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Motion Control

7344/7334 Hardware User Manual

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Worldwide Technical Support and Product Information

ni.com

National Instruments Corporate Headquarters

11500 North Mopac Expressway Austin, Texas 78759-3504 USA Tel: 512 794 0100

Worldwide Offices

Australia 03 9879 5166, Austria 0662 45 79 90 0, Belgium 02 757 00 20, Brazil 011 284 5011,
Canada (Calgary) 403 274 9391, Canada (Montreal) 514 288 5722, Canada (Ottawa) 613 233 5949,
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About This Manual

This manual describes the electrical and mechanical aspects of each controller in the 7344/7334 family and contains information concerning their operation and programming. Unless otherwise noted, text applies to all controllers in the 7344/7334 family.

The following controllers are in the 7344/7334 family:

- PCI-7344
- PXI-7344
- FW-7344
- PCI-7334
- PXI-7334

The 7344/7334 controllers are designed for PCI, PXI, and 1394 bus computers.

Refer to the *Glossary* for definitions of selected related terms.

Conventions

The 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, DBIO<3..0>.
♦	This 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 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.
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.

Related Documentation

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

- *FlexMotion Software Reference Manual*
- FlexMotion Software Reference online help
- FlexMotion VI online help
- *PCI Local Bus Specification*, Revision 2.1
- Your computer's technical reference manual

1

Introduction

This chapter describes National Instruments' FlexMotion 7344 and 7334 controllers and their operation.

About the 7344/7334 Controller

The PCI/PXI-7344/7334 and FW-7344 controllers feature advanced motion control with easy-to-use software tools and add-on motion VI libraries for use with LabVIEW.

Features

The 7344 controllers are a combination of servo and stepper motor controllers for PCI, PXI, and 1394 bus computers. The 7334 controllers are exclusively stepper motor controllers for PCI and PXI bus computers. Both controller families provide fully programmable motion control for up to four independent or coordinated axes of motion, with dedicated motion I/O for limit and home switches and additional I/O for general-purpose functions.

You can use the 7334 motion controllers for point-to-point and straight-line vector moves for stepper motor applications. The 7344 controllers add the ability to perform arbitrary and complex motion trajectories using stepper motors or servo devices. Refer to the *FlexMotion Software Reference Manual* for a complete list of the feature differences between the 7344 and 7334 controller lines.

Servo axes can control servo motors, servo hydraulics, servo valves, and other servo devices. 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 ±10 V.

Stepper axes control stepper motors. These axes can operate in open or closed-loop mode. They use quadrature encoders or analog inputs for position and velocity 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

The 7344/7334 controllers have high-performance capabilities because of the advanced dual-processor architecture that uses a Motorola MC68331 real-time 32-bit CPU, combined with an Analog Devices ADSP-2185 digital signal processor (DSP) and custom field programmable gate arrays (FPGAs). The first-in-first-out (FIFO) bus interface and powerful function set provide high-speed communications while off-loading complex motion functions from the host PC for optimum command throughput and system performance.

With the 7344 controllers, you can use full onboard programming to execute up to 10 simultaneous motion programs in a preemptive, real-time multitasking operating system environment.

The 7344 features motion profiles that are controlled with enhanced *PID*/*PIVff* servo updates at 62 µs per axis. With all 7344/7334 controllers, each axis has motion I/O for end-of-travel limit and home switch inputs, breakpoint output, trigger input, and encoder feedback rates up to 20 MHz. The 7344/7334 controller also has non-dedicated user I/O including 32 bits of digital I/O and four analog inputs for ±10 V signals, joystick inputs, or monitoring of analog sensors. Additionally, the 7344/7334 analog inputs can provide feedback for loop closure.

RTSI

The 7344/7334 controllers support 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

To set up and use your 7344/7334 controller, you will need the following items:

- ❑ One of the following 7344/7334 controllers:
  - PCI-7344
  - PXI-7344
  - FW-7344
  - PCI-7334
  - PXI-7334
- ❑ *7344/7334 Hardware User Manual*
- ❑ *FlexMotion Software Reference Manual*
- ❑ One of the following software packages and documentation:
  - LabVIEW
  - LabWindows/CVI
  - FlexMotion software
- ❑ A computer with an available PCI or PXI slot or a 1394 port

Software Programming Choices

The simple but powerful high-level function set application programming interface (API) makes programming the 7344/7334 controllers easy. All setup and motion control functions are easily executed by calling into either a static or dynamically-linked library (DLL). These libraries are callable from C, Visual Basic, and other high-level languages. Full function set implementations are available for LabVIEW, LabWindows/CVI, and other industry-standard software programs.

National Instruments' Application Software

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 FlexMotion VI Library, a series

of virtual instruments (VIs) for using LabVIEW with National Instruments' motion control hardware. The FlexMotion VI library implements the full function set API and a powerful set of demo functions, example programs, and fully operational, high-level application routines.

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, and all measurement and automation solutions. The FlexMotion software includes a series of sample programs for using LabWindows/CVI with National Instruments' motion control hardware.

Optional Equipment

National Instruments offers a variety of products for use with the 7344/7334 controllers, including cables, Universal Motion Interfaces (UMIs), drive power amplifier units, and the following accessories:

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

For more specific information about these products, refer to the National Instruments catalog, the National Instruments Web site at `ni.com`, or call your National Instruments sales representative.

Motion I/O Connections

The external motion and digital I/O connectors on the 7344/7334 controller are high-density, 68-pin female VHDCI connectors.

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

2

Configuration and Installation

This chapter describes how to configure and install the 7344/7334 controllers.

Software Installation

Before installing your 7344/7334 controller, install the FlexMotion software and, if appropriate, the Motion VI libraries. Refer to the release notes included with the controller for specific instructions on the software installation sequence for your host PC.

Controller Configuration

Because motion I/O-related configuration of 7344/7334 controllers is performed entirely with software, it is not necessary to set jumpers for motion I/O configuration.

The PCI-7344, PXI-7344, PCI-7334, and PXI-7334 controllers are fully compatible with the *PCI Local Bus Specification*, Revision 2.1. The FW-7344 controller is fully compatible with the IEEE 1394 specification. This compatibility allows the computer to automatically perform all bus-related configuration and requires no user interaction. It is not necessary to configure jumpers for bus-related configuration.

Safety Information



Caution The following paragraphs contain important safety information you *must* follow when installing and operating the device.

Do *not* operate the device in a manner not specified in the documentation. Misuse of the device may result in a hazard and may compromise the safety protection built into the device. If the device is damaged, turn it off and do *not* use it until service-trained personnel can check its safety. If necessary, return the device to National Instruments for repair.

Keep away from live circuits. Do *not* remove equipment covers or shields unless you are trained to do so. If signal wires are connected to the device, hazardous voltages can exist even when the equipment is turned off. To avoid a shock hazard, do *not* perform procedures involving cover or shield removal unless you are qualified to do so. Disconnect all field power prior to removing covers or shields.

If the device is rated for use with hazardous voltages (>30 V_{rms}, 42.4 V_{pk}, or 60 V_{dc}), it may require a safety earth-ground connection wire. See the device specifications for maximum voltage ratings.

Because of the danger of introducing additional hazards, do *not* install unauthorized parts or modify the device. Use the device only with the chassis, modules, accessories, and cables specified in the installation instructions. All covers and filler panels must be installed while operating the device.

Do *not* operate the device in an explosive atmosphere or where flammable gases or fumes may be present. Operate the device only at or below the pollution degree stated in the specifications. Pollution consists of any foreign matter—solid, liquid, or gas—that may reduce dielectric strength or surface resistivity. Pollution degrees are listed below.

- Pollution Degree 1—No pollution or only dry, nonconductive pollution occurs. The pollution has no effect.
- Pollution Degree 2—Normally only nonconductive pollution occurs. Occasionally, nonconductive pollution becomes conductive because of condensation.
- Pollution Degree 3—Conductive pollution or dry, nonconductive pollution occurs. Nonconductive pollution becomes conductive because of condensation.

Clean the device and accessories by brushing off light dust with a soft, nonmetallic brush. Remove other contaminants with a stiff, nonmetallic brush. The unit *must* be completely dry and free from contaminants before returning it to service.

You *must* insulate signal connections for the maximum voltage for which the device is rated. Do *not* exceed the maximum ratings for the device. Remove power from signal lines before connection to or disconnection from the device.

Operate this device only at or below the installation category stated in the specifications. Installation categories are listed below.

- Installation Category IV—for measurements performed at the source of the low-voltage (<1000 V) installation. Examples include electricity meters, measurements on primary overcurrent protection devices, and ripple-control units.
- Installation Category III—for measurements performed in the building installation. Examples include measurements on distribution boards, circuit-breakers, wiring (including cables), bus bars, junction boxes, switches, socket outlets in the fixed installation, equipment for industrial use, and some other types of equipment, such as stationary motors permanently connected to the fixed installation.
- Installation Category II—for measurements performed on circuits directly connected to the low-voltage installation. Examples include measurements on household appliances, portable tools, and other similar equipment.
- Installation Category I—for measurements performed on circuits not directly connected to mains[1]. Examples include measurements on circuits not derived from mains, and specially-protected (internal) mains-derived circuits.

Figure 2-1 illustrates a sample installation.

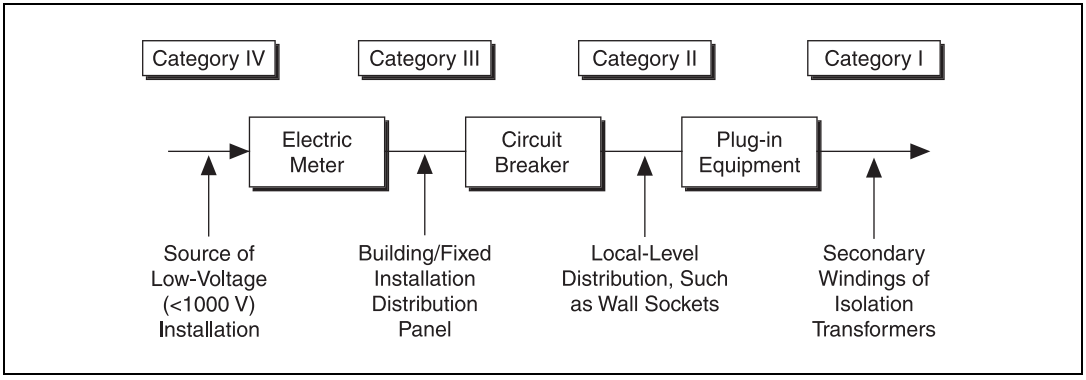


Figure 2-1. Sample Installation

[1] *Mains* is defined as the electricity supply system to which the equipment concerned is designed to be connected for either powering the equipment or for measurement purposes.

Hardware Installation

Install the PCI-7344, PXI-7344, PCI-7334, or PXI-7334 controllers in any open compatible expansion slot in your computer. Appendix A, *Specifications*, lists the typical power required for each controller.

Connect the FW-7344 to any available 1394 port. The FW-7344 supports IEEE 1394 transfer rates up to 400 Mbits/s.

The following instructions are for general installation. Consult your computer user manual or technical reference manual for specific instructions and warnings.

Caution 7344/7334 controllers are sensitive electronic devices shipped in an antistatic bag. Open only at an approved workstation and observe precautions for handling electrostatic-sensitive devices.

- PCI-7344 and PCI-7334
  1. Turn off and unplug your computer.
  2. Remove the top cover or access port to the PCI expansion slots in your computer.
  3. Wait for any motherboard LEDs to turn off to ensure system power has dissipated.
  4. Remove the expansion slot connector port cover on the back panel of your computer.
  5. Insert the 7344/7334 controller into a +3 V or +5 V PCI slot. Gently rock the board to ease it into place. It may be a tight fit, but do *not* force the board into place.
  6. If available, screw the7344/7334 controller mounting bracket to the back panel rail of the computer.
  7. Replace the cover.
  8. Plug in the 68-pin cable for motion I/O to the 7344/7334 controller.
  9. Plug in and turn on your computer.

  Your PCI-7344/7334 controller is installed.

- PXI-7344 and PXI-7334
  1. Turn off and unplug your chassis.
  2. Remove the filler panel from a +3 V or +5 V peripheral slot.

3. Touch a metal part on your chassis to discharge any static electricity that might be on your clothes or body.
4. Insert the PXI board into the slot. Use the injector/ejector handle to fully inject the device into place.
5. Screw the front panel of the PXI board to the front panel mounting rails of the chassis.
6. Visually verify the installation.
7. Plug in and turn on the chassis.

Your PXI-7344/7334 controller is installed.

- FW-7344

Note If you are *not* using the BP-1 battery pack, follow the instructions below. If you are using the BP-1 battery pack, follow the installation instructions in your *BP-1 Battery Pack Installation Guide* and then start with step 2 below.

1. Connect the power cord to the wall outlet and the FW-7344 controller.
2. Connect the 1394 cable from the computer or any other 1394 device to the port on your FW-7344 controller. Your computer should immediately detect the controller. The COM LED on the front panel blinks when the computer recognizes the controller.
3. Verify that the power LED is on.

Your FW-7344 controller is installed.

Use the Power LED and the Communication LED (described below) to determine the state of the device.

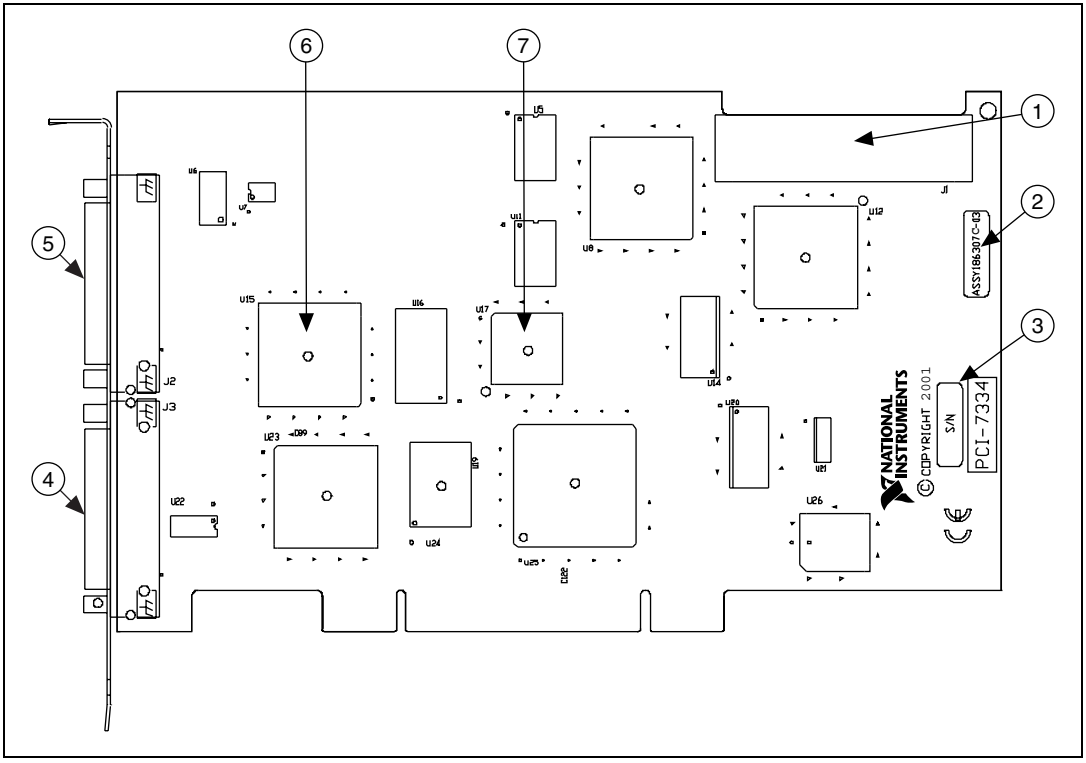
- Power LED
  - Power LED off—The controller is receiving no power. Either the power cord is unplugged or the power source is broken.
  - Power LED dim—The controller is receiving power but is not connected to an active 1394 port.
  - Power LED on—The controller is receiving power and is connected to an active 1394 port.
- Communication LED—The COM LED blinks when the controller sends or receives any commands or data. This LED should blink once when you first plug in your controller. This light remains on or blinks continuously when large amounts of data are transferring.

3

Hardware Overview

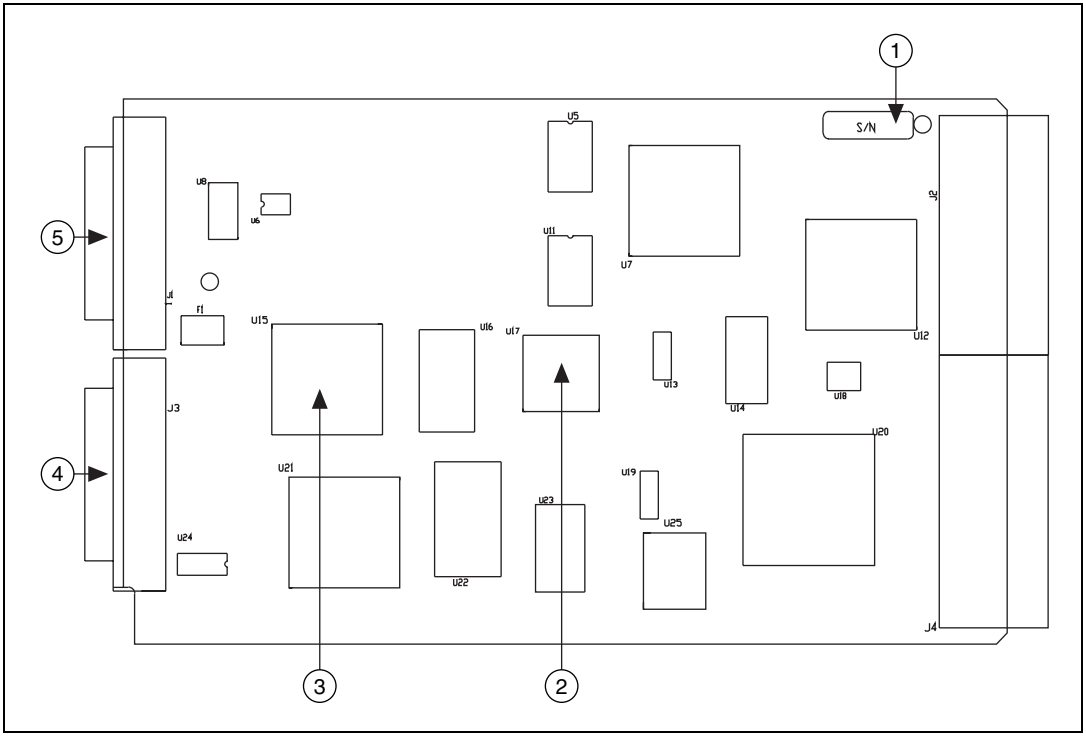
This chapter presents an overview of the 7344/7334 controller hardware functionality.

Figures 3-1, 3-2, 3-4, and 3-5 show the PCI-7344, PXI-7344, PCI-7334, and PXI-7334 parts locator diagrams, respectively. Figure 3-3 shows the FW-7344 back panel.



1 RTSI Connector	4 68-Pin Digital I/O Connector	6 MC68331 CPU
2 Assembly Number Label	5 68-Pin Motion I/O Connector	7 ADSP 2185 DSP
3 Serial Number Label		

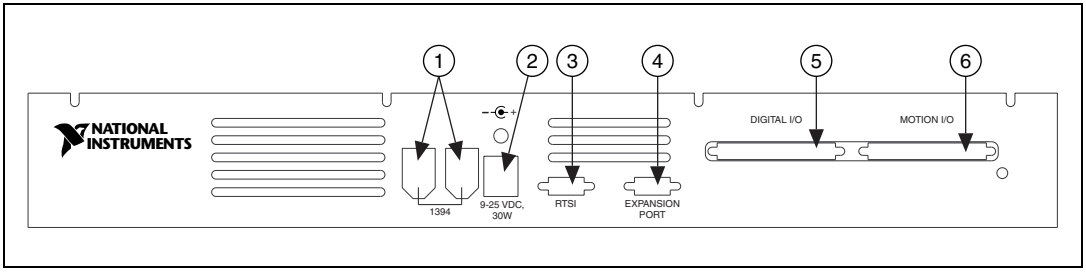
Figure 3-1. PCI-7344 Parts Locator Diagram



1	Serial Number Label	3	MC68331 CPU	5	68-Pin Motion I/O Connector
2	ADSP 2185 DSP	4	68-Pin Digital I/O Connector		

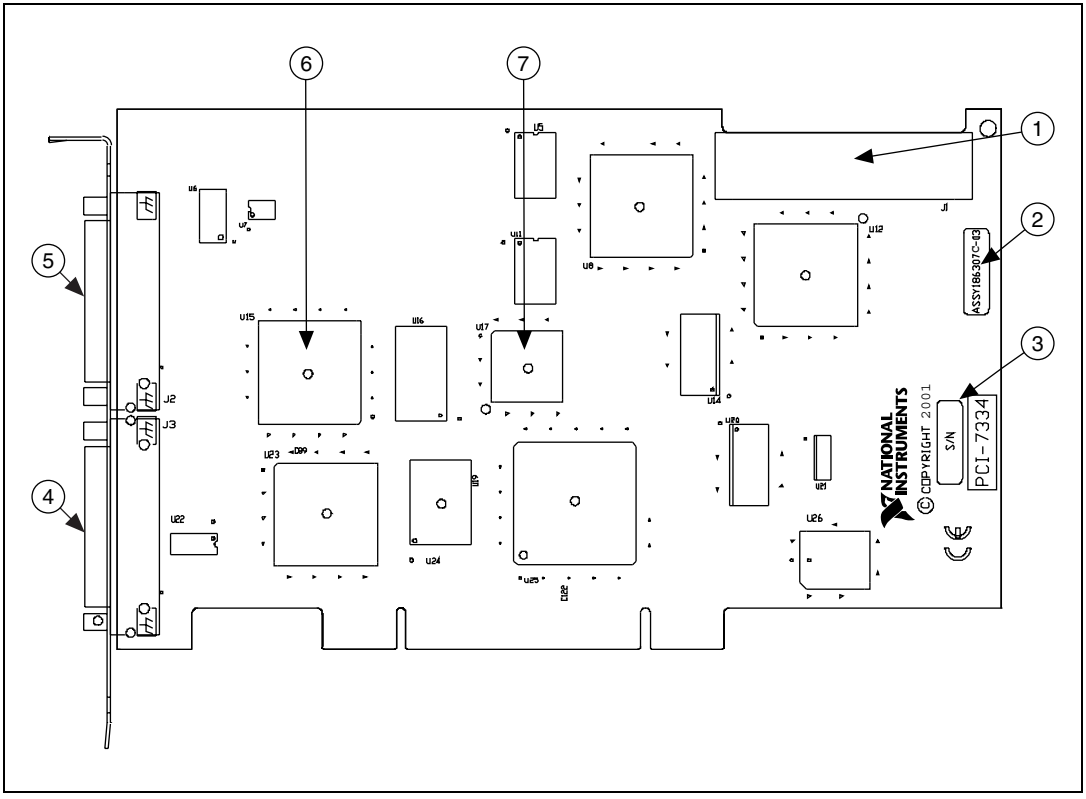
Figure 3-2. PXI-7344 Parts Locator Diagram

Note The PXI-7344 assembly number is located on the back of the PXI module.



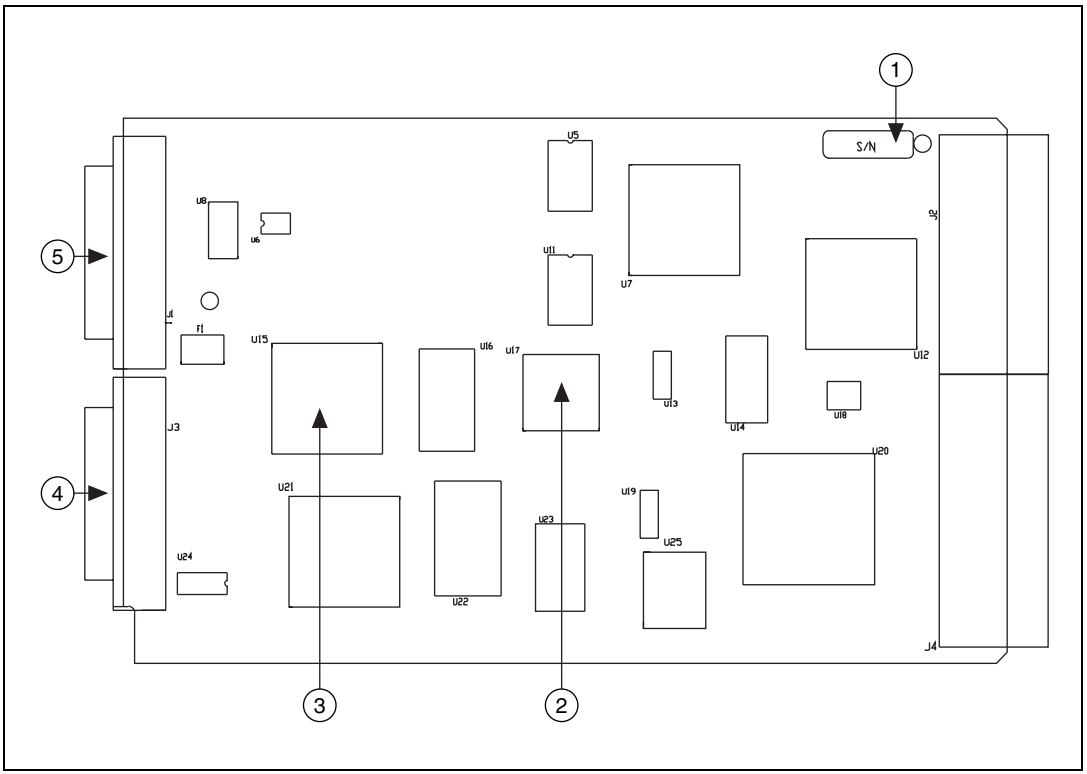
1	1394 Connectors	3	RTSI Connector	5	68-Pin Digital I/O Connector
2	Power Connector	4	Expansion Port Connector	6	68-Pin Motion I/O Connector

Figure 3-3. FW-7344 Back Panel



1	RTSI Connector	4	68-Pin Digital I/O Connector	6	MC68331 CPU
2	Assembly Number Label	5	68-Pin Motion I/O Connector	7	ADSP 2185 DSP
3	Serial Number Label				

Figure 3-4. PCI-7334 Parts Locator Diagram



1	Serial Number Label	3	MC68331 CPU	5	68-Pin Motion I/O Connector
2	ADSP 2185 DSP	4	68-Pin Digital I/O Connector		

Figure 3-5. PXI-7334 Parts Locator Diagram

Note The PXI-7334 assembly number is located on the back of the PXI module.

User Connectors

The 68-pin motion I/O connector provides all the signals for four 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 connector.

The 68-pin digital I/O connector provides 32 bits of user-configurable digital I/O. Refer to Chapter 5, *Signal Connections*, for details about the signals in the digital I/O connector.

The RTSI connector provides up to seven triggers and one high-speed clock signal to facilitate synchronization between multiple 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.

The RTSI bus can also be used for general-purpose I/O. Refer to Chapter 5, *Signal Connections*, for details about RTSI connector signals.

4

Functional Overview

This chapter provides an overview of the motion control algorithms and the 7344/7334 controller capabilities.

Dual Processor Architecture

With 7344/7334 controllers, you can perform up to four axes of simultaneous, coordinated motion control in a preemptive, multitasking, real-time environment.

An advanced dual-processor architecture that uses a Motorola MC68331 real-time 32-bit CPU combined with an Analog Devices ADSP 2185 DSP and custom FPGAs give the 7344/7334 controllers high-performance capabilities. The FIFO bus interface and powerful function set provide high-speed communications while off-loading complex motion functions from the host PC for optimized system performance.

The 7344/7334 controllers use the digital signal processor for all closed-loop control, including position tracking, PID control closed-loop computation, and motion trajectory generation. The DSP chip is supported by custom FPGAs that perform 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, multitasking real-time CPU 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 by an internal packet-based command, data, and messaging event structure. The 7344/7334 controllers are true multiprocessing and multitasking embedded controllers.

The advanced architecture of the 7344/7334 controller enables advanced motion features, such as enhanced PID functions. Refer to the *FlexMotion Software Reference Manual* for more information on the features available on the 7344/7334 controllers.

Trajectory Generators

The 7344/7334 controller trajectory generators 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 7344/7334 controller has eight 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 Feedback

The 7344/7334 controllers have an 8-channel multiplexed, 12-bit ADC. The converted analog values are broadcast to both the DSP and CPU via a dedicated internal high-speed serial bus. The multiplexer scan rate is approximately 50 µs per enabled ADC channel, which provides the high sampling rates required for feedback loop closure, joystick inputs, or monitoring analog sensors. Four of these channels are intended for calibration, leaving the other four available for analog feedback.

Flash Memory

Nonvolatile memory on the 7344/7334 controllers is implemented with flash ROM, which means that the controllers can electrically erase and reprogram their own ROM. Since all the embedded firmware, including the RTOS and DSP code, of the 7344/7334 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 parameter 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.

The FPGA configuration programs are also stored in the flash ROM. At power-up, the FPGAs are booted with these programs, which means that updates to the FPGA programs can be performed in the field.

A flash memory download utility is included with the FlexMotion software that ships with the controller.

Axes and Motion Resources

The 7344/7334 controllers can control up to four axes of motion. The axes can be completely independent, simultaneously coordinated, or mapped in multidimensional groups called vector spaces. You can also synchronize vector 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 have either an encoder or ADC channel feedback resource. 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 7344/7334 controllers, you can map one or two feedback resources and one or two output resources to the axis. An axis with its primary output resource mapped to a stepper output is by definition a stepper axis. An axis with its primary output resource mapped to a DAC is by definition a servo axis.

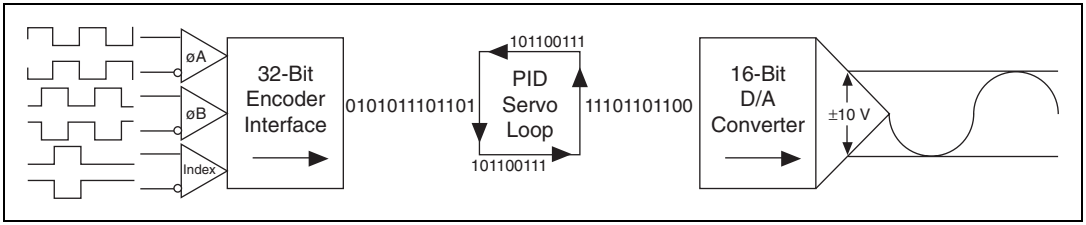


Figure 4-1. Servo Axis Resources

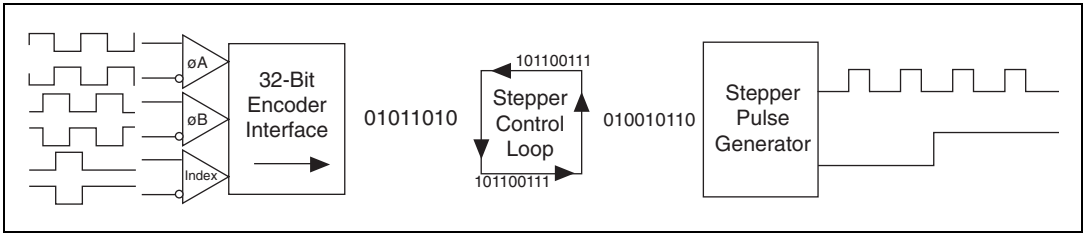


Figure 4-2. Stepper Axis Resources

The 7344/7334 controller supports axes with secondary output resources (DACs for servo axes or stepper outputs). 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 7344 controllers also support secondary feedback resources (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 *Axis and Resource Configuration* section of the *FlexMotion Software Reference Manual* for more information on 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 nonmotion-specific applications. You can directly control an unmapped DAC as a general-purpose analog output (±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 or velocity 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 breakpoint output, and an inhibit output. These signals can be used for general-purpose digital I/O when not being used for their motion-specific purpose.

Note Once mapped to an axis, all features and functions of a resource are available as part of the axis. It is not necessary to remember or use the resource number directly when accessing these features. Resources are referenced by axis number once assigned to that axis.

Onboard Programs (7344 only)

The 7344 controllers have full onboard programmability with the capability of executing up to 10 simultaneous motion programs in a real-time preemptive multitasking environment.

This powerful feature is designed for real-time applications that need tight synchronization and/or minimum latency—from a motion or other I/O event—and fast command execution.

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

Implementing part or all of your motion application as an onboard program or programs offloads the host PC from handling these real-time tasks and events. Doing so leaves the host PC available for the other integrated tasks, such as data acquisition, image processing, user interface, data analysis, and/or overall measurement and automation system control.

Onboard programs can also isolate your application from the non-real-time operating system of the host PC. Only the bus power is required to correctly execute an onboard FlexMotion program once it is started, and this program continues to run even if the host PC hangs, assuming the host power supply remains.

You can run onboard programs from RAM or optionally save them to flash ROM. The 7344 controllers have 64 KB of RAM and 128 KB of ROM (divided into two 64 KB sectors) for program and object storage. You can run programs from either RAM or ROM, but you cannot split programs between the two, and you cannot split programs between the two 64 KB ROM sectors. With an average command size of 10 bytes, a single program

can be as large as 6,400 commands. For example, the 7344 controllers can simultaneously execute 10 programs, five from RAM and five from ROM, with each program up to 1,280 commands long.

Note Refer to the *Onboard Programming Functions* section of the *FlexMotion Software Reference Manual* for detailed information on all of these onboard programming features.

Host Communications

The host computer communicates with the controller through a number of memory port addresses on the host bus. The host bus can be any of the supported bus standards: PCI, PXI, or 1394.

The primary bidirectional data transfer port is at the base address of the controller. This port supports FIFO data passing in both send and readback directions. The 7344/7334 controllers have both a command buffer for incoming commands and a return data buffer (RDB) for readback data.

Two read-only status registers are at offsets from the base address. 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.

5

Signal Connections

This chapter describes how to make input and output signal connections directly to the 7344/7334 controllers and briefly describes the associated I/O circuitry.

The 7344/7334 controllers have three connectors that handle all signals to and from the external motion system:

- 68-pin motion I/O connector
- 68-pin digital I/O connector
- RTSI connector

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

Caution Turn off power to all devices when connecting or disconnecting the 7344/7334 controller motion I/O and auxiliary digital I/O cables. Failure to do so may damage the controller.

Motion I/O Connector

The motion I/O connector contains all of the signals required to control up to four axes of servo (7344 only) 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

The motion I/O connector also contains four channels of 12-bit A/D inputs for analog feedback or general-purpose analog input.

Figure 5-1 shows the pin assignments for the 68-pin motion I/O connector on the 7344/7334 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 $\overline{\text{Index}}$
Trigger 1	5	39	Axis 1 Forward Limit Switch
Axis 1 $\overline{\text{Inhibit}}$	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 $\overline{\text{Index}}$
Trigger 2	11	45	Axis 2 Forward Limit Switch
Axis 2 $\overline{\text{Inhibit}}$	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 $\overline{\text{Index}}$
Trigger 3	17	51	Axis 3 Forward Limit Switch
Axis 3 $\overline{\text{Inhibit}}$	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 $\overline{\text{Index}}$
Trigger 4	23	57	Axis 4 Forward Limit Switch
Axis 4 $\overline{\text{Inhibit}}$	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

* Available only on the 7344 motion controllers

Figure 5-1. 68-Pin Motion I/O Connector Pin Assignment

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
Axis <1..4> Dir (CCW)	Digital Ground	Output	Motor direction or counter-clockwise control
Axis <1..4> Step (CW)	Digital Ground	Output	Motor step or clockwise control
Axis <1..4> Encoder Phase A	Digital Ground	Input	Closed-loop only—phase A encoder input
Axis <1..4> Encoder Phase B	Digital Ground	Input	Closed-loop only—phase B encoder input
Axis<1..4> Encoder $\overline{\text{Index}}$	Digital Ground	Input	Closed-loop only—index encoder input
Axis <1..4> Home Switch	Digital Ground	Input	Home switch
Axis <1..4> Forward Limit Switch	Digital Ground	Input	Forward/clockwise limit switch
Axis <1..4> Reverse Limit Switch	Digital Ground	Input	Reverse/counter-clockwise limit switch
Axis <1..4> $\overline{\text{Inhibit}}$	Digital Ground	Output	Drive inhibit
Trigger <1..4>	Digital Ground	Input	High-speed position capture trigger input <1..4>
Breakpoint <1..4>	Digital Ground	Output	Breakpoint output <1..4>
Host +5 V	Digital Ground	Output	+5 V—host computer +5 V supply
Analog Input Ground	—	—	Reference for analog inputs
Analog Input <1..4>	Analog Input Ground	Input	12-bit analog input
Analog Output <1..4>	Analog Output Ground	Output	16-bit analog output (7344 only)
Analog Output Ground	—	—	Reference for analog outputs (7344 only)
Shutdown	Digital Ground	Input	Controlled device shutdown
Analog Reference (output)	Analog Input Ground	Output	+7.5 V—analog reference level
Digital Ground	—	—	Reference for digital I/O

Motion Axis Signals

The following signals control the servo amplifier or stepper driver:

- Analog Output <1..4> (7344 only)—These 16-bit DAC outputs are typically the servo command outputs for each axis. They can drive the industry-standard ±10 V output, and can be software limited to any positive or negative voltage range desired. They also feature a software-programmable voltage offset.

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

- Analog Output Ground (7344 only)—To help keep digital noise separate from the analog DAC outputs, there is a separate return connection. Use this analog ground connection and not Digital Ground (digital I/O reference) as the reference for the DAC outputs when connecting to servo amplifiers.

- Axis <1..4> Step (CW) and Dir (CCW)—These open-collector signals are the stepper command outputs for each axis. The 7344/7334 controller supports both major industry standards for stepper command signals: step and direction, or independent CW and 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 mode produces 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.

  The Step (CW) and Dir (CCW) outputs are driven by high-speed open-collector TTL buffers that feature 64 mA sink current capability and built-in 3.3 kΩ pull-up resistors to +5 V.

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..4> Inhibit—Use the inhibit output signals to control the enable/inhibit function of a servo amplifier or stepper driver. When properly connected and configured, the inhibit function causes the connected motor to be de-energized and its shaft turns freely. These open-collector inhibit signals feature 64 mA current sink capability with built-in 3.3 kΩ pull-up resistors to +5 V, and can directly drive most driver/amplifier inhibit input circuits.

  While 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 and unique drive compatibility.

  Inhibit output signals can be activated automatically upon a Kill Motion command or any motion error that causes a kill motion condition (for example, following error trip). You can also directly control the inhibit output signals to enable or disable a driver or amplifier.

Limit and Home Inputs

The following signals control limit and home inputs:

- Axis <1..4> Forward Limit Input
- Axis <1..4> Home Input
- Axis <1..4> Reverse Limit Input

These inputs are typically connected to limit switches located at physical ends of travel and/or at a specific home position. Limit and home inputs can be software enabled or disabled at any time. When enabled, an active transition on a limit or home input causes a full torque halt stop of the associated motor 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 at least 1 ms to be recognized. 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 7344/7334 controllers and are not required for basic motion control. These inputs are part of a system solution for complete motion control.

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. Miswired limits may prevent motion from occurring at all.

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

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

Limit and Home Input Circuit

All limit and home inputs are digitally filtered and must be active for at least 1 ms. Figure 5-2 shows a simplified schematic diagram of the circuit used by the limit and home switch inputs for input signal buffering and detection.

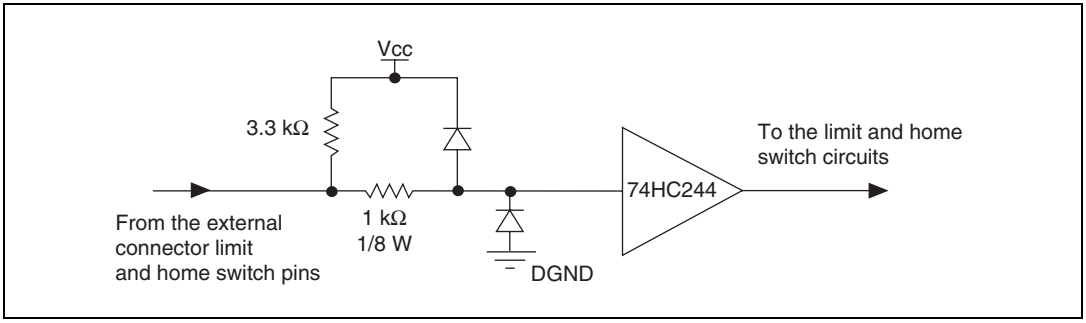


Figure 5-2. Limit and Home Input Circuit

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

Encoder Signals

The 7344/7334 controllers offer four 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..4> 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 or velocity monitoring, digital potentiometer encoder inputs, or as a master encoder input for master/slave (electronic gearing) applications.

The encoder channels (Encoder <1..4>) are implemented in an FPGA and are high performance with extended input frequency response and advanced features, such as high-speed position capture inputs and breakpoint outputs. The encoders have a maximum count frequency of 20 MHz.

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 FlexMotion 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 (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..4> Index

The Index input is primarily used with the Find Index function. This function uses the number of counts per revolution (or linear distance) to initiate a search move that locates the index position. When a valid Index signal transition occurs during a Find Index sequence, the position of the Index signal is captured very accurately. Use this captured position to establish a reference zero position for absolute position control or any other motion system position reference required. Figure 5-3 shows the quadrature encoder phasing diagram.

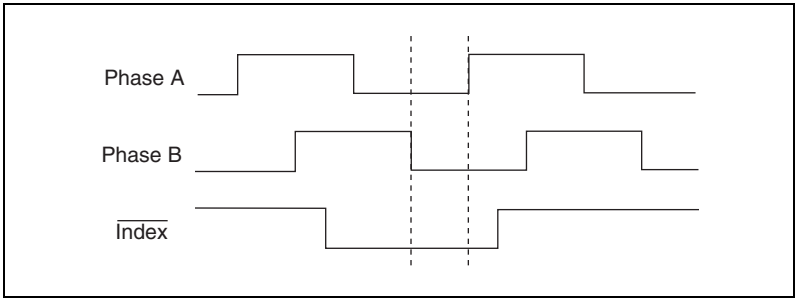


Figure 5-3. Quadrature Encoder Phasing Diagram

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.

Encoders with differential line driver outputs are strongly recommended for all applications and must be used if the encoder cable length is longer than 10 ft (3.05 m). 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 cable can cause noise to corrupt the encoder signals, resulting in lost counts and reduced motion system accuracy.

Encoder Input Circuit

Figure 5-4 shows a simplified schematic diagram of the circuit used for the Phase A, Phase B, and Index encoder inputs. 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 required for initialization functionality with the Find Index function.

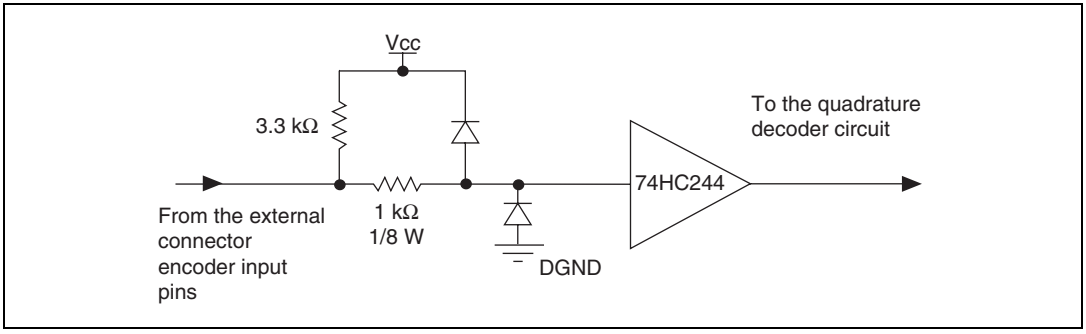


Figure 5-4. Encoder Input Circuit

Trigger Inputs, Shutdown Input, and Breakpoint Outputs

The 7344/7334 controllers offer additional high-performance features in the encoder FPGA. The encoder channels have high-speed position capture trigger inputs and 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..4>—When enabled, an active transition on a high-speed position capture input causes instantaneous position capture (<100 ns latency) 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 7344/7334 controller position mode is to move an axis Relative to Captured Position.

  The polarity of the trigger input is programmable in software as active-low (inverting) or active-high (non-inverting), rising or falling

edge. You can also 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 (rising edge).
- Breakpoint Output <1..4>—A breakpoint output can be programmed 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*, *modulo*, or *relative* position. 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, or toggle.

  The breakpoint outputs are driven by open-collector TTL buffers that feature 64 mA sink current capability and built in 3.3 kΩ pull-up resistors to +5 V.

  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 driver/amplifier signal and encoder signal connections. Wiring these signals near each other can cause faulty operation.

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

Trigger Input, Shutdown Input, and Breakpoint Output Circuits

Figures 5-5, 5-6, and 5-7 show a simplified schematic diagram of the circuits used by the trigger inputs, shutdown inputs, and breakpoint outputs for signal buffering.

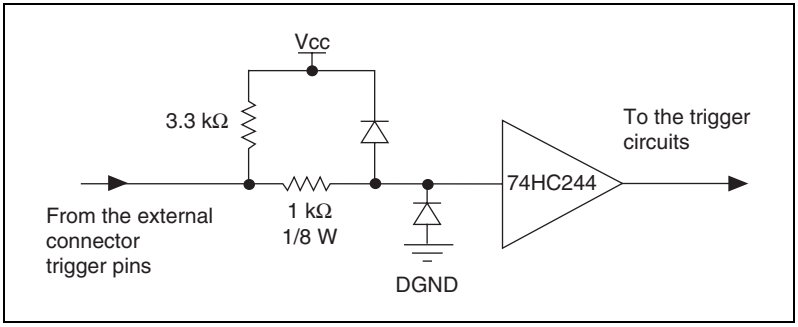


Figure 5-5. Trigger Input Circuit

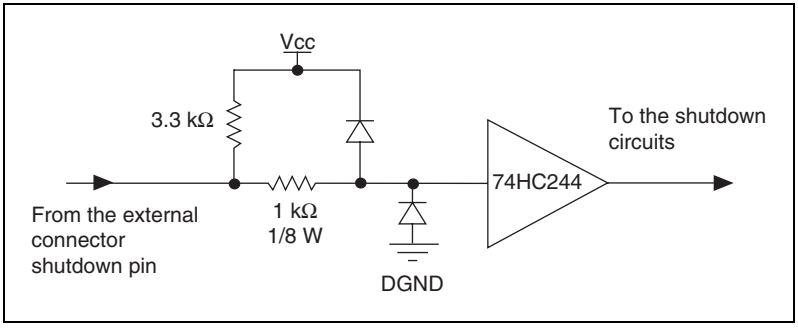


Figure 5-6. Shutdown Input Circuit

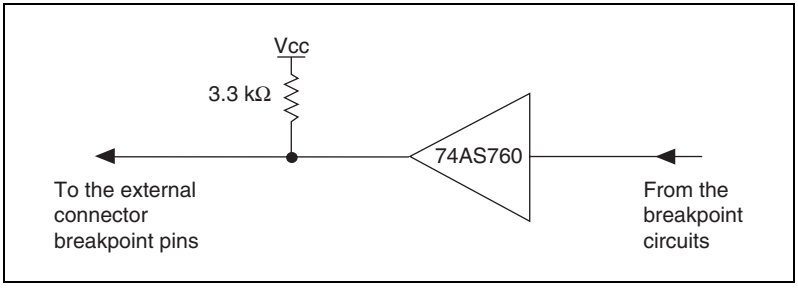


Figure 5-7. Breakpoint Output Circuit

Analog Inputs

The 7344/7334 controllers have the following ADC input signals:

- Analog Input <1..4>—The 7344/7334 controllers include an eight-channel multiplexed, 12-bit ADC capable of measuring ±10 V, ±5 V, 0–10 V, and 0–5 V inputs. ADC channels 1 through 4 are brought out externally on the 68-pin motion I/O connector. ADC channels 5 through 8 are connected internally, as shown in Table 5-2. These signals can be used for ADC test and calibration.

Table 5-2. Internal ADC Channels

ADC Input	Signal
5	Filtered +5 V
6	Floating (NC)
7	Analog Reference (7.5 V)
8	Analog Input Ground

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 eight ADC channels of the controller by using the Read ADC function. Table 5-3 shows the range of values read back and the voltage resolution for each setting. The voltage resolution is in volts per least significant bit (V/LSB).

Table 5-3. Analog Input Voltage Ranges

Input Range	Binary Values	Resolution
±10 V	–2,048 to 2,047	0.0049 V/LSB
±5 V	–2,048 to 2,047	0.0024 V/LSB
0–10 V	0 to 4,095	0.0024 V/LSB
0–5 V	0 to 4,095	0.0012 V/LSB

As indicated in Figure 5-3, 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 Reference—For convenience, 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.
- 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.

Note The analog reference output is an output signal only and must not connect 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.

Other Motion I/O Connection

The 7344/7334 controllers provide the following other motion I/O connection:

- Host +5 V—This signal is the internal +5 V supply of the host computer. It is typically used to detect when the host computer is powered and to shut down external motion system components when the host computer is turned off or disconnected from the motion accessory.

Caution The host +5 V signal is limited to <100 mA 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.

Digital I/O Connector

All the general-purpose digital I/O lines on the 7344/7334 controllers are available on a separate 68-pin digital I/O connector. Figure 5-8 shows the pin assignments for this connector.

+5 V	1	35	Digital Ground
PCLK	2	36	Digital Ground
Reserved	3	37	Digital Ground
Reserved	4	38	DPull
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
Port 4:bit 3	31	65	Digital Ground
Port 4:bit 4	32	66	Port 4:bit 5
Digital Ground	33	67	Port 4:bit 6
Port 4:bit 7	34	68	Digital Ground

Figure 5-8. 68-Pin Digital I/O Connector Pin Assignments

The 32-bit digital I/O port is configured in hardware as four 8-bit digital I/O ports. The bits in a port are typically controlled and read with byte-wide bitmapped commands.

All digital I/O lines have programmable direction and polarity. Each output circuit can sink and source 24 mA.

The DPull pin controls the state of the input pins at power-up. Connecting DPull to +5 V or leaving it unconnected configures all pins in all ports for 100 kΩ pull-ups. Connecting DPull to ground configures the ports for 100 kΩ pull-downs.

PWM Features

The 7344/7334 controllers provide two pulse width modulation (PWM) outputs on the digital I/O connector. The PWM outputs generate periodic waveforms whose period and duty cycles can be independently controlled through software commands. Think of PWM as 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 desired, you can use 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 your *FlexMotion Software Reference Manual* for more information.

RTSI Connector

The physical RTSI bus interface varies depending on the type of 7334/7334 controller.

For the PCI-7344 and PCI-7334, the RTSI bus is connected with a ribbon cable across National Instruments' PCI devices with RTSI capability.

The FW-7344 RTSI bus is connected with an external 14-pin shielded cable across National Instruments' distributed devices with RTSI capability.

The PXI-7344 and PXI-7334 require no extra cable, because the PXI bus directly connects the RTSI bus across all of National Instruments' PXI devices.

RTSI Signal Considerations

The 7344/7334 motion controllers allow you to use the RTSI signals as sources for trigger inputs, or as destinations for breakpoint outputs and encoder signals. The RTSI bus can also serve as a generic digital I/O port. Breakpoint outputs are output-only signals that generate an active-high pulse of 90–120 ns duration, as shown in Figure 5-9.

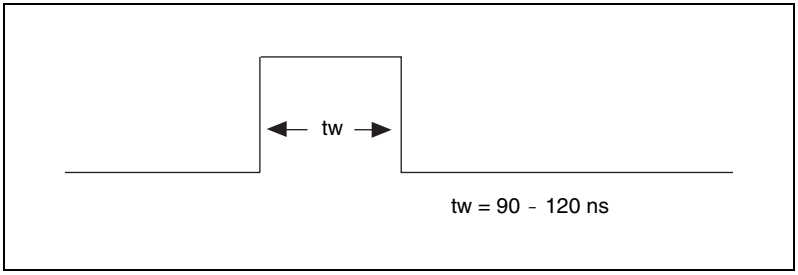


Figure 5-9. Breakpoint Across RTSI

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.

A

Specifications

This appendix lists the hardware and software performance specifications for the 7344/7334 controllers. Hardware specifications are typical at 25 °C, unless otherwise stated.

Servo Performance (7344 only)

PID update rate range ..... 62.5 to 500 µs/sample
- Max PID update rate ..... 62.5 µs/axis
- 4-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 ..... $\pm 2^{31}$ counts
- Max relative move size ..... $\pm 2^{31}$ counts
- Velocity range ..... 1 to ±20,000,000 counts/s
- RPM range ..... 10^{-5} to 10^{6} revolutions/minute
- Acceleration/deceleration ..... 4,000 to 128,000,000 counts/s^2
- RPS/s range ..... 10^{-1} to 10^{8} revolutions/s^2
- S-Curve time range ..... 1 to 32,767 samples
- Following error range ..... 0 to 32,767 counts
- Gear ratio (7344 only) ..... ±32,767:1 to 1:32,767

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/axis
4-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 .....$\pm 2^{31}$ steps
Max relative move size.....$\pm 2^{31}$ steps
Velocity range .....1 to 4,000,000 steps/s
RPM range.....10^{-5} to 10^{6} revolutions/minute
Acceleration/deceleration .....4,000 to 128,000,000 steps/s^2
RPS/s range .....10^{-1} to 10^{8} revolutions/s^2
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

Stepper outputs

- Max pulse rate ..... 4 MHz (full, half, and microstep)
- Min pulse width ..... 120 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 ..... Open collector with built-in 3.3 kΩ 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 ms

Shutdown input

- Voltage range ..... 0 to 12 V
  - Input low voltage ..... 0.8 V
  - Input high voltage ..... 2 V
  - Polarity ..... Rising edge
- Control ..... Disable all axes and command outputs

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 12 V
  - Input low voltage ..... 0.8 V
  - Input high voltage ..... 2 V
- Min index pulse width ..... 60 ns

Forward, reverse, and home inputs

- Number of inputs.....12 (3 per axis)
- Voltage range.....0 to 12 V
  - Input low voltage.....0.8 V
  - Input high voltage.....2 V
- Polarity .....Programmable, active-high or active-low
- Min pulse width.....1 ms
- Control.....Individual enable/disable, stop on input, prevent motion, Find Home

Trigger inputs

- Number of inputs.....4 (Encoders 1 through 4)
- Voltage range.....0 to 12 V
  - Input low voltage.....0.8 V
  - Input high voltage.....2 V
- Polarity .....Programmable, active-high or active-low
- Min pulse width.....83 ns
- Capture latency.....<100 ns
- Capture accuracy .....1 count
- Max repetitive capture rate.....1 kHz

Breakpoint outputs

- Number of outputs.....4 (Encoders 1 through 4)
- Voltage range.....0 to 5 V
  - Output low voltage .....< 0.6 V at 64 mA sink
  - Output high voltage.....Open collector with built-in 3.3 kΩ pull-up to +5 V
- Polarity .....Programmable, active-high or active-low

Inhibit/enable output

- Number of outputs.....4 (1 per-axis)
- Voltage range.....0 to 5 V
  - Output low voltage .....< 0.6 V at 64 mA sink
  - Output high voltage.....Open collector with built-in 3.3 kΩ pull-up to +5 V

- Polarity ..... Programmable, active-high or active-low
- Control ..... MustOn/MustOff or automatic when axis off

Analog inputs

- Number of inputs ..... 8, multiplexed
  - Number for user signals 4
  - Number for calibration 4
- Voltage range (programmable) ..... ±10 V, ±5 V, 0–10 V, 0–5 V
- Input resistance ..... 10 kΩ min
- Resolution ..... 12 bits
- Analog reference output ..... 7.5 V (nominal)
- Reference drift ..... ±30 ppm/°C typical
- INL ..... ±1 LSB
- DNL ..... ±1 LSB
- Offset error
  - Unipolar ..... ±5 LSB
  - Bipolar ..... ±10 LSB
- Gain error
  - Unipolar ..... ±10 LSB
  - Bipolar ..... ±10 LSB
- Conversion time ..... 6 µs
- Multiplexor scan rate ..... 50 µs/enabled channel

Analog outputs (7344 only)

- Number of outputs 4
- Voltage range ..... ±10 V
- Output current ..... ±5 mA
- Resolution ..... 16 bits (0.000305 V/LSB)
- Gain accuracy ..... ±3%
- Drift ..... 100 ppm/°C typical

Digital I/O

Ports .....4, 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

Outputs
Voltage range.....0 to 5 V
Output low voltage .....< 0.45 V at 24 mA sink
Output high voltage.....> 2.4 V at 24 mA source
Polarity .....Programmable, active-high or active-low
PWM outputs
Number of PWM outputs 2
Max PWM frequency .....32 kHz
Resolution.....8-bit
Duty cycle range.....0 to (255/256)%
Clock Sources.....Internal or external

RTSI

Trigger Lines 7

Maximum Power Requirements

- PCI-7344, PXI-7344, PCI-7334, and PXI-7334

+5 V (±3%).....1 A

+12 V (±3%).....30 mA

–12 V (±3%) .....30 mA

Power consumption .....5.7 W

- FW-7344

  Voltage range ..... 9 to 25 VDC

  Power consumption..... 30 W

Physical

Dimensions (Not Including Connectors)

PCI-7344/7334 ..... 17.5 by 9.9 cm (6.9 by 3.9 in.)

PXI-7344/7334..... 16 by 10 cm (6.3 by 3.9 in.)

FW-7344 ..... 30.7 by 25.4 by 4.3 cm (12.1 by 10.0 by 1.7 in.)

Connectors

Motion I/O connector..... 68-pin female high-density VHDCI type

32-bit digital I/O connector..... 68-pin female high-density VHDCI type

Weight

PCI-7344/7334 ..... 113 g (4 oz.)

PXI-7344..... 170 g (6 oz.)

FW-7344 ..... 1.7 kg (60 oz.)

Maximum Working Voltage

Channel to earth ..... 12 V, Installation Category 1 (signal voltage plus common-mode voltage)

Channel to channel..... 22 V, Installation Category 1 (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, please 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.....2000 m

Pollution degree 2

Electromagnetic Compatibility

EMC/EMI .....CE, C-Tick, and FCC Part 15 (Class A) Compliant

Electrical emissions .....EN 55011 Class A at 10 meters
FCC Part 15A above 1 GHz

Electrical immunity .....Evaluated to EN 61326:1997/ A1:1998, Table 1

Note For full EMC compliance, you must operate this device with shielded cabling. In addition, all covers and filler panels must be installed. See the Declaration of Conformity (DoC) for this product for any additional regulatory compliance information. To obtain the DoC for this product, click Declaration of Conformity at `ni.com/hardref.nsf/`. This Web site lists the DoCs by product family. Select the appropriate product family, followed by your product, and a link to the DoC (in Adobe Acrobat format) appears. Click the Acrobat icon to download or read the DoC.

Safety

This device meets the following electrical equipment safety standard requirements for measurement, control, and laboratory use:

- EN 61010-1:1993/A2:1995, IEC 61010-1:1990/A2:1995
- UL 3101-1:1993, UL 3111-1:1994, UL 3121:1998
- CAN/CSA C22.2 no. 1010.1:1992/A2:1997

B

Cable Connector Descriptions

This appendix describes the connector pinout for the cables that connect to your 7344/7334 controllers.

Figures B-1 and B-2 show the pin assignments for the stepper and 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.

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 $\overline{\text{Inhibit}}$	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 $\overline{\text{Inhibit}}$	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 $\overline{\text{Inhibit}}$	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 $\overline{\text{Inhibit}}$	47	48	Axis 4 Reverse Limit Switch
Digital Ground	49	50	Host +5 V

Figure B-1. 50-Pin Stepper Connector Pin Assignment

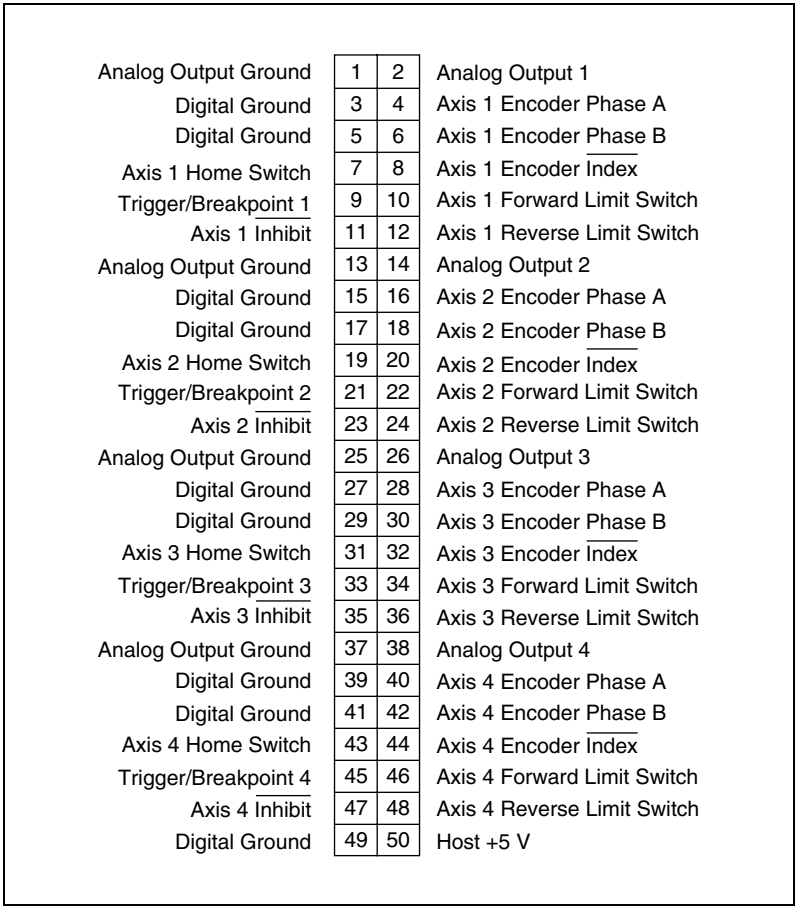


Figure B-2. 50-Pin Servo Connector Pin Assignment (7344 only)

C

Technical Support Resources

Web Support

National Instruments' Web support is your first stop for help in solving installation, configuration, and application problems and questions. Online problem-solving and diagnostic resources include frequently asked questions, knowledge bases, product-specific troubleshooting wizards, manuals, drivers, software updates, and more. Web support is available through the Technical Support section of `ni.com`.

NI Developer Zone

The NI Developer Zone at `ni.com/zone` is the essential resource for building measurement and automation systems. At the NI Developer Zone, you can easily access the latest example programs, system configurators, tutorials, technical news, as well as a community of developers ready to share their own techniques.

Customer Education

National Instruments provides a number of alternatives to satisfy your training needs, from self-paced tutorials, videos, and interactive CDs to instructor-led hands-on courses at locations around the world. Visit the Customer Education section of `ni.com` for online course schedules, syllabi, training centers, and class registration.

System Integration

If you have time constraints, limited in-house technical resources, or other dilemmas, you may prefer to employ consulting or system integration services. You can rely on the expertise available through our worldwide network of Alliance Program members. To find out more about our Alliance system integration solutions, visit the System Integration section of `ni.com`.

Worldwide Support

National Instruments has offices located around the world to help address your support needs. You can access our branch office Web sites from the Worldwide Offices section of `ni.com`. Branch office Web sites provide up-to-date contact information, support phone numbers, e-mail addresses, and current events.

If you have searched the technical support resources on our Web site and still cannot find the answers you need, contact your local office or National Instruments corporate. Phone numbers for our worldwide offices are listed at the front of this manual.

Glossary

Prefix	Meanings	Value
p-	pico-	10^{-12}
n-	nano-	10^{-9}
µ-	micro-	10^{-6}
m-	milli-	10^{-3}
c-	centi	10^{-2}
k-	kilo-	10^{3}
M-	mega-	10^{6}

Numbers/Symbols

°	degrees
/	per
%	percent
±	plus or minus
+	positive of, or plus
–	negative of, or minus
Ω	ohm
+5 V	+5 VDC source signal
1394	A high-speed external bus that implements the IEEE 1394 serial bus protocol

A

A	amperes
A/D	analog-to-digital
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	a signal is active when its value goes high (1)
active-low	a signal is active when its value goes 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	the drive that delivers power to operate the motor in response to low level control signals. In general, the amplifier is designed to operate with a particular motor type—you cannot use a stepper drive to operate a DC brush motor, for instance
Analog Input <1..4>	12-bit analog ADC input
Analog Output <1..4>	DAC voltage output
API	application programming interface
axis	unit that controls a motor or any similar motion or control device
Axis <1..4> $\overline{\text{Inhibit}}$	axis 1 through 4 inhibit output
Axis <1..4> Forward Limit Input	axis 1 through 4 forward/clockwise limit switch

Axis <1..4> Home Input	axis 1 through 4 home input
Axis <1..4> Reverse Limit Input	axis 1 through 4 reverse/counter-clockwise 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	a number system with a base of 2
buffer	temporary storage for acquired or generated data (software)
bus	the 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.
byte	eight related bits of data, an eight-bit binary number. Also used to denote the amount of memory required to store one byte of data.

C

CCW	counter-clockwise—implies direction of rotation of the motor
closed-loop	a 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	an 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
DC	direct current
dedicated	assigned to a particular function
DGND	digital ground signal
digital I/O port	a group of digital input/output signals
DIP	dual inline package
DLL	dynamic link library—provides the API for the motion control boards
drivers	software that communicates commands to control a specific motion control board
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	the 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
filtering	a type of signal conditioning that filters unwanted signals from the signal being measured
filter parameters	indicates the control loop parameter gains (PID gains) for a given axis
flash ROM	a type of electrically reprogrammable read-only memory

following error trip point	the difference between the instantaneous commanded trajectory position and the feedback position
FPGA	Field Programmable Gate Array
freewheel	the 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)	A 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 into which the motion control board is plugged

I

I/O	input/output—the transfer of data to and from a computer system involving communications channels, operator interface devices, and/or motion control interfaces
ID	identification
in.	inches

index	marker between consecutive encoder revolutions
inverting	the polarity of a switch (limit switch, home switch, and so on) in *active* 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
K	kilo—the prefix for 1,024, or 2^{10}, used with B in quantifying data or computer memory

L

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

M

m	meters
MCS	Move Complete Status
microstep	The proportional control of energy in the coils of a Stepper Motor that 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 within the range of total quadrature counts per revolution for an axis

N

noise	an 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	the polarity of a switch (limit switch, home switch, etc.) in *active* state. If these switches are active-high, they are said to have non-inverting polarity.

O

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. It 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) a communications connection on a computer or a remote controller (2) a digital port, consisting 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	the encoder line resolution times four

R

RAM	random-access memory
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	a flat cable in which the conductors are side by side
RPM	revolutions per minute—units for velocity.
RPSPS or RPS/S	revolutions per second squared—units for acceleration and deceleration.
RTR	Ready to Receive

S

s	seconds
servo	specifies an axis that controls a servo motor
stepper	specifies an axis that controls a stepper motor
stepper <1..4> Dir (CCW)	direction output or counter-clockwise direction control
stepper <1..4> 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

trapezoidal profile	a 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	volts
V_{CC}	positive voltage supply
velocity mode	move the axis continuously at the specified velocity

W

watchdog	a timer task that shuts down (resets) the motion control board if any serious error occurs
word	the standard number of bits that a processor or memory manipulates at one time, typically 8-, 16-, or 32-bit

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