2
Breakpoint 3	27	61	Breakpoint 4
Digital Ground	28	62	Shutdown
Analog Output 1	29	63	Analog Output 2
Analog Output 3	30	64	Analog Output 4
Analog Output Ground	31	65	Reserved
Analog Input 1	32	66	Analog Input 2
Analog Input 3	33	67	Analog Input 4
Analog Reference (Output)	34	68	Analog Input Ground

**Figure 5-1.** 68-Pin Motion I/O Connector Pin Assignment for Axes 1–4

Axis 5 Dir (CCW)	1	35	Axis 5 Step (CW)
Digital Ground	2	36	Axis 5 Encoder Phase A
Digital Ground	3	37	Axis 5 Encoder Phase B
Axis 5 Home Switch	4	38	Axis 5 Encoder Index
Trigger 5	5	39	Axis 5 Forward Limit Switch
Axis 5 Inhibit	6	40	Axis 5 Reverse Limit Switch
Axis 6 Dir (CCW)	7	41	Axis 6 Step (CW)
Digital Ground	8	42	Axis 6 Encoder Phase A
Digital Ground	9	43	Axis 6 Encoder Phase B
Axis 6 Home Switch	10	44	Axis 6 Encoder Index
Trigger 6	11	45	Axis 6 Forward Limit Switch
Axis 6 Inhibit	12	46	Axis 6 Reverse Limit Switch
Axis 7 Dir (CCW)	13	47	Axis 7 Step (CW)
Digital Ground	14	48	Axis 7 Encoder Phase A
Digital Ground	15	49	Axis 7 Encoder Phase B
Axis 7 Home Switch	16	50	Axis 7 Encoder Index
Trigger 7	17	51	Axis 7 Forward Limit Switch
Axis 7 Inhibit	18	52	Axis 7 Reverse Limit Switch
Axis 8 Dir (CCW)	19	53	Axis 8 Step (CW)
Digital Ground	20	54	Axis 8 Encoder Phase A
Digital Ground	21	55	Axis 8 Encoder Phase B
Axis 8 Home Switch	22	56	Axis 8 Encoder Index
Trigger 8	23	57	Axis 8 Forward Limit Switch
Axis 8 Inhibit	24	58	Axis 8 Reverse Limit Switch
Digital Ground	25	59	Host +5 V
Breakpoint 5	26	60	Breakpoint 6
Breakpoint 7	27	61	Breakpoint 8
Digital Ground	28	62	Shutdown
Analog Output 5	29	63	Analog Output 6
Analog Output 7	30	64	Analog Output 8
Analog Output Ground	31	65	Reserved
Analog Input 5	32	66	Analog Input 6
Analog Input 7	33	67	Analog Input 8
Analog Reference (Output)	34	68	Analog Input Ground

**Figure 5-2.** 68-Pin Motion I/O Connector Pin Assignment for Axes 5–8

Table 5-1 describes the signals on the motion I/O connector.

**Table 5-1.** Motion I/O Signal Connections

Signal Name	Reference	Direction	Description
Digital Ground	—	—	Reference for digital I/O
Axis <1..8> Dir (CCW)	Digital Ground	Output	Motor direction or counter-clockwise control
Axis <1..8> Step (CW)	Digital Ground	Output	Motor step or clockwise control
Axis <1..8> Encoder Phase A	Digital Ground	Input	Closed-loop only—phase A encoder input
Axis <1..8> Encoder Phase B	Digital Ground	Input	Closed-loop only—phase B encoder input
Axis <1..8> Encoder $\overline{\text{Index}}$	Digital Ground	Input	Closed-loop only—index encoder input
Axis <1..8> Home Switch	Digital Ground	Input	Home switch
Axis <1..8> Forward Limit Switch	Digital Ground	Input	Forward limit switch
Axis <1..8> Reverse Limit Switch	Digital Ground	Input	Reverse limit switch
Axis <1..8> $\overline{\text{Inhibit}}$	Digital Ground	Output	Drive inhibit
Trigger <1..8>	Digital Ground	Input	High-speed position capture trigger input <1..8>
Breakpoint <1..8>	Digital Ground	Output	Position breakpoint output <1..8>
Host +5 V	Digital Ground	Output	+5 V—host computer +5 V supply
Analog Input Ground	—	—	Reference for analog inputs
Analog Input <1..8>	Analog Input Ground	Input	16-bit analog input
Analog Output <1..8>	Analog Output Ground	Output	16-bit analog output
Analog Output Ground	—	—	Reference for analog outputs
Shutdown	Digital Ground	Input	Controlled device shutdown
Analog Reference (output)	Analog Output Ground	Output	+7.5 V—analog reference level

## Motion Axis Signals

The following signals control the servo amplifier or stepper drive.

- **Analog Output <1..8>**—These 16-bit DAC outputs are typically the servo command outputs for each axis. They can drive the industry-standard  $\pm 10$  V output, and can be software limited to any positive or negative voltage range desired. These outputs also feature a software-programmable voltage offset.

Although typically used as the command output of an axis control loop, unused DACs also can function as independent analog outputs for general-purpose control.

- **Analog Reference**—For convenience, a 7.5 V (nominal) analog reference voltage is available. You can use this output as a low-current supply to sensors that require a stable reference.



**Note** The analog reference output is an output signal only and must not be connected to an external reference voltage. Connect the common of the external reference to the Analog Input Ground pin for proper A/D reference and improved voltage measurement.

- **Analog Output Ground**—To help keep digital noise separate from the analog DAC outputs, there is a separate return connection. Use this analog ground connection as the reference for the DAC outputs when connecting to servo amplifiers instead of the Digital Ground (digital I/O reference).
- **Axis <1..8> Step (CW) and Dir (CCW)**—These signals are the stepper command outputs for each axis. The 7350 controller supports both industry standards for stepper command signals: step and direction, or independent clockwise (CW) and counter-clockwise (CCW) pulse outputs.

The output configuration and signal polarity is software programmable for compatibility with various third-party drives, as follows:

- When step and direction mode is configured, each commanded step (or microstep) produces a pulse on the step output. The direction output signal level indicates the command direction of motion, either forward or reverse.
- CW and CCW modes produce pulses (steps) on the CW output for forward-commanded motion and pulses on the CCW output for reverse-commanded motion.

In either case, you can set the active polarity of both outputs to active-low (inverting) or active-high (non-inverting). For example,



with step and direction, you can make a logic high correspond to either forward or reverse direction.

You can choose to drive the Step (CW) and Dir (CCW) outputs by using either *Totem-Pole* mode or Open Collector mode. In Totem-Pole mode, the output buffer can both sink and source current, which is appropriate for most applications. In Open Collector mode, the output buffer can only sink current. By default, Step (CW) and Dir (CCW) outputs are set to Totem-Pole mode.



**Caution** Do *not* connect these outputs to anything other than a +5 V circuit. The output buffers will fail if subjected to voltages in excess of +5.5 V.

- Axis <1..8> Inhibit—Use the inhibit output signals to control the enable/inhibit function of a servo amplifier or stepper drive. When properly connected and configured, the inhibit function causes the connected motor to be de-energized and its shaft turns freely.

You can set the inhibits to either Totem-Pole or Open Collector mode. In Totem-Pole mode, the inhibits can both sink and source current. In Open Collector mode, the output buffer can only sink current. By default, inhibits are set to Open Collector mode.

Whereas the industry standard for inhibits is active-low (inverting), these outputs have programmable polarity and can be set to active-high (non-inverting) for increased flexibility.

Inhibit output signals can be activated automatically upon a Kill Motion command or any motion error that causes a kill motion condition, such as a following-error trip.

You also can use the inhibit outputs of unused axes as general-purpose outputs. However, for safety considerations, National Instruments recommends that you use the inhibit outputs for all active axes.

## Limit and Home Inputs

The following signals control limit and home inputs:

- Axis <1..8> Forward Limit Input
- Axis <1..8> Home Input
- Axis <1..8> Reverse Limit Input

These inputs are typically connected to limit switches located at physical ends of travel and/or at a specific home position. You can use software to enable and disable limit and home inputs at any time. When enabled, an active transition on a limit or home input causes a full torque halt stop of

the associated axis. In addition, an active forward or reverse limit input impedes future commanded motion in that direction for as long as the signal is active.



**Note** Limit and home inputs are digitally filtered and must remain active for a certain amount of time to be recognized. Refer to Appendix A, *Specifications*, for more information. Active signals should remain active to prevent motion from proceeding further into the limit. Pulsed limit signals stop motion, but they do not prevent further motion in that direction if another move is started.

The input polarity of these signals is software programmable for active-low (inverting) or active-high (non-inverting).

You can use software disabled limit and home inputs as general-purpose inputs. You can read the status of these inputs at any time and set and change their polarity as required.

Limit and home inputs are a per-axis enhancement on the 7350 controller and are not required for basic motion control. These inputs are part of a system solution for complete motion control.



**Caution** National Instruments recommends using limits for personal safety, as well as to protect the motion system.

## Wiring Concerns

For the end of travel limits to function correctly, the forward limit must be located at the forward or positive end of travel, and the reverse limit at the negative end of travel.



**Caution** Failure to follow these guidelines may result in motion that stops at, but then travels through, a limit, potentially damaging the motion system. Limits that are wired incorrectly may prevent motion from occurring at all.

Keep limit and home switch signals and their ground connections wired separately from the motor drive/amplifier signal and encoder signal connections.



**Caution** Wiring these signals near each other can cause faulty motion system operation that is due to signal noise and crosstalk.

## Limit and Home Input Circuit

All limit and home inputs are digitally filtered and must be active for a certain amount of time to be recognized. Refer to Appendix A, *Specifications*, for more information. These inputs have an onboard pull-up resistor. If left floating, the inputs are interpreted as a high logic level.



**Caution** Excessive input voltages can cause erroneous operation and/or component failure. Verify that the input voltage is within the specification range.

## Encoder Signals

The 7350 controller offers up to eight channels of single-ended quadrature encoder inputs. All National Instruments power drives and UMI accessories provide built-in circuitry that converts differential encoder signals to single-ended encoder signals. Each channel consists of a Phase A, Phase B, and Index input, as described in the following sections.

### Encoder <1..8> Phase A/Phase B

The encoder inputs provide position and velocity feedback for absolute and relative positioning of axes in any motion system configuration.

If an encoder resource is not needed for axis control, it is available for other functions including position monitoring, digital potentiometer encoder inputs, or as a master encoder input for master/slave (electronic gearing) applications.

The encoder channels (Encoder <1..8>) are implemented in an FPGA and are high performance with advanced features, such as high-speed position capture inputs and position breakpoint outputs.

An encoder input channel converts quadrature signals on Phase A and Phase B into 32-bit up/down counter values. Quadrature signals are generated by optical, magnetic, laser, or electronic devices that provide two signals, Phase A and Phase B, that are 90° out of phase. The leading phase, A or B, determines the direction of motion. The four transition states of the relative signal phases provide distinct pulse edges that cause count up or count down pulses in the direction determined by the leading phase.

A typical encoder with a specification of  $N$  ( $N$  = number) lines per unit of measure (revolutions or linear distance) produces  $4 \times N$  quadrature counts per unit of measure. The count is the basic increment of position in National Instruments motion systems.

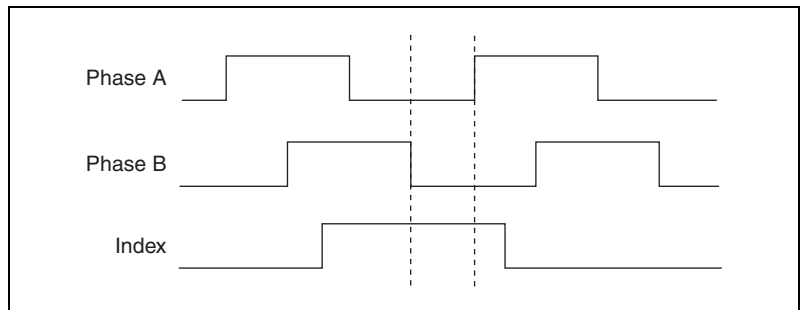


**Note** Determine quadrature counts by multiplying the encoder resolution, in encoder lines, by 4. The encoder resolution is the number of encoder lines between consecutive encoder indexes, such as marker or Z-bit. If the encoder does not have an index output, the resolution is referred to as lines per revolution, or lines per unit of measure: inch, centimeter, millimeter, and so on.

## Encoder <1..8> Index

The Index input is primarily used to establish a reference position. This function uses the number of counts per revolution or the linear distance to initiate a search move that locates the index position. When a valid index signal transition occurs during a find reference routine, the position of the index signal is captured accurately. Use this captured position to establish a reference zero position for absolute position control or any other motion system position reference required.

The default MAX settings guarantee that the find index routine completes successfully if the encoder generates a high index pulse when phases A and B are low and the encoder is connected through an NI UMI or drive accessory. Figure 5-3 shows the default encoder phasing diagram at the inputs to an NI UMI or drive accessory.



**Figure 5-3.** Quadrature Encoder Phasing Diagram

You can set the index reference criteria in MAX to change the pattern of phases A and B for the index search. You also can set the encoder polarity for phases A, B, and I in MAX.

## Wiring Concerns

The encoder inputs are connected to quadrature decoder/counter circuits. It is very important to minimize noise at this interface. Excessive noise on these encoder input signals may result in loss of counts or extra counts and

erroneous closed-loop motion operation. Verify the encoder connections before powering up the system.



**Caution** Wire encoder signals and their ground connections separately from all other connections. Wiring these signals near the motor drive/amplifier or other signals can cause positioning errors and faulty operation.

National Instruments strongly recommends you use encoders with differential line drive outputs for all applications. You *must* use differential encoders if the encoder cable length is longer than 3.05 m (10 ft). Shielded, 24 AWG wire is the minimum recommended size for the encoder cable. Cables with twisted pairs and an overall shield are recommended for optimized noise immunity.

All National Instruments power drives and UMI accessories provide built-in circuitry that converts differential encoder signals to single-ended encoder signals.



**Caution** Unshielded cables can cause noise to corrupt the encoder signals, resulting in lost or additional counts and reduced motion system accuracy.

## Encoder Input Circuit

The Phase A, Phase B, and Index encoder inputs all have an onboard pull-up resistor, and are interpreted as high logic level if left floating. Both phases A and B are required for proper encoder counter operation, and the signals must support the 90° phase difference within system tolerance. The encoder and Index signals are conditioned by a software-programmable digital filter inside the FPGA. The Index signal is optional but highly recommended and is required for initialization functionality with the Find Reference function.

## Trigger Inputs, Shutdown Input, and Breakpoint Outputs

The 7350 controller offers additional high-performance features. The encoder channels have high-speed position capture trigger inputs and position breakpoint outputs. These signals are useful for high-speed synchronization of motion with actuators, sensors, and other parts of the complete motion system:

- **Trigger Input <1..8>**—When enabled, an active transition on a high-speed position capture input causes instantaneous position capture of the corresponding encoder count value. You can use this high-speed position capture functionality for applications ranging from simple position tagging of sensor data to complex camming

systems with advance/retard positioning and registration. An available 7350 controller position mode is to move an axis relative to a captured position.

The polarity of the trigger input is programmable in software as active-low (inverting), or active-high (non-inverting), rising edge or falling edge. You also can use a trigger input as a latching general-purpose digital input by simply ignoring the captured position.

- **Shutdown Input**—When enabled in software, the shutdown input signal can be used to kill all motion by asserting the controller inhibits, setting the analog outputs to 0 V, and stopping any stepper pulse generation. To activate shutdown, the signal must transition from a low to high state.
- **Breakpoint Output <1..8>**—You can program a breakpoint output to transition when the associated encoder value equals the breakpoint position. You can use a breakpoint output to directly control actuators or as a trigger to synchronize data acquisition or other functions in the motion control system.

You can program breakpoints as either *absolute*, *relative*, *periodic*, or *buffered* positions. Breakpoint outputs can be preset to a known state so that the transition when the breakpoint occurs can be low to high, high to low, toggle, or pulse.

You can set the breakpoint outputs to be Totem-Pole mode or Open Collector mode. In Totem-Pole mode, the output buffer can both sink and source current, which is appropriate for most applications. In Open Collector mode, the output buffer can only sink current. By default, breakpoint outputs are set to Totem-Pole mode.

You can directly set and reset breakpoint outputs to use them as general-purpose digital outputs.

## Wiring Concerns



**Caution** Keep trigger input, shutdown input, and breakpoint output signals and their ground connections wired separately from the motor drive/amplifier signal and encoder signal connections. Wiring these signals near each other can cause faulty operation.



**Caution** Excessive input voltages can cause erroneous operation and/or component failure.

## Trigger Input and Shutdown Input Circuits

Trigger input and shutdown input circuits have onboard pull-up resistors, and are interpreted as high logic level if left floating.

## Analog Inputs

The 7350 controller has the following ADC input signals:

- **Analog Input <1..8>**—The 7350 controller includes an eight-channel multiplexed, 16-bit ADC capable of measuring  $\pm 10$  V,  $\pm 5$  V, 0–10 V, and 0–5 V inputs.

You can configure each ADC channel for motion feedback, simple A/D conversion, or both.

You can read the digital value of analog voltage on any of the ADC channels of the controller by using the Read ADC function. Table 5-2 shows the range of values read back and the voltage resolution for each setting. The voltage resolution is in microvolts per least significant bit ( $\mu\text{V}/\text{LSB}$ ).

**Table 5-2.** Analog Input Voltage Ranges

Input Range	Binary Values	Resolution
$\pm 10$ V	–32,768 to 32,767	305 $\mu\text{V}/\text{LSB}$
$\pm 5$ V	–32,768 to 32,767	153 $\mu\text{V}/\text{LSB}$
0–10 V	0 to 65,535	153 $\mu\text{V}/\text{LSB}$
0–5 V	0 to 65,535	76 $\mu\text{V}/\text{LSB}$

When configured as analog feedback, an analog sensor acts like a limited range absolute position device with a full-scale position range. You can map any ADC channel as feedback to any axis.

You can enable and disable individual ADC channels in software. Disable unused ADC channels for the highest multiplexer scan rate performance. Properly enabled, the scan rate is high enough to support analog feedback at the highest PID sample rate.

- **Analog Input Ground**—To help keep digital noise out of the analog input, a separate return connection is available. Use this reference ground connection and not Digital Ground (digital I/O reference) or Analog Output Ground as the reference for the analog inputs.

## Wiring Concerns

For proper use of each ADC input channel, the analog signal to be measured should be connected to the channel input and its ground reference connected to the Analog Input Ground.

## Other Motion I/O Connection

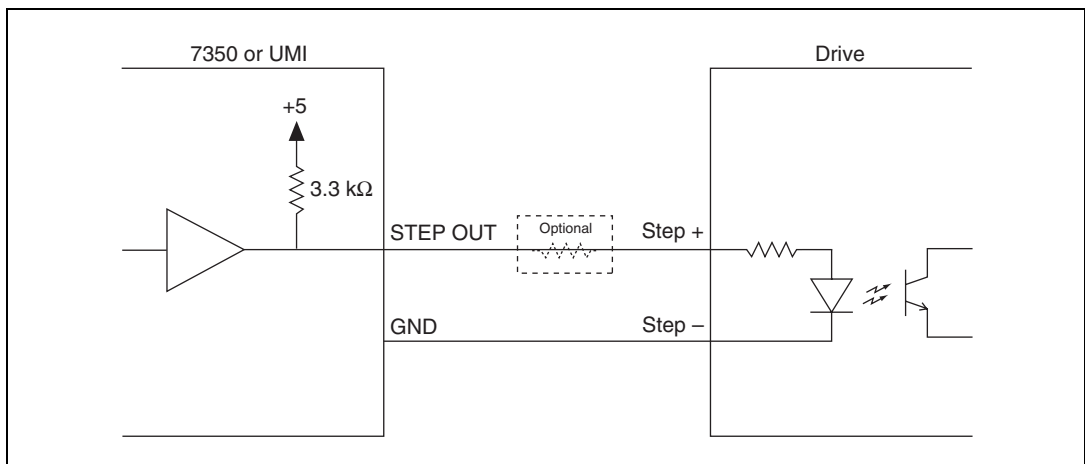
The 7350 controller provides the host +5 V signal, which is the internal +5 V supply of the host computer. This signal is typically used to detect when the host computer is powered and to shut down external motion system components when the host computer is powered off or disconnected from the motion accessory.



**Caution** The host +5 V signal is limited and should not be used to power any external devices, except those intended in the host bus monitor circuits on the UMI and drive products.

## Interfacing With Optocouplers

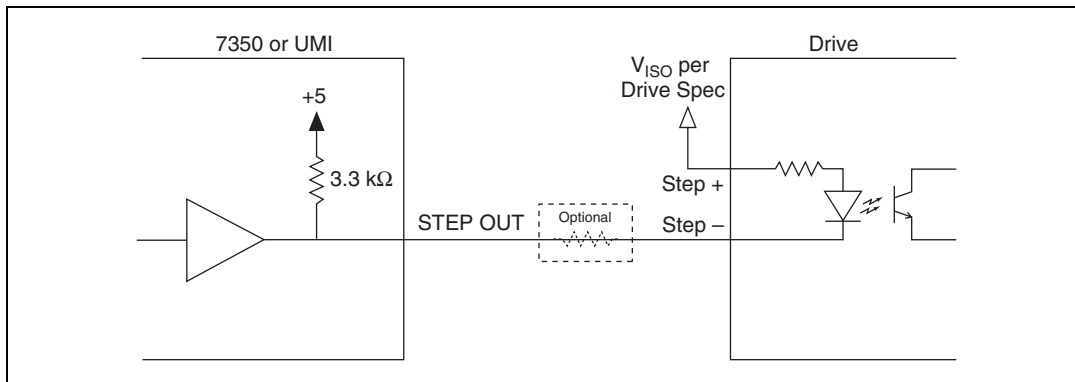
Many motor drive manufacturers offer opto-isolated inputs for Step (CW)/Dir (CCW) and other motion control signals. The 7350 is well-suited to drive most of these inputs directly when you connect the controller output signal to the positive side of the optocoupler input and connect the controller GND to the negative side of the optocoupler input. This method works if the optocoupler is designed to work with a 5 V signal, requires less current than the maximum the controller can supply, and the 7350 output is configured for Totem-Pole output mode. Figure 5-4 shows a typical optocoupler wiring example.



**Figure 5-4.** Typical Optocoupler Wiring (Totem-Pole Output Mode)



In some rare circumstances, the optocoupler will not work with a 5 V signal, or it requires more current than the maximum the controller can provide. In this case, connect the controller output to the negative side of the optocoupler input, connect the positive side of the input to a supply as specified by the drive manufacturer, and configure the controller output for Open Collector mode. Figure 5-5 shows this special case wiring example.



**Figure 5-5.** Special Case Optocoupler Wiring (Open-Collector Output Mode)



**Caution** If the optocoupler input does not include its own current-limiting resistor, you must provide an external resistor in series with the 7350 output. To prevent damage to the 7350 controller or other motion hardware, use a resistor that limits the current to a value below the maximum specifications of the controller and other hardware.

## Digital I/O Connector

The general-purpose digital I/O lines on the 7350 controller are available on two separate 68-pin digital I/O connectors. Figures 5-6 and 5-7 show the pin assignments for these connectors.

+5 V	1	35	Digital Ground
PCLK	2	36	Digital Ground
Reserved	3	37	Digital Ground
Reserved	4	38	DPull (P1:P4)
PWM1	5	39	Digital Ground
Reserved	6	40	Reserved
Reserved	7	41	Digital Ground
Reserved	8	42	Digital Ground
PWM2	9	43	Digital Ground
Port 1:bit 0	10	44	Port 1:bit 1
Digital Ground	11	45	Port 1:bit 2
Port 1:bit 3	12	46	Digital Ground
Port 1:bit 4	13	47	Port 1:bit 5
Digital Ground	14	48	Port 1:bit 6
Port 1:bit 7	15	49	Digital Ground
Port 2:bit 0	16	50	Digital Ground
Port 2:bit 1	17	51	Port 2:bit 2
Digital Ground	18	52	Port 2:bit 3
Digital Ground	19	53	Port 2:bit 4
Digital Ground	20	54	Port 2:bit 5
Port 2:bit 6	21	55	Digital Ground
Port 2:bit 7	22	56	Digital Ground
Port 3:bit 0	23	57	Port 3:bit 1
Digital Ground	24	58	Port 3:bit 2
Port 3:bit 3	25	59	Digital Ground
Port 3:bit 4	26	60	Port 3:bit 5
Digital Ground	27	61	Port 3:bit 6
Port 3:bit 7	28	62	Digital Ground
Port 4:bit 0	29	63	Port 4:bit 1
Digital Ground	30	64	Port 4:bit 2/Axis 1, Hall 1
Axis 1, Hall 2/Port 4:bit 3	31	65	Digital Ground
Axis 1, Hall 3/Port 4:bit 4	32	66	Port 4:bit 5/Axis 2, Hall 1
Digital Ground	33	67	Port 4:bit 6/Axis 2, Hall 2
Axis 2, Hall 3/Port 4:bit 7	34	68	Digital Ground

**Figure 5-6.** 68-Pin Digital I/O Connector Pin Assignments (Ports 1–4)

+5 V	1	35	Digital Ground
Reserved	2	36	Digital Ground
Reserved	3	37	Digital Ground
Reserved	4	38	DPull (P5:P8)
Reserved	5	39	Digital Ground
Reserved	6	40	Reserved
Reserved	7	41	Digital Ground
Reserved	8	42	Digital Ground
Reserved	9	43	Digital Ground
Port 5:bit 0	10	44	Port 5:bit 1
Digital Ground	11	45	Port 5:bit 2
Port 5:bit 3	12	46	Digital Ground
Port 5:bit 4	13	47	Port 5:bit 5
Digital Ground	14	48	Port 5:bit 6
Port 5:bit 7	15	49	Digital Ground
Port 6:bit 0	16	50	Digital Ground
Port 6:bit 1	17	51	Port 6:bit 2
Digital Ground	18	52	Port 6:bit 3
Digital Ground	19	53	Port 6:bit 4
Digital Ground	20	54	Port 6:bit 5
Port 6:bit 6	21	55	Digital Ground
Port 6:bit 7	22	56	Digital Ground
Port 7:bit 0	23	57	Port 7:bit 1
Digital Ground	24	58	Port 7:bit 2
Port 7:bit 3	25	59	Digital Ground
Port 7:bit 4	26	60	Port 7:bit 5
Digital Ground	27	61	Port 7:bit 6
Port 7:bit 7	28	62	Digital Ground
Port 8:bit 0	29	63	Port 8:bit 1
Digital Ground	30	64	Port 8:bit 2/Axis 3, Hall 1
Axis 3, Hall 2/Port 8:bit 3	31	65	Digital Ground
Axis 3, Hall 3/Port 8:bit 4	32	66	Port 8:bit 5/Axis 4, Hall 1
Digital Ground	33	67	Port 8:bit 6/Axis 4, Hall 2
Axis 4, Hall 3/Port 8:bit 7	34	68	Digital Ground

**Figure 5-7.** 68-Pin Digital I/O Connector Pin Assignments (Ports 5–8)

The 64-bit digital I/O ports are configured in hardware as up to eight 8-bit digital I/O ports. The bits in a port are typically controlled and read with byte-wide bitmapped commands.

Bits 2–7 in DIO ports 4 and 8 are dual-purpose bits that can be used for either general-purpose I/O or Hall sensor feedback during system configuration and initialization, but not both. When you set these bits to provide Hall sensor feedback, they are reserved for this activity and cannot be used for general-purpose I/O until you reinitialize the motion system.

All digital I/O lines have programmable direction and polarity.

The DPull(P1:P4) and DPull(P5:P8) pins control the state of the digital input pins at power-up.

Connecting DPull(P1:P4) to +5 V or leaving it unconnected configures all pins in ports 1–4 for 10 k $\Omega$  pull-ups. Connecting DPull(P1:P4) to ground configures these ports for 10 k $\Omega$  pull-downs.

Connecting DPull(P5:P8) to +5 V or leaving it unconnected configures all pins in ports 5–8 for 10 k $\Omega$  pull-ups. Connecting DPull(P5:P8) to ground configures these ports for 10 k $\Omega$  pull-downs.

## PWM Features

The 7350 controller provides two pulse width modulation (PWM) outputs on the digital I/O connector for ports 1–4. The PWM outputs generate periodic waveforms whose period and duty cycles can be independently controlled through software commands. You can compare PWM to a digital representation of an analog value, because the duty cycle is directly proportional to the desired output value. PWM outputs are typically used for transmitting an analog value through an optocoupler. A simple lowpass filter turns a PWM signal back into its corresponding analog value.

If appropriate, you can use an external clock source connected to the PCLK input instead of the internal source as the clock for the PWM generators.



**Note** These signals are configured in software and are in no way associated with the PID servo control loop. Refer to the appropriate NI-Motion documentation for more information.

## RTSI Connector

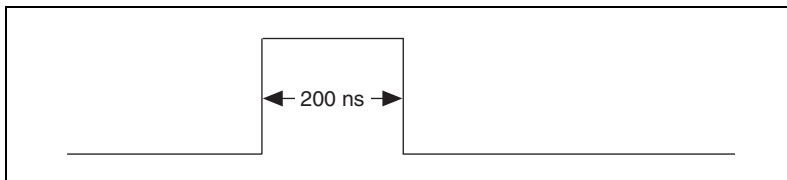
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The PXI-7350 uses the PXI chassis backplane to connect to other RTSI-capable devices.

The PCI-7350 uses a ribbon cable to connect to other RTSI-capable PCI devices.

## RTSI Signal Considerations

The 7350 controller allows you to use up to eight RTSI trigger lines as sources for trigger inputs, or as destinations for breakpoint outputs and encoder signals. The RTSI trigger lines also can serve as a generic digital I/O port. The RTSI star trigger line, which is available only on the PXI-7350, can be used only for a trigger input. Breakpoint outputs are output-only signals that generate an active-high pulse of 200 ns duration, as shown in Figure 5-8.



**Figure 5-8.** Breakpoint across RTSI

Encoder and Index signals are output-only signals across RTSI that are the digitally-filtered versions of the raw signals coming into the controller. If you are using the RTSI bus for trigger inputs or generic digital I/O, all signals are passed through unaltered.

## Specifications

This appendix lists the hardware and software performance specifications for the PXI/PCI-7350 controller. Hardware specifications are typical at 25 °C, unless otherwise stated.

### Servo Performance

PID update rate range.....	62.5µs/sample to 5 ms/sample
Max PID update rate .....	62.5 µs per 2 axes
8-axis PID update rate.....	250 µs total
Trajectory update rate .....	Same as PID update rate
Multi-axis synchronization .....	<1 update sample
Position accuracy	
Encoder feedback.....	±1 quadrature count
Analog feedback .....	±1 LSB
Double-buffered trajectory parameters	
Absolute position range .....	±2 <sup>31</sup> counts
Max relative move size .....	±2 <sup>31</sup> counts
Velocity range.....	1 to ±20,000,000 counts/s
RPM range <sup>1</sup> .....	±1,200,000 revolutions/min
Acceleration/deceleration <sup>1</sup> .....	±512,000,000 counts/s <sup>2</sup>
RPS/s range <sup>1</sup> .....	±256,000 revolutions/s <sup>2</sup>
S-Curve time range .....	1 to 32,767 samples
Following error range .....	0 to 32,767 counts
Gear ratio .....	±32,767:1 to ±1:32,767

<sup>1</sup> Assumes a PID update rate of 250 µs and a 2,000-count encoder.

Servo control loop modes .....	PID, PIVff, S-Curve, Dual Loop
PID (Kp, Ki, and Kd) gains .....	0 to 32,767
Integration limit (Ilim).....	0 to 32,767
Derivative sample period (Td).....	1 to 63 samples
Feedforward (Aff, Vff) gains .....	0 to 32,767
Velocity feedback (Kv) gain .....	0 to 32,767
Servo command analog outputs	
Voltage range.....	±10 V
Resolution.....	16 bits (0.000305 V/LSB)
Programmable torque (velocity) limits	
Positive limit .....	±10 V (–32,768 to +32,767)
Negative limit.....	±10 V (–32,768 to +32,767)
Programmable offset .....	±10 V (–32,768 to +32,767)

## Stepper Performance

Trajectory update rate range .....	62.5 to 500 µs/sample
Max update rate .....	62.5 µs per 2 axes
8-axis update rate.....	250 µs total
Multi-axis synchronization .....	<1 update sample
Position accuracy	
Open-loop stepper .....	1 full, half, or microstep
Encoder feedback .....	±1 quadrature count
Analog feedback.....	±1 LSB
Double-buffered trajectory parameters	
Position range .....	±2 <sup>31</sup> steps
Max relative move size.....	±2 <sup>31</sup> steps
Velocity range .....	1 to 8,000,000 steps/s
RPM range <sup>1</sup> .....	±1,200,000 revolutions/min
Acceleration/deceleration <sup>1</sup> .....	±512,000,000 steps/s <sup>2</sup>
RPS/s range <sup>1</sup> .....	±256,000 revolutions/s <sup>2</sup>
S-curve time range.....	1 to 32,767 samples

---

<sup>1</sup> Assumes a PID update rate of 250 µs and a 2,000-count encoder.

Following error range ..... 0 to 32,767 counts  
 Gear ratio .....  $\pm 32,767:1$  to  $\pm 1:32,767$

#### Stepper outputs

Max pulse rate ..... 8 MHz (full, half, and microstep)  
 Max pulse width ..... 6.5  $\mu$ s at <40 kHz  
 Min pulse width ..... 40 ns at >4 MHz  
 Step output mode ..... Step and direction or CW/CCW  
 Voltage range ..... 0 to 5 V  
     Output low voltage ..... 0.6 V at 64 mA sink  
     Output high voltage ..... Totem Pole: 2V at 16 mA source;  
     open collector: built-in 3.3 k $\Omega$   
     pull-up to +5 V  
 Polarity ..... Programmable, active-high  
     or active-low

## System Safety

Watchdog timer function ..... Resets board to startup state  
 Watchdog timeout ..... 63 or 256 ms, programmable

#### Shutdown input

Voltage range ..... 0 to 5 V  
     Input low voltage ..... 0.8 V  
     Input high voltage ..... 2 V  
 Built-in pull-up resistor ..... 3.3 k $\Omega$  to +5 V  
 Polarity ..... Rising edge  
 Control ..... Disable all axes and  
     command outputs; resets I/O  
     to default states

Host +5 V max current  
 sourced from controller ..... 100 mA at 5 V

## Motion I/O

Encoder inputs ..... Quadrature, incremental,  
     single-ended  
 Max count rate ..... 20 MHz  
 Min pulse width ..... Programmable; depends  
     on digital filter settings



Voltage range.....	0 to 5 V
Input low voltage.....	0.8 V
Input high voltage.....	2 V
Built-in pull-up resistor .....	3.3 kΩ to +5 V
Min index pulse width.....	Programmable; depends on digital filter settings

Forward, reverse, and home inputs

Number of inputs.....	3 per axis, up to 24
Voltage range.....	0 to 5 V
Input low voltage.....	0.8 V
Input high voltage.....	2 V
Built-in pull-up resistor .....	3.3 kΩ to +5 V
Polarity .....	Programmable, active-high or active-low
Min pulse width.....	800 μs
Control.....	Individual enable/disable, stop on input, prevent motion, Find Reference

Trigger inputs

Number of inputs.....	Up to 8 (Encoders 1 through 8)
Voltage range.....	0 to 5 V
Input low voltage.....	0.8 V
Input high voltage.....	2 V
Built-in pull-up resistor .....	3.3 kΩ to +5 V
Polarity .....	Programmable, active-high or active-low
Min pulse width.....	100 ns
Max capture latency .....	100 ns
Capture accuracy .....	1 count
Max capture rate (non-buffered) .....	150 Hz
Max buffered capture rate <sup>1</sup> .....	2 kHz per axis

---

<sup>1</sup> Assumes a PID update rate of 250 μs. 2 kHz per axis for PID rates between 62.5 and 250 μs, and 1 kHz per axis for PID rates greater than 250 μs. This value is not to exceed 8 kHz total for all ongoing buffered breakpoint and trigger operation.

## Breakpoint outputs

Number of outputs .....	Up to 8 (Encoders 1 through 8)
Voltage range .....	0 to 5 V
Output low voltage .....	0.6 V at 64 mA sink
Output high voltage .....	Totem Pole: 2 V at 16 mA source; open collector: built-in 3.3 k $\Omega$ pull-up to +5 V
Polarity .....	Programmable, active-high or active-low
Max trigger rate (non-buffered) .....	150 Hz
Max buffered trigger rate <sup>1</sup> .....	2 kHz per axis
Max periodic rate .....	4 MHz per axis
Pulse width (pulse mode only) .....	200 ns

## Inhibit/enable output

Number of outputs .....	1 per axis, up to 8
Voltage range .....	0 to 5 V
Output low voltage .....	0.6 V at 64 mA sink
Output high voltage .....	Totem Pole: 2 V at 16 mA source; open collector: built-in 3.3 k $\Omega$ pull-up to +5 V
Polarity .....	Programmable, active-high or active-low
Control .....	MustOn/MustOff or automatic when axis off

## Analog inputs

Control .....	Assigned to axis for analog feedback or general-purpose analog input
Number of inputs .....	Up to 8, multiplexed, single-ended
Multiplexer scan rate .....	25 $\mu$ s per enabled ADC
Input coupling .....	DC
Input impedance .....	100 M $\Omega$ min
Voltage range (programmable) .....	$\pm$ 10 V, $\pm$ 5 V, 0–10 V, 0–5 V

<sup>1</sup> Assumes a PID update rate of 250  $\mu$ s. 2 kHz per axis for PID rates between 62.5 and 250  $\mu$ s, and 1 kHz per axis for PID rates greater than 250  $\mu$ s. This value is not to exceed 8 kHz total for all ongoing buffered breakpoint and trigger operation.

Bandwidth.....	234 kHz
Resolution.....	16 bits, no missing codes
Monotonicity .....	Guaranteed
Absolute accuracy	
All ranges.....	0.5% of full-scale

System noise

±10 V .....	220 µVrms, typical
±5 V .....	120 µVrms, typical
0–10 V .....	130 µVrms, typical
0–5 V .....	60 µVrms, typical

Maximum working voltage .....±11 V

Overvoltage protection

Powered on .....	±25 V
Powered off .....	±15 V

Analog outputs

Number of outputs.....	Up to 8, single-ended
Output coupling.....	DC
Voltage range.....	±10 V
Output current.....	±5 mA
Minimum load .....	2 kΩ at full-scale
Resolution.....	16 bits, no missing codes
Monotonicity .....	Guaranteed
Absolute accuracy .....	0.5% of full-scale
Noise.....	100 µVrms Max
Protection.....	Short-circuit to ground
Settling time.....	15 µs, full-scale step
Analog reference output voltage .....	7.5 V (nominal)
Analog reference output current .....	5 mA

Onboard temperature sensor accuracy .....±4 °C

## Digital I/O

Ports .....	Up to 8 8-bit ports
Line direction .....	Individual bit programmable
Inputs	
Voltage range .....	0 to 5 V
Input low voltage .....	0.8 V
Input high voltage .....	2.0 V
Polarity .....	Programmable, active-high or active-low
Built-in pull-up resistor .....	10 k $\Omega$ , configurable pull-up to +5 V or pull-down to GND
Outputs	
Voltage range .....	0 to 5 V
Output low voltage .....	0.45 V at 24 mA
Output high voltage .....	2.4 V at 24 mA
Max total DIO current	
Sourced from controller .....	1 A
Polarity .....	Programmable, active-high or active-low
PWM outputs	
Number of PWM outputs .....	2
Max PWM frequency .....	50 kHz
Resolution .....	8-bit
Duty cycle range .....	0 to (255/256)%
Clock sources .....	Internal or external

## RTSI

Trigger lines .....	8
PXI Star Trigger (PXI-7350 only) .....	1

## Maximum Power Requirements

+3.3 V ( $\pm 10\%$ )	2 A
+5 V ( $\pm 5\%$ )	2 A
+12 V ( $\pm 5\%$ )	30 mA
-12 V ( $\pm 3\%$ )	0 mA
Power consumption	18 W

## Physical

### Dimensions (Not Including Connectors)

PXI-7350	16 cm $\times$ 10 cm (6.3 in. $\times$ 3.9 in.)
PCI-7330	17.5 cm $\times$ 9.9 cm (6.9 in. $\times$ 3.9 in.)

### Connectors

Motion I/O connectors	2 68-pin female high-density VHDCI type
32-bit digital I/O connectors	2 68-pin female high-density VHDCI type
RTSI connector (PCI-7350 only)	37-pin male for ribbon cable

### Weight

PXI-7350	170 g (6 oz)
PCI-7350	113 g (4 oz)

## Maximum Working Voltage

Channel-to-earth.....	11 V, Installation Category I (signal voltage plus common-mode voltage)
Channel-to-channel .....	22 V, Installation Category I (signal voltage plus common-mode voltage)



**Caution** These values represent the maximum allowable voltage between any accessible signals on the controller. To determine the acceptable voltage range for a particular signal, refer to the individual signal specifications.

## Environment

Operating temperature.....	0 to 55 °C
Storage temperature .....	-20 to 70 °C
Humidity .....	10 to 90% RH, noncondensing
Maximum altitude .....	2,000 m
Pollution Degree .....	2

## Safety

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

- IEC 61010-1, EN 61010-1
- UL 3111-1, UL 61010B-1
- CAN/CSA C22.2 No. 1010.1



**Note** For UL and other safety certifications, refer to the product label or visit [ni.com/hardref.nsf](http://ni.com/hardref.nsf), search by model number or product line, and click the appropriate link in the Certification column.

## Electromagnetic Compatibility

Emissions .....	EN 55011 Class A at 10 m FCC Part 15A above 1 GHz
Immunity .....	EN 61326:1997 + A2:2001, Table 1
EMC/EMI .....	CE, C-Tick, and FCC Part 15 (Class A) Compliant



**Note** For EMC compliance, you *must* operate this device with shielded cabling.

## CE Compliance

This product meets the essential requirements of applicable European Directives, as amended for CE marking, as follows:

Low-Voltage Directive (safety).....73/23/EEC

Electromagnetic Compatibility  
Directive (EMC).....89/336/EEC



**Note** Refer to the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, visit [ni.com/hardref.nsf](http://ni.com/hardref.nsf), search by model number or product line, and click the appropriate link in the Certification column.

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## Cable Connector Descriptions

This appendix describes the connector pinout for the cables that connect to the PXI/PCI-7350 controller.

Figures B-1 and B-2 show the pin assignments for the stepper 50-pin motion connectors, while Figures B-3 and B-4 show the pin assignments for the servo 50-pin motion connectors. These connectors are available when you use the SH68-C68-S shielded cable assembly and the 68M-50F step/servo bulkhead cable adapter. You can order the cable assembly and cable adapter from [ni.com](http://ni.com). The following list includes part numbers for each of these products:

- 186380-02—2m SHC68-C68-S Cable
- 186380-0R5—0.5m SHC68-C68-S Cable
- 184670-02—68M-50F Extended I/O Cable Adapter



Axis 1 Dir (CCW)	1	2	Axis 1 Step (CW)
Digital Ground	3	4	Axis 1 Encoder Phase A
Digital Ground	5	6	Axis 1 Encoder Phase B
Axis 1 Home Switch	7	8	Axis 1 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 1	9	10	Axis 1 Forward Limit Switch
Axis 1 Inhibit	11	12	Axis 1 Reverse Limit Switch
Axis 2 Dir (CCW)	13	14	Axis 2 Step (CW)
Digital Ground	15	16	Axis 2 Encoder Phase A
Digital Ground	17	18	Axis 2 Encoder Phase B
Axis 2 Home Switch	19	20	Axis 2 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 2	21	22	Axis 2 Forward Limit Switch
Axis 2 Inhibit	23	24	Axis 2 Reverse Limit Switch
Axis 3 Dir (CCW)	25	26	Axis 3 Step (CW)
Digital Ground	27	28	Axis 3 Encoder Phase A
Digital Ground	29	30	Axis 3 Encoder Phase B
Axis 3 Home Switch	31	32	Axis 3 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 3	33	34	Axis 3 Forward Limit Switch
Axis 3 Inhibit	35	36	Axis 3 Reverse Limit Switch
Axis 4 Dir (CCW)	37	38	Axis 4 Step (CW)
Digital Ground	39	40	Axis 4 Encoder Phase A
Digital Ground	41	42	Axis 4 Encoder Phase B
Axis 4 Home Switch	43	44	Axis 4 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 4	45	46	Axis 4 Forward Limit Switch
Axis 4 Inhibit	47	48	Axis 4 Reverse Limit Switch
Digital Ground	49	50	Host +5 V

**Figure B-1.** 50-Pin Stepper Connector Pin Assignment (Axes 1–4)

Axis 5 Dir (CCW)	1	2	Axis 5 Step (CW)
Digital Ground	3	4	Axis 5 Encoder Phase A
Digital Ground	5	6	Axis 5 Encoder Phase B
Axis 5 Home Switch	7	8	Axis 5 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 5	9	10	Axis 5 Forward Limit Switch
Axis 5 Inhibit	11	12	Axis 5 Reverse Limit Switch
Axis 6 Dir (CCW)	13	14	Axis 6 Step (CW)
Digital Ground	15	16	Axis 6 Encoder Phase A
Digital Ground	17	18	Axis 6 Encoder Phase B
Axis 6 Home Switch	19	20	Axis 6 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 6	21	22	Axis 6 Forward Limit Switch
Axis 6 Inhibit	23	24	Axis 6 Reverse Limit Switch
Axis 7 Dir (CCW)	25	26	Axis 7 Step (CW)
Digital Ground	27	28	Axis 7 Encoder Phase A
Digital Ground	29	30	Axis 7 Encoder Phase B
Axis 7 Home Switch	31	32	Axis 7 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 7	33	34	Axis 7 Forward Limit Switch
Axis 7 Inhibit	35	36	Axis 7 Reverse Limit Switch
Axis 8 Dir (CCW)	37	38	Axis 8 Step (CW)
Digital Ground	39	40	Axis 8 Encoder Phase A
Digital Ground	41	42	Axis 8 Encoder Phase B
Axis 8 Home Switch	43	44	Axis 8 Encoder $\overline{\text{Index}}$
Trigger/Breakpoint 8	45	46	Axis 8 Forward Limit Switch
Axis 8 Inhibit	47	48	Axis 8 Reverse Limit Switch
Digital Ground	49	50	Host +5 V

**Figure B-2.** 50-Pin Stepper Connector Pin Assignment (Axes 5–8)

Analog Output Ground	1	2	Analog Output 1
Digital Ground	3	4	Axis 1 Encoder Phase A
Digital Ground	5	6	Axis 1 Encoder Phase B
Axis 1 Home Switch	7	8	Axis 1 Encoder Index
Trigger/Breakpoint 1	9	10	Axis 1 Forward Limit Switch
Axis 1 Inhibit	11	12	Axis 1 Reverse Limit Switch
Analog Output Ground	13	14	Analog Output 2
Digital Ground	15	16	Axis 2 Encoder Phase A
Digital Ground	17	18	Axis 2 Encoder Phase B
Axis 2 Home Switch	19	20	Axis 2 Encoder Index
Trigger/Breakpoint 2	21	22	Axis 2 Forward Limit Switch
Axis 2 Inhibit	23	24	Axis 2 Reverse Limit Switch
Analog Output Ground	25	26	Analog Output 3
Digital Ground	27	28	Axis 3 Encoder Phase A
Digital Ground	29	30	Axis 3 Encoder Phase B
Axis 3 Home Switch	31	32	Axis 3 Encoder Index
Trigger/Breakpoint 3	33	34	Axis 3 Forward Limit Switch
Axis 3 Inhibit	35	36	Axis 3 Reverse Limit Switch
Analog Output Ground	37	38	Analog Output 4
Digital Ground	39	40	Axis 4 Encoder Phase A
Digital Ground	41	42	Axis 4 Encoder Phase B
Axis 4 Home Switch	43	44	Axis 4 Encoder Index
Trigger/Breakpoint 4	45	46	Axis 4 Forward Limit Switch
Axis 4 Inhibit	47	48	Axis 4 Reverse Limit Switch
Digital Ground	49	50	Host +5 V

**Figure B-3.** 50-Pin Servo Connector Pin Assignment (Axes 1–4)

Analog Output Ground	1	2	Analog Output 5
Digital Ground	3	4	Axis 5 Encoder Phase A
Digital Ground	5	6	Axis 5 Encoder Phase B
Axis 5 Home Switch	7	8	Axis 5 Encoder Index
Trigger/Breakpoint 5	9	10	Axis 5 Forward Limit Switch
Axis 5 Inhibit	11	12	Axis 5 Reverse Limit Switch
Analog Output Ground	13	14	Analog Output 6
Digital Ground	15	16	Axis 6 Encoder Phase A
Digital Ground	17	18	Axis 6 Encoder Phase B
Axis 6 Home Switch	19	20	Axis 6 Encoder Index
Trigger/Breakpoint 6	21	22	Axis 6 Forward Limit Switch
Axis 6 Inhibit	23	24	Axis 6 Reverse Limit Switch
Analog Output Ground	25	26	Analog Output 7
Digital Ground	27	28	Axis 7 Encoder Phase A
Digital Ground	29	30	Axis 7 Encoder Phase B
Axis 7 Home Switch	31	32	Axis 7 Encoder Index
Trigger/Breakpoint 7	33	34	Axis 7 Forward Limit Switch
Axis 7 Inhibit	35	36	Axis 7 Reverse Limit Switch
Analog Output Ground	37	38	Analog Output 8
Digital Ground	39	40	Axis 8 Encoder Phase A
Digital Ground	41	42	Axis 8 Encoder Phase B
Axis 8 Home Switch	43	44	Axis 8 Encoder Index
Trigger/Breakpoint 8	45	46	Axis 8 Forward Limit Switch
Axis 8 Inhibit	47	48	Axis 8 Reverse Limit Switch
Digital Ground	49	50	Host +5 V

**Figure B-4.** 50-Pin Servo Connector Pin Assignment (Axes 5–8)



# Input/Output Reset States

This appendix lists the various states of the PXI/PCI- 7350 hardware during reset.

**Table C-1.** I/O States During Reset

Signal Names	Direction	During Reset			After Reset/Before Device Initialization		
		Mode	Polarity	State	Mode	Polarity	State
Motion I/O Connector							
Inhibit <1..8>	Output	Open collector	Active-low	Active	Open collector	Active-low	Active
Breakpoint <1..8>	Output	Totem Pole	Active-low	Inactive	Totem Pole	Active-low	Inactive
Step <1..8>	Output	Totem Pole	Active-low	Inactive	Totem Pole	Active-low	Inactive
Direction <1..8>	Output	Totem Pole	Active-low	Inactive	Totem Pole	Active-low	Inactive
Digital I/O Connector							
Digital I/O Ports <1..8>	Input	—	Active-low	Pulled up if DPull left floating	—	Active-low	Pulled up if DPull left floating

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# Glossary

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## A

absolute mode	treat the target position loaded as position relative to zero (0) while making a move
absolute position	position relative to zero
acceleration/ deceleration	a measurement of the change in velocity as a function of time. Acceleration and deceleration describes the period when velocity is changing from one value to another.
active-high	signal is active when its value is high (1)
active-low	signal is active when its value is low (0)
ADC	analog-to-digital converter
address	character code that identifies a specific location (or series of locations) in memory or on a host PC bus system
amplifier	drive that delivers power to operate the motor in response to control signals. In general, the amplifier is designed to operate with a particular motor type. For example, you cannot use a stepper drive to operate a DC brush motor.
Analog Input <1..8>	16-bit analog ADC input
Analog Output <1..8>	DAC voltage output
API	application programming interface
axis	unit that controls a motor or any similar motion or control device
Axis <1..8> Forward Limit Input	axis 1 through 8 forward limit switch
Axis <1..8> Home Input	axis 1 through 8 home input



Axis <1..8> $\overline{\text{Inhibit}}$	axis 1 through 8 inhibit output
Axis <1..8> Reverse Limit Input	axis 1 through 8 reverse limit input

## **B**

b	bit—one binary digit, either 0 or 1
base address	memory address that serves as the starting address for programmable or I/O bus registers. All other addresses are located by adding to the base address.
binary	number system with a base of 2
buffer	temporary storage for acquired or generated data (software)
bus	group of conductors that interconnect individual circuitry in a computer. Typically, a bus is the expansion vehicle to which I/O or other devices are connected.

## **C**

CCW	counter-clockwise—implies direction of rotation of the motor
closed-loop	motion system that uses a feedback device to provide position and velocity data for status reporting and accurately controlling position and velocity
common	reference signal for digital I/O
CPU	central processing unit
crosstalk	unwanted signal on one channel due to an input on a different channel
CSR	Communications Status Register
CW	clockwise—implies direction of motor rotation

**D**

DAC	Digital-to-Analog Converter
DAQ	Data Acquisition
dedicated	assigned to a particular function
DGND	digital ground signal
digital I/O port	group of digital input/output signals
DIP	dual inline package
DLL	dynamic link library—provides the API for the motion control boards
drive	electronic signal amplifier that converts motor control command signals into higher-voltage signals suitable for driving motors
DSP	Digital Signal Processor

**E**

encoder	device that translates mechanical motion into electrical signals; used for monitoring position or velocity in a closed-loop system
encoder resolution	number of encoder lines between consecutive encoder indexes (marker or Z-bit). If the encoder does not have an index output the encoder resolution can be referred to as lines per revolution.

**F**

F	Farad
FIFO	First-In, First-Out
filter parameters	indicates the control loop parameter gains (PID gains) for a given axis
filtering	type of signal conditioning that filters unwanted signals from the signal being measured
flash ROM	type of electrically reprogrammable read-only memory

following error trip point	difference between the instantaneous commanded trajectory position and the feedback position
FPGA	Field Programmable Gate Array
freewheel	condition of a motor when power is de-energized and the motor shaft is free to turn with only frictional forces to impede it
full-step	full-step mode of a stepper motor—for a two phase motor this is done by energizing both windings or phases simultaneously

## G

Gnd	ground
GND	ground

## H

half-step	mode of a stepper motor—for a two phase motor this is done by alternately energizing two windings and then only one. In half step mode, alternate steps are strong and weak but there is significant improvement in low-speed smoothness over the full-step mode.
hex	hexadecimal
home switch (input)	physical position determined by the mechanical system or designer as the reference location for system initialization. Frequently, the home position is also regarded as the zero position in an absolute position frame of reference.
host computer	computer the motion control board is plugged into

## I

index	marker between consecutive encoder revolutions
inverting	polarity of a switch (limit switch, home switch, and so on) in <i>active</i> state. If these switches are active-low, they are said to have inverting polarity.
IRQ	interrupt request

**K**

k kilo—the standard metric prefix for 1,000, or  $10^3$ , used with units of measure such as volts, hertz, and meters

**L**

LIFO Last-In, First-Out

limit switch/  
end-of-travel position  
(input) sensors that alert the control electronics that the physical end of travel is being approached and that the motion should stop

**M**

MCS Move Complete Status

microstep proportional control of energy in the coils of a Stepper Motor, which allow the motor to move to or stop at locations other than the fixed magnetic/mechanical pole positions determined by the motor specifications. This capability facilitates the subdivision of full mechanical steps on a stepper motor into finer microstep locations that greatly smooth motor running operation and increase the resolution or number of discrete positions that a stepper motor can attain in each revolution.

modulo position treat the position as if it is within the range of total quadrature counts per revolution for an axis

**N**

noise undesirable electrical signal—noise comes from external sources such as the AC power line, motors, generators, transformers, fluorescent lights, soldering irons, CRT displays, computers, electrical storms, welders, radio transmitters, and internal sources such as semiconductors, resistors, and capacitors. Noise corrupts signals you are trying to send or receive.

noninverting polarity of a limit switch, home switch, and so on, in *active* state. If these switches are active-high, they are said to have non-inverting polarity.

## O

open collector	method of output capable of sinking current, but not sourcing current
open-loop	refers to a motion control system where no external sensors (feedback devices) are used to provide position or velocity correction signals

## P

PCI	Peripheral Component Interconnect—a high-performance expansion bus architecture originally developed by Intel to replace ISA and EISA. PCI is achieving widespread acceptance as a standard for PCs and workstations; it offers a theoretical maximum transfer rate of 132 MB/s.
PID	proportional-integral-derivative control loop
PIVff	proportional-integral-velocity feed forward
port	(1) communications connection on a computer or a remote controller; (2) digital port, consisting of eight lines of digital input and/or output
position breakpoint	position breakpoint for an encoder can be set in absolute or relative quadrature counts. When the encoder reaches a position breakpoint, the associated breakpoint output immediately transitions.
power cycling	turning the host computer off and then back on, which causes a reset of the motion control board
PWM	Pulse Width Modulation—a method of controlling the average current in a motor phase winding by varying the on-time (duty cycle) of transistor switches
PXI	PCI eXtensions for Instrumentation

## Q

quadrature counts	encoder line resolution multiplied by four
-------------------	--

**R**

relative breakpoint	sets the position breakpoint for an encoder in relative quadrature counts
relative position	destination or target position for motion specified with respect to the current location regardless of its value
relative position mode	position relative to current position
ribbon cable	flat cable in which the conductors are side by side
RPM	revolutions per minute—units for velocity
RPS/PS or RPS/S	revolutions per second squared—units for acceleration and deceleration
RTR	Ready to Receive

**S**

servo	specifies an axis that controls a servo motor
sinusoidal commutation	method of controlling current in the windings of a brushless servo motor by using the pattern of a sine wave to shape the smooth delivery of current to three motor inputs, each 120° out of phase from the next
stepper	specifies an axis that controls a stepper motor
stepper <1..8> Dir (CCW)	direction output or counter-clockwise direction control
stepper <1..8> Step (CW)	stepper pulse output or clockwise direction control

**T**

toggle	changing state from high to low, back to high, and so on
torque	force tending to produce rotation
Totem Pole	method of output capable of sinking and sourcing current

trapezoidal profile      typical motion trajectory, where a motor accelerates up to the programmed velocity using the programmed acceleration, traverses at the programmed velocity, then decelerates at the programmed acceleration to the target position

trigger      any event that causes or starts some form of data capture

TTL      transistor-transistor logic

## **V**

$V_{CC}$       positive voltage supply

velocity mode      move the axis continuously at a specified velocity

## **W**

watchdog      timer task that shuts down (resets) the motion control board if any serious error occurs

word      standard number of bits that a processor or memory manipulates at one time, typically 8-bit, 16-bit, or 32-bit

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