Motion Control

7344 Hardware User Manual

Worldwide Technical Support and Product Information

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About This Manual

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

The 7344 family of controllers includes the following controllers:

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

The 7344 controllers are high-performance controllers for PCI, PXI, and 1394 bus computers.

Conventions

The following conventions appear in this manual:

`<>`	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 icon denotes a note, which alerts you to important information.
	This icon denotes a caution, which advises you of precautions to take to avoid injury, data loss, or a system crash.
bold	Bold text denotes items that you must select or click on in the software, such as menu items and dialog box options. Bold text also denotes parameter names.
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 that 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 the FlexMotion 7344 controllers and their operation.

About the 7344 Controllers

Thank you for purchasing a 7344 controller. The 7344 controllers have advanced motion control performance along with easy-to-use software tools and add-on motion VI libraries for use with LabVIEW and BridgeVIEW—LabVIEW for Industrial Automation.

The 7344 line of controllers are a combination of servo and stepper motor controllers for PCI, PXI, and 1394 bus computers. These controllers 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 configure any axis for either servo or stepper motor control. You can use these controllers for all position and velocity control applications, including the following:

• Point-to-point positioning
• Velocity profiling
• 3-D Linear interpolation
• Electronic gearing
• Circular, helical, and spherical interpolation
• Time-based motion integration
• Vector space motion

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. You can also configure the 7344 controllers as stepper axes to control stepper motors. These axes can operate in open or closed-loop mode. They use quadrature encoders 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.

The 7344 controller's high-performance capabilities are the result of an advanced dual-processor architecture using 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 (FPGA). Its 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.

You can use the 7344 controller's full onboard programming to execute up to 10 simultaneous motion programs in a preemptive, real-time multitasking operating system environment.

Motion profiles are controlled with enhanced PID/PIVff servo updates at 62 µs per axis and encoder feedback rates up to 20 MHz. Each axis has motion I/O for end-of-travel limit and home switch inputs, breakpoint output, and trigger input. The 7344 controllers also have non-dedicated user I/O including 32 bits of digital I/O and four analog inputs for ±10 V signals, providing motion PID feedback for loop closure, joystick inputs, or coarse monitoring of analog sensors.

What You Need to Get Started

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

❑   One of the 7344 controllers:
  •   PCI-7344
  •   PXI-7344
  •   FW-7344

❑   *7344 Hardware User Manual*

❑   *FlexMotion Software Reference Manual*

❑   One of the following software packages and documentation:
  •   LabVIEW
  •   LabWindows/CVI
  •   BridgeVIEW—LabVIEW for Industrial Automation
  •   FlexMotion software (includes FlexCommander)

❑   Your computer with an available PCI or PXI slot or 1394 port as appropriate.

Software Programming Choices

You have several options to choose from when programming your National Instruments 7344 controller. You can use National Instruments application software, FlexMotion VIs for LabVIEW and BridgeVIEW, or the FlexMotion software.

Programming the 7344 controller is straightforward using a simple but powerful high-level function set application programming interface (API). 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, BridgeVIEW, and other industry-standard software programs.

National Instruments Application Software

LabVIEW and BridgeVIEW, based on the graphical programming language G, feature interactive graphics and a state-of-the-art user interface. In LabVIEW and BridgeVIEW, 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 and BridgeVIEW with National Instruments motion control hardware. The Motion 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 7344 controllers, including cables, Universal Motion Interfaces (UMIs), drive power amplifier units, and other accessories as follows:

- Cables and cable assemblies
- 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 your National Instruments catalogue, the motion control product brochure, or call the office nearest you.

Motion Signal and Motion I/O Connections

The external motion I/O connector on the 7344 controllers is a high-density 68-pin female VHDCI connector.

The external 32-bit digital I/O connector is a high-density 68-pin female VHDCI connector.

You can use any compatible male mating connector.

2

Configuration and Installation

This chapter describes how to configure and install your 7344 controller.

Software Installation

Install your FlexMotion software, along with your Motion VI libraries (if appropriate) before you install the 7344 controller. Refer to the release notes included with your 7344 controller for specific instructions on the software installation sequence for your host PC.

Controller Configuration

The motion I/O-related configuration of the 7344 controller is performed entirely with software, so there are no jumpers to set for motion I/O configuration.

The PCI-7344 and PXI-7344 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. There are no jumpers to configure for bus-related configuration.

Hardware Installation

You can install the PCI or PXI 7344 controller in any open compatible expansion slot in your computer. The typical power required for each 7344 controller is given in Appendix A, *Specifications*.

You can connect your FW-7344 to any available 1394 port. The FW-7344 supports IEEE 1394 transfer rates at up to 400 Mbits/s.

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

⚠ **Caution**   7344 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

1. Turn off and unplug your computer.

2. Remove the top cover or access port to the PCI expansion slots in your computer.

3. Remove the expansion slot connector port cover on the back panel of the computer if installed.

4. Insert the 7344 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.

5. If available, screw the mounting bracket of the 7344 controller to the back panel rail of the computer.

6. Replace the cover.

7. Plug in the 68-pin cable for motion I/O to the 7344 controller.

8. Plug in and turn on your computer.

Your PCI-7344 controller is installed.

♦ PXI-7344

1. Turn off and unplug your chassis.

2. Choose an unused +5 V peripheral slot.

3. Remove the filler panel for the peripheral slot you have chosen.

4. Touch a metal part on your chassis to discharge any static electricity that might be on your clothes or body.

5. Insert the PXI board into the slot. Use the injector/ejector handle to fully inject the device into place.

6. Screw the front panel of the PXI board to the front panel mounting rails of the chassis.

7. Visually verify the installation.

8. Plug in and turn on the chassis.

Your PXI-7344 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 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 detect the controller immediately. When the computer recognizes your controller, the COM LED on the front panel will blink.
3. Verify that the power LED is on.

Your FW-7344 controller is installed.

The FW-7344 controller has two LEDs to help you determine the state of your device:

- Power LED
  - Power LED off—No power is being supplied to the controller. 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 whenever the controller sends or receives any commands or data. This LED should blink once when you first plug in your controller. If you are transferring a large amount of data, this light should be on or blinking continuously.

3

Hardware Overview

This chapter presents an overview of the 7344 controller hardware functionality. The 7344 controller comes in three versions:

- PCI-7344 for PCI bus computers
- PXI-7344 for PXI bus computers
- FW-7344 for 1394 bus computers

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

1	RTSI Connector	4	14-Pin Test Connector	7	10-Pin Test Connector
2	Serial Number Label	5	68-Pin Digital I/O Connector	8	MC68331 CPU
3	Assembly Number Label	6	68-Pin Motion I/O Connector	9	ADSP 2185 DSP
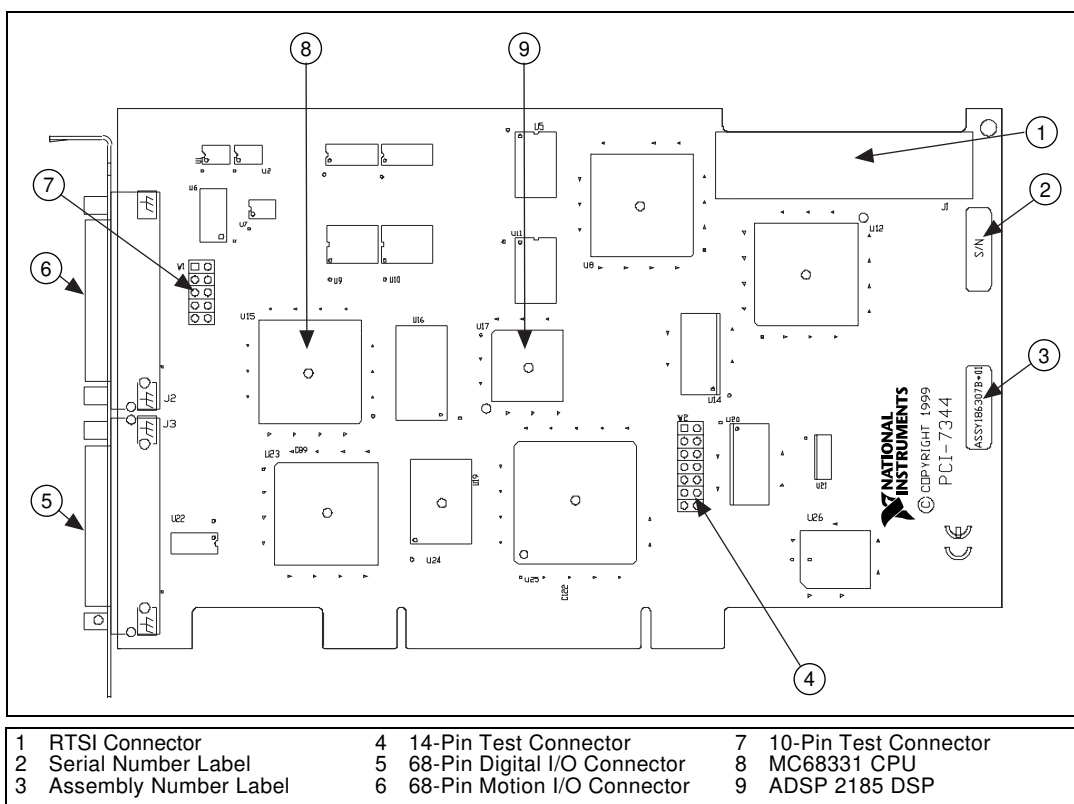
Figure 3-1. PCI-7344 Parts Locator Diagram

1	10-Pin Test Connector	4	14-Pin Test Connector	7	68-Pin Digital I/O Connector
2	Assembly Number Label	5	ADSP 2185 DSP	8	68-Pin Motion I/O Connector
3	Serial Number Label	6	MC68331 CPU		
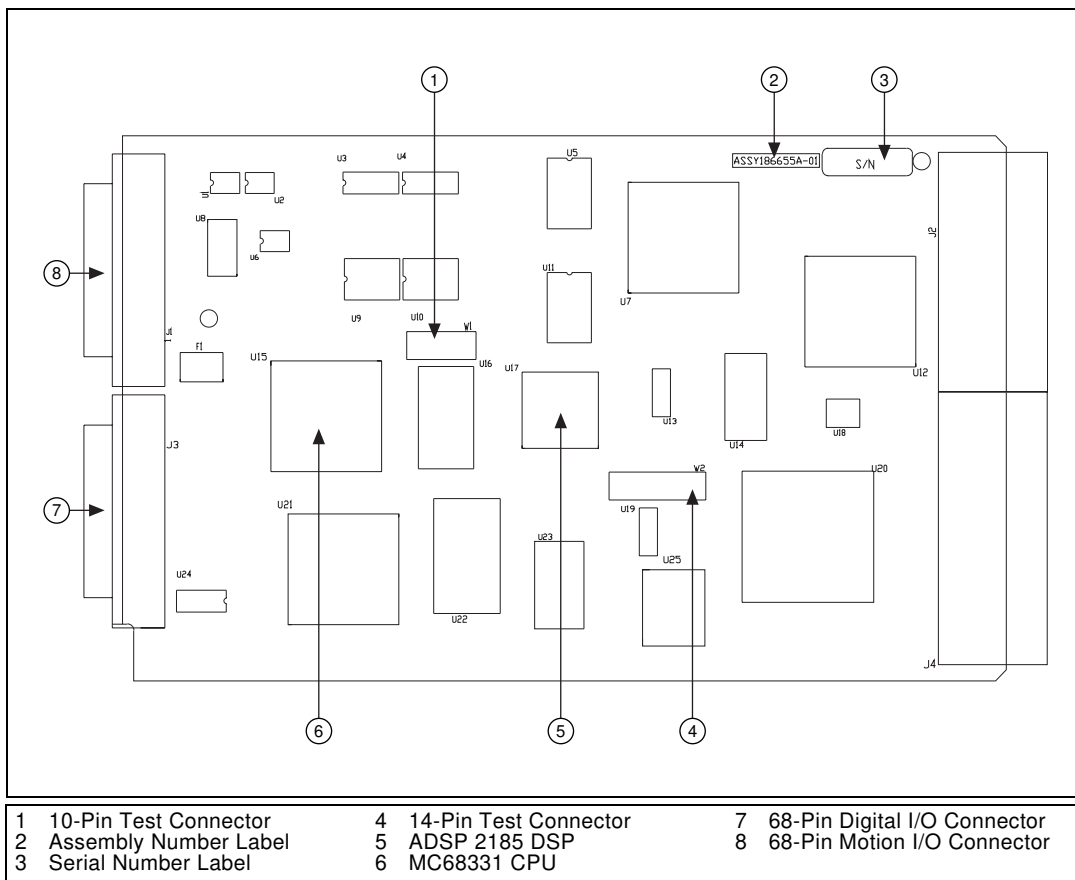
Figure 3-2. PXI-7344 Parts Locator Diagram

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
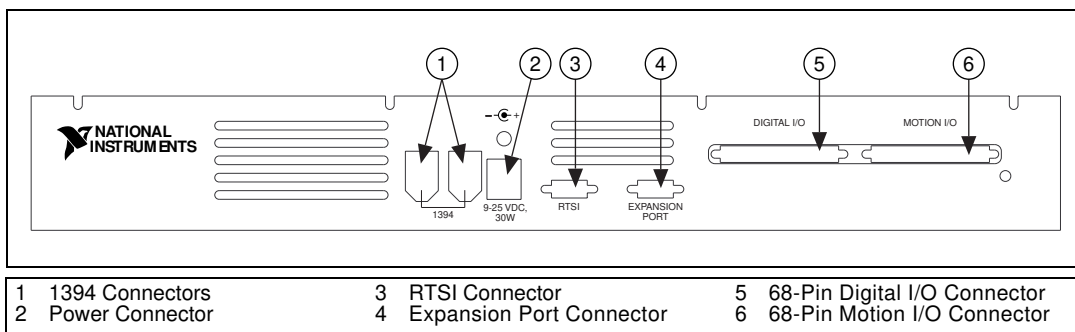
Figure 3-3. FW-7344 Back Panel

User Connectors

The 68-pin motion I/O connector provides all of 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 on the digital I/O connector.

Test Connectors

The test connectors are proprietary interfaces for production testing and troubleshooting. These connectors may or may not be installed during the manufacturing process. Do not plug anything into these connectors.

⚠ **Caution**   Misuse of these reserved connectors may seriously damage the 7344 controller. Unauthorized use of the connectors will void any warranty coverage for the product.

With the 7344 controller properly installed, only two connectors are typically used—the 68-pin motion I/O connector and the 68-pin digital I/O connector. Cables and accessories provide connections to your motion system.

Interface accessories for the 7344 family vary from the Universal Motion Interface (UMI) units with signal conditioning and screw terminal connectors to simple screw terminal blocks. Available drive units provide pluggable connectors, power supplies, amplifier/drivers, and direct motion system interfacing capabilities.

4

Functional Overview

This chapter presents an overview of the motion control algorithms and embedded firmware functionality on the 7344 controller.

Dual Processor Architecture

You can perform up to four axes of simultaneous, coordinated motion control in a preemptive, multitasking, real-time environment with the 7344 controller.

The 7344 controller's high-performance capabilities result from an advanced dual-processor architecture using a Motorola MC68331 real-time 32-bit CPU combined with an Analog Devices ADSP 2185 DSP and custom FPGAs. Its 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 controller uses 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 the RTXC embedded RTOS kernel for optimum system performance in varying motion applications. Motion tasks are prioritized. Task execution order depends upon each task's priority, 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 controller is a true multiprocessing *and* multitasking embedded controller.

Enhanced PID Functions

The DSP chip implements an enhanced PID/PIVff closed-loop servo control algorithm. PID update rates are user-programmable and can be as fast as 62 µs per axis. The trajectory generators calculate the instantanous desired position in each PID update period for unsurpassed trajectory control and smoothness. On stepper axes, the DSP chip services the stepper pulse generators each update period, resulting in accurate step pulse frequency outputs.

In addition to the standard PID loop control terms, the 7344 controller adds the following functionality:

- An integration limit value to minimize the effects of integrator windup by limiting the contribution on the integral sum

- A derivative sample time multiplier to minimize quantization-induced torque noise and to control the effect of the derivative gain

- Velocity and acceleration feedforward for following error minimization

- A velocity estimator and feedback gain for improved low-speed smoothness

The 7344 controller also supports dual-loop feedback configurations where the primary sensor is used for position feedback and the secondary sensor is used for velocity estimation and feedback damping.

Note   Refer to the *Axis and Resource Configuration* section of the *FlexMotion Software Reference Manual* for more information on enhanced PID and dual-loop feedback functions.

Trajectory Generators

The 7344 controller trajectory generators calculate the instantaneous position command that controls acceleration and velocity while it moves the axis to its target position. This command is then sent to the PID servo loop or stepper pulse generator, depending on how you configure the axis.

To implement infinite trajectory control, the 7344 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.

The following sections describe the five primary trajectory types supported by the 7344 controller.

Trapezoidal Point-to-Point Position Control

Like virtually all motion controllers, the 7344 controller implements trapezoidal profile control for point-to-point moves. The 7344 controller has enhanced the trapezoidal profile to offer independent acceleration and deceleration value programming and S-curve smoothing (jerk control) of the acceleration/deceleration inflection points.

Motion occurs first with a programmable acceleration (smoothed by the S-curve value), then for a period at a constant velocity (if required) and then with a programmed deceleration, stopping at the desired target position. You can interrupt motion by executing a stop or kill motion function. Motion is automatically halt-stopped if an enabled limit or home input signal becomes active during the move.

Note   Refer to the *FlexMotion Software Reference Manual* for more information on the programming of trapezoidal trajectory control parameters.

Velocity Control

Velocity control is a simple variation of trapezoidal position control. The same trajectory generator implements a continuous velocity control mode. If you select this mode, the target position is effectively set to infinity and the axis moves at the programmed constant velocity. You can change velocity on the fly and all existing acceleration, deceleration, and S-curve limits are in effect during the velocity transition. You can interrupt motion by executing a stop or kill function. Motion is automatically halt-stopped if an enabled limit or home input signal becomes active. This mode is useful for jogging moves, simple speed control, and continuous contouring motion applications.

Move Blending

You can use the 7344 controller to blend moves together with a programmable blend factor. Using the user-defined blend factor, the 7344 controller DSP chip starts a second trajectory generator with the second move on an axis while the first trajectory generator is still

decelerating from the previous trajectory move. The 2-position command outputs are combined digitally by superposition. You can use the 7344 controller's infinite trajectory control processing to automatically and smoothly blend any move type into any other move without stopping the axis or axes involved.

Note   Refer to the *FlexMotion Software Reference Manual* for more information on blending and blend factors.

Electronic Gearing

With electronic gearing, you can slave both position and velocity on one or more axes to a master position/velocity source for synchronous ratio-based motion. The master can be the feedback of an axis, an independent encoder input or ADC channel, or even the trajectory generator output of another axis.

A slave axis operates in a special mode that calculates an instantaneous position command value that is a ratio of the master position. Since this calculation is completed every PID update, the axis accurately tracks the ratio of the master position velocity. For example, setting a gear ratio of 3:2 results in the slave axis rotating three revolutions for every two revolutions of the master. Each slave axis can have its own gear ratio independent and relative to the master axis.

You can also superimpose any move type on top of the geared slave because its trajectory generators are not used for gearing. Again, the target position command values are combined digitally using superpositon. This very powerful feature allows registration moves in an electronically geared, master/slave system.

Note   Refer to the *FlexMotion Software Reference Manual* for more information on electronic master/slave gearing.

Linear and Circular Interpolation

You can synchronize and control multiple axes to perform 2D and 3D linear interpolation, 2D circular interpolation, and 3D helical and spherical interpolation.

The 7344 controller generates linear interpolated moves by scaling the velocity, acceleration, deceleration, and S-curve values appropriately so that the axes assigned to the 2D/3D move travel in a straight line in 2D or 3D space and arrive at their target positions simultaneously.

For circular, helical, and spherical arcs, the 7344 controller embedded CPU calculates points along the arc segment, and the DSP performs a cubic spline algorithm that interpolates between these points. The resulting arc is extremely smooth and accurate with none of the chordal error associated with blended straight line segment approaches.

You can use the 7344 controller's infinite trajectory control processing to blend any arc move into another 2D or 3D arc or 2D or 3D vector straight line segment without stopping the axes involved.

Note   Refer to the *FlexMotion Software Reference Manual* for more information on circular, helical, and spherical arcs.

Analog Feedback

The 7344 controller has 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. This provides the high sampling rates required for PID 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 controller is implemented with flash ROM. This means that the 7344 controller can electrically erase and reprogram its own ROM. Since all of the 7344 controller's embedded firmware, including the RTOS and DSP code, 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 7344 controller automatically loads and returns the configuration to these new saved default values.

The FPGA configuration programs are also stored in the flash ROM. Upon power-up, the FPGAs are booted with these programs. This 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, Motion Resources, and Vector Spaces

The 7344 controller 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 or stepper control block, and at least one output resource, either a DAC output 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, open-loop stepper axes do not. These axis configurations are shown in Figures 4-1 and 4-2.

With the 7344 controller, you configure an axis with the Configure Axis Resources function. This action maps 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.
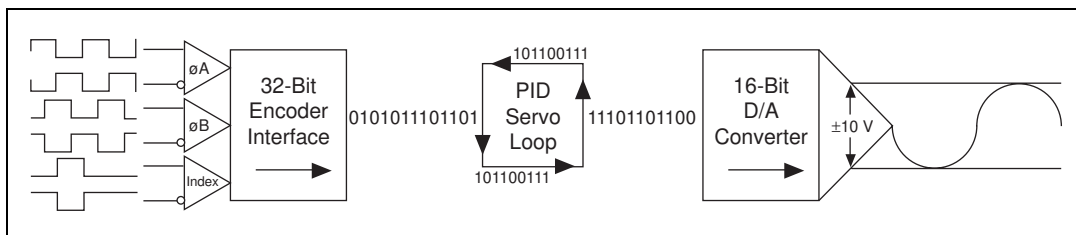
Figure 4-1. Servo Axis Resources
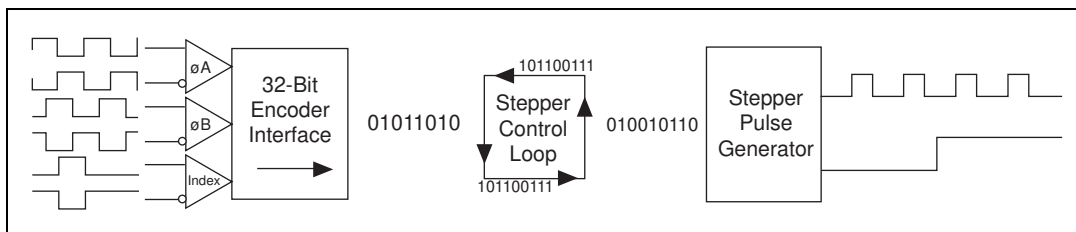
Figure 4-2. Stepper Axis Resources

In its default configuration, the 7344 controller comes preconfigured as four servo axes with Encoder 1 and DAC 1 mapped to Axis 1, Encoder 2 and DAC 2 mapped to Axis 2, and so on through Axis 4. However, it is simple for advanced users to map any feedback and output resource to any axis. This flexibility allows you to tailor each axis to accommodate your specific motion system requirements.

Note For many servo applications, the factory-default mapping of encoders and DACs to axes will meet your system requirements.

Available feedback resources are Encoder <1..4> and ADC <1..4>. Available output resources are DAC <1..4> and Stepper <1..4>.

Axes use the dedicated motion I/O signal lines assigned to them. A forward and reverse limit input, a home input, and an inhibit output are dedicated to each axis. Since there are four identical sets of these motion I/O signals, mapping is not required. If the motion I/O is not needed by the axis, you can reuse the signals as general-purpose I/O by disabling their indicated function.

The 7344 controller supports axes with optional secondary feedback resources (encoders or ADCs) and/or secondary output resources (DACs or stepper outputs). Two feedback resources are used when implementing dual-loop control. Defining two output resources is useful when controlling axes with multiple motors, such as gantry systems where two DAC outputs can be configured with different torque limits and/or offsets.

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, and ADC 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.

The encoders feature high-speed capture trigger inputs and breakpoint outputs. These features are implemented in the encoder processor FPGA and are fully functional when an encoder is used as feedback to an axis or as an independent input resource.

🖉   **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.

Vector Spaces

Vector spaces are logical, multidimensional groups of axes. They can be either single-dimensional, two dimensional with x and y axes, or three dimensional with x, y, and z axes. The 7344 controller supports up to three separate one, two, or three-axis vector spaces defined at the same time.

Figure 4-3 shows a single three-axis vector space.
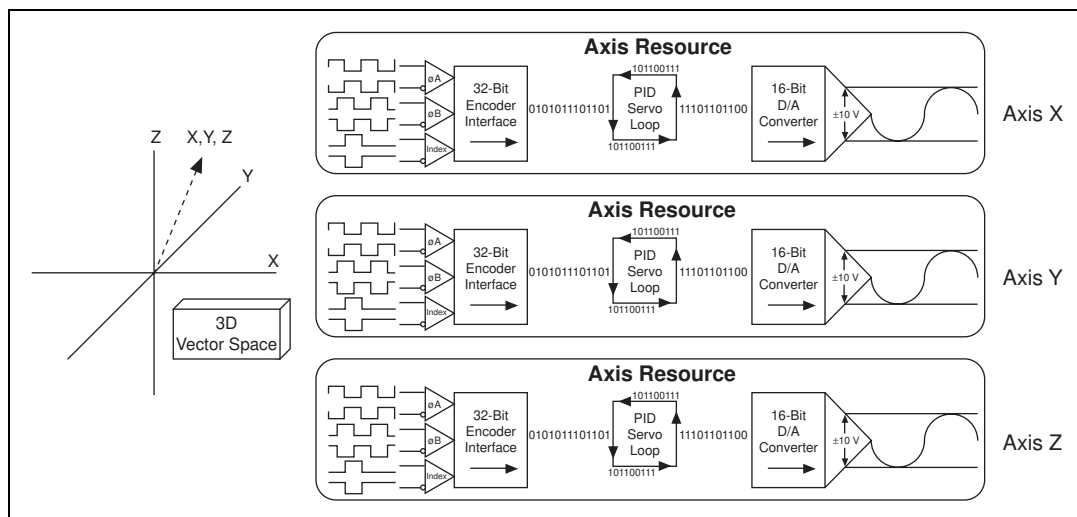
Figure 4-3. 3D Vector Space

Vector spaces facilitate 2D and 3D interpolation: linear, circular, helical, and spherical. You can send many FlexMotion commands to a vector space to define vector position, vector velocity, vector acceleration, and so on.

Vector spaces are configured by mapping axes to the vector space. Vector spaces are logical, not physical, and do not require motion resources other than those used by the axes themselves.

🖉   **Note**   Refer to the *Axis and Resource Configuration* section of the *FlexMotion Software Reference Manual* for more information on configuring vector spaces.

Onboard Programs

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

This extremely 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 on up to 120 general-purpose variables.

Onboard programs also offer high-level, event-based functions such as Jump to Label on Condition and Wait on Condition, which allow you to sequence and make decisions in your programs. Onboard programs can even start and stop other onboard programs.

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. This leaves the host PC more 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 host PC's non-real-time operating system. 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 controller has 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. As another example, the 7344 controller 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.

Find Home and Find Index

The 7344 controller features two built-in programs to aid in initializing your system and establishing a repeatable zero-position reference for system-wide operation and control.

Find Home

You use the Find Home function to search for a home switch, stop on a specific edge of the switch, or, optionally, go past and approach the home switch edge from a programmed direction. You can specify the initial search direction and are guaranteed to find the home switch (if one exists) because end-of-travel limit conditions are handled by reversing the home search direction.

Note Refer to the *Find Home and Index Functions* section of the *FlexMotion Software Reference Manual*, for more information on the Find Home function.

Find Index

You can use the Find Index function to search one revolution for the Index mark of the feedback encoder. The program records the index position and returns the axis to the captured position, plus or minus an optional programmable offset. The encoder index mark is accurate to one quadrature count and provides a much more repeatable reference than a typical home switch.

Notes The Find Index function is only available on closed-loop axes with quadrature encoder feedback. The encoder must provide a valid, properly phased index signal. See Figure 5-3, *Quadrature Encoder Phasing Diagram*, for more information.

Refer to the *Find Home and Index Functions* section of the *FlexMotion Software Reference Manual* for more information on the Find Index function.

Host Communications

The host computer communicates with a 7344 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 controller's base address. This port supports FIFO data passing in both send and readback directions. The 7344 controller has both a command buffer for incoming commands and a return data buffer (RDB) for readback data.

At address offsets from the controller's base address are two read-only status registers. 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.

Packets, Handshaking, and FIFO Buffers

This section briefly describes how commands and data are passed between the host computer and the 7344 controller. This information is provided for reference purposes. The FlexMotion software that ships with the controller provides drivers, DLLs, and C function libraries that handle the host to controller communications automatically, with built-in error reporting.

Data passed to or from the 7344 controller is handled in a packet format. A packet consists of a packet identifier word, command and data content, and a packet terminator word. This approach to communications enhances the accuracy of data communications, speeds the processing of the transferred command and data, and organizes operation into powerful, high-level motion functions.

Each word in a packet is sent over the host PC bus after checking the Ready-to-Receive (RTR) handshaking bit in the CSR. Refer to the Read Communication Status (`read_csr`) function in the *FlexMotion Software Reference Manual* for the Status bitmap and more information on the status reported in the CSR.

Command and data packets are checked for packet format errors as the controller receives the packets. If a packet error is detected, it is immediately reported by setting an error bit in the CSR. Once the packet is received without error, the command and data is stored in a FIFO buffer.

This FIFO can hold up to 16 commands. The 7344 controller RTOS will process commands whenever it is not busy with higher priority tasks. In the unlikely occurrence that the FIFO fills up before any commands can be processed, the host detects a Not-Ready-to-Receive condition and waits for available room in the FIFO before sending additional packets.

Each command is processed and a determination is made whether to execute the command immediately, or store it away in an onboard program to be executed later. Commands are also checked for data and modal (sequence) errors at this time. A modal error is flagged by setting the error message bit in the CSR. A modal error is functionally different from the packet communication error described above. See the *Error Stack* section later in this chapter for additional information on modal errors.

Return Data Buffer

Data or status requested by the host with a command is buffered in the return data FIFO buffer (RDB). The RDB is 26 words deep and is large enough to hold the biggest return data packet or many smaller return data packets.

When data exists in the RDB, the Ready-to-Send bit in the CSR is set. The host can then perform a bus read to get the return data from the controller.

You can use the RDB in two ways—as a temporary buffer holding a single data return packet, or as a small FIFO buffer. Typically, once the requested data is available in the RDB, it is read back by the host. It is possible however, to request a number of pieces of data and leave them in the buffer (RDB) for retrieval at a later time. The FlexMotion software supports both ways of using the RDB.

If the RDB fills up and there is no place to put requested return data, the 7344 controller generates an error and sets the error message bit in the CSR.

Note Refer to the *FlexMotion Software Reference Manual* for more information on RDB buffering and readback.

Error Stack

To handle run-time or modal errors, the 7344 controller maintains an error stack. If an error is detected during command execution, the Command ID, Resource ID, and Error Code are placed on a last-in-first-out (LIFO) stack and the error message bit in the CSR is set.

Since commands can be buffered in the command FIFO, errors detected at command execution time are delayed and are not reported as packet errors. Errors are pushed on the error stack to be read back by the host at a later time. This error-handling structure also correctly detects errors generated by incorrectly sequenced programs and other modal errors.

The error stack is organized as a LIFO buffer so that old errors can be ignored and the most recent error is readily available to be read with the Read Error Message function, just like any other status or data value. Older errors can then be read back in the inverse order to which they were generated, and reviewed for their relevance.

The error stack can hold up to 30 errors. If the error stack fills up before any error message is read back (an unlikely event), additional error messages are thrown away.

Notes   Refer to the *Error Codes* section of the *FlexMotion Software Reference Manual* for additional information on types of errors and possible reasons for their occurrence.

If the host or onboard program is correctly written, you should not see any packet or modal errors. These error-handling structures are used mostly during application development and debugging.

5

Signal Connections

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

The 7344 controller has two connectors that handle all signals to and from the external motion system:

- 68-pin motion I/O connector
- 68-pin digital I/O 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 controller motion I/O and auxiliary digital I/O cables. Failure to do so may damage the 7344 controller.

Motion I/O Connector

The motion I/O connector contains all of the signals required to control up to four 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

This 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 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 $\overline{\text{Phase B}}$
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 $\overline{\text{Index}}$
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

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 bus interlock
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
Analog Output Ground	—	—	Reference for analog outputs
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>—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—To help keep digital noise separate from the analog DAC outputs, there is a separate return connection. You should 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 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 high sink current capability.

⚠ **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 high current sink capability 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 and 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   While limit and home transitions are edge-detected and always stop motion, 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.

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 controllers and are not required for basic motion control. These inputs are part of a system solution for complete motion control. All motion control functions can be operated without limit switches except the Find Home function, which requires enabled limit and home inputs for operations.

Note   Both limits and home inputs must be enabled to use the Find Home function.

During Find Home function execution, the first active limit signal in the search direction does not simply stop the motor, but causes motion to turn around and travel in the opposite direction and continue to search for the home switch.

Similarly, during Find Home, you can use a home switch to either stop motion or to begin a predetermined sequence of homing moves to find the correct edge of the home switch and to approach it from the desired direction.

Note   After a Find Home sequence is complete, the home input should be disabled, since it is no longer required, assuming you do not want to stop at the home position the next time the system moves past it.

Wiring Concerns

Cautions   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. Failure to do so 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. Wiring these signals near each other can cause faulty motion system operation.

Limit and Home Input Circuit

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.
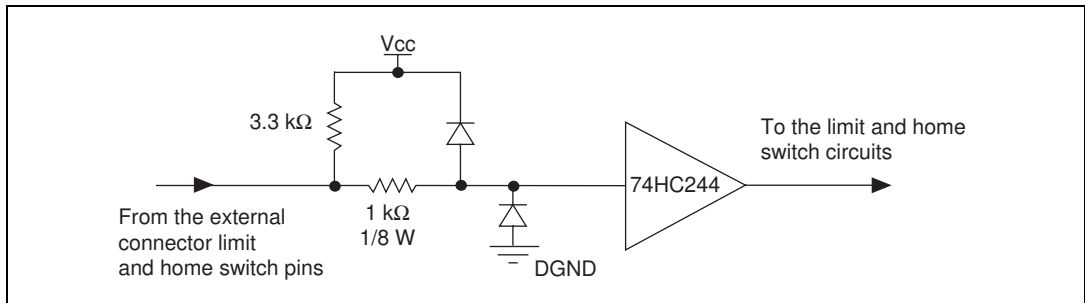
Figure 5-2. Limit and Home Input Circuit

⚠️ **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 controller offers four channels of single-ended quadrature encoder inputs. Each channel consists of a Phase A, a Phase B, and an 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 a 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 would be 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. You then 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.
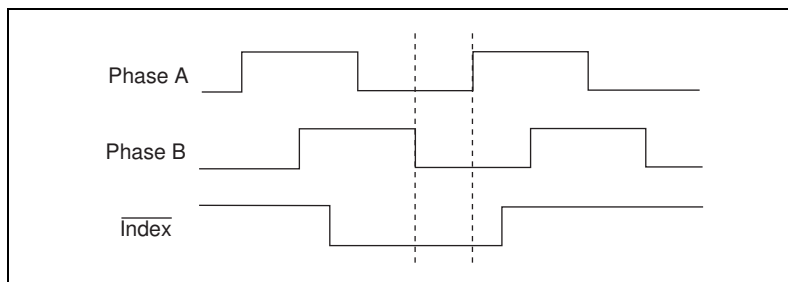
Figure 5-3. Quadrature Encoder Phasing Diagram

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 feet. 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.

⚠ **Caution**   Use of an unshielded cable can permit 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 Index signal is optional but highly recommended and required for initialization functionality with the Find Index function.
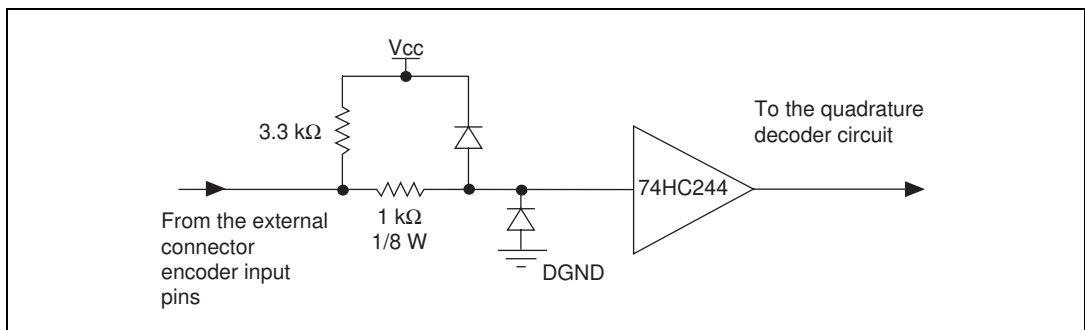
Figure 5-4. Encoder Input Circuit

Trigger Inputs and Breakpoint Outputs

The 7344 controller offers 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 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). You can also use a trigger input as a latching general-purpose digital input by simply ignoring the captured position. The trigger functions as a one-shot and must be enabled appropriately.

- 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. Breakpoints are one-shot and must be enabled and re-enabled each time they occur to function properly. The Enable Breakpoint function also allows you to preset the breakpoint output to a known state so that the transition when the breakpoint occurs can be low to high, high to low, or toggle.

  You can read the status of the breakpoint function at any time. When a breakpoint is enabled, its corresponding status bit is reset to FALSE and its status goes TRUE when the breakpoint occurs.

Note   The Read Breakpoint Status function does not return the digital I/O value of the breakpoint outputs; it returns the enabled/occurred status instead.

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

Wiring Concerns

Cautions   Keep trigger 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 and Breakpoint Output Circuits

Figures 5-5 and 5-6 show a simplified schematic diagram of the circuits used by the trigger inputs and breakpoint outputs for signal buffering.
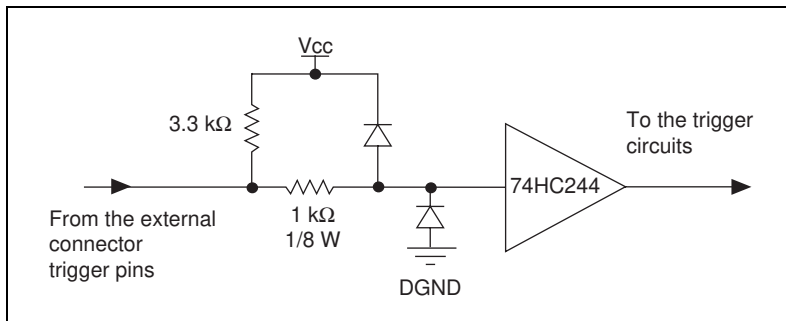
Figure 5-5. Trigger Input Circuit
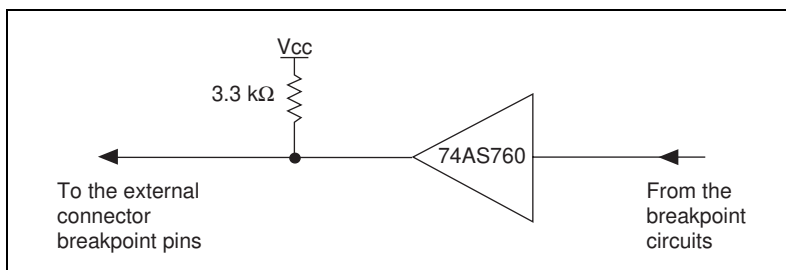
Figure 5-6. Breakpoint Output Circuit

Analog Inputs

The 7344 controller has the following ADC input signals:

- Analog Input <1..4>—The 7344 controller includes 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 controller's eight ADC channels by using the Read ADC function. The range of values read back and the voltage resolution for each setting are shown in Table 5-3. The voltage resolution is given 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

When configured as analog feedback, an analog sensor acts like a limited range absolute position device with a full-scale position range as indicated in Table 5-3. You can map any ADC channel as feedback to any axis.

You can enable and disable individual ADC channels in software. You should 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 made 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 provided. You should 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   If an external reference voltage is used, it must not be connected to the analog reference output, since this is an output signal only. You should, however, connect the external reference's common to the Analog Input Ground pin for proper A/D reference and improved voltage measurement.

Other Motion I/O Connections

The 7344 controller provides other motion I/O connections as follows:

- Host +5 V—This is the host computer's internal +5 V supply. It is used to detect when the host computer is powered and as an interlock to shut down external motion system components when the host computer is turned off.

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.

- Shutdown—The shutdown input signal, when enabled in software, can be used to kill all motion by zeroing the analog outputs and freezing the stepper pulse and/or direction outputs.

Digital I/O Connector

All of the 7344 controller's general-purpose digital I/O lines are available on a separate 68-pin digital I/O connector. The pin assignments for this connector are shown in Figure 5-7.

+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 5-7. 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 you can configure each bit as active-low (inverting) or active-high (non-inverting). Software commands that read and write the port use logical values (TRUE/FALSE) for each bit. Depending upon the programmed polarity for a bit, a TRUE value may correspond to a high voltage (active-high) or low voltage (active-low) on the physical pin.

Reads from input pins always return the logic value of the input bits. Writes to input pins do nothing. Writes to output pins set/reset the logic levels of the output bits. Reads from output pins return the logic levels last written to the port.

The FlexMotion software supports the MustOn/MustOff (MOMO) protocol for setting and resetting the output bits in a port. The MOMO approach allows you to define which bits must be On (active), which bits must be Off (non-active), and which bits you want to stay in the same state. In this way, an individual bit or bits can be set or reset without worrying about the values of the other bits in the port. Of course, the entire port can also be set or reset at any time. Each output circuit can sink and source 24 mA.

The state of the input pins at power-up is controlled by the DPull pin. 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 controller provides 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. You can 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.

A

Specifications

This appendix lists the hardware and software performance specifications for the 7344 controller.

Servo Performance

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

Long-term velocity accuracy .... Oscillator based, ±100 ppm

Double-buffered trajectory parameters

    Absolute position range .... $\pm2^{31}$ counts

    Max relative move size .... $\pm2^{31}$ 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 .... ±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

Long-term velocity accuracy ....Oscillator based, ±100 ppm

Double-buffered trajectory parameters

  Position range ....±2^{31} steps

  Max relative move size....................±2^{31} steps

  Velocity range ....1 to 8,000,000 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 .... 8 MHz (full, half, and microstep)

    Min pulse width .... 60 ns at 8 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

    Control .... Disable all axes and command
    outputs

Motion I/O

Encoder inputs .... Quadrature, incremental,
single-ended

    Max count rate .... 20 MHz

    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

    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 .... ±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 typ.

    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

    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 typ.

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

Power Requirements (Max)

◆ PCI-7344 and PXI-7344

+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 .... 17.5 by 9.9 cm (6.9 by 3.9 in.)

PXI-7344 .... 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

Environment

Operating temperature .... 0 to 55 °C

Storage temperature .... −20 to 70 °C

Relative humidity range .... 10 to 90% (noncondensing)

B

Cable Connector Descriptions

This appendix describes the connector pinout for the cables that connect to your 7344 boards.

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 or 68M-50F 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

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 $\overline{\text{Index}}$
Trigger/Breakpoint 1	9	10	Axis 1 Forward Limit Switch
Axis 1 $\overline{\text{Inhibit}}$	11	12	Axis 1 Reverse Limit Switch
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 $\overline{\text{Index}}$
Trigger/Breakpoint 2	21	22	Axis 2 Forward Limit Switch
Axis 2 $\overline{\text{Inhibit}}$	23	24	Axis 2 Reverse Limit Switch
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 $\overline{\text{Index}}$
Trigger/Breakpoint 3	33	34	Axis 3 Forward Limit Switch
Axis 3 $\overline{\text{Inhibit}}$	35	36	Axis 3 Reverse Limit Switch
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 $\overline{\text{Index}}$
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-2. 50-Pin Servo Connector Pin Assignment

C

Technical Support Resources

This appendix describes the comprehensive resources available to you in the Technical Support section of the National Instruments Web site and provides technical support telephone numbers for you to use if you have trouble connecting to our Web site or if you do not have internet access.

NI Web Support

To provide you with immediate answers and solutions 24 hours a day, 365 days a year, National Instruments maintains extensive online technical support resources. They are available to you at no cost, are updated daily, and can be found in the Technical Support section of our Web site at `www.natinst.com/support`.

Online Problem-Solving and Diagnostic Resources

- **KnowledgeBase**—A searchable database containing thousands of frequently asked questions (FAQs) and their corresponding answers or solutions, including special sections devoted to our newest products. The database is updated daily in response to new customer experiences and feedback.

- **Troubleshooting Wizards**—Step-by-step guides lead you through common problems and answer questions about our entire product line. Wizards include screen shots that illustrate the steps being described and provide detailed information ranging from simple getting started instructions to advanced topics.

- **Product Manuals**—A comprehensive, searchable library of the latest editions of National Instruments hardware and software product manuals.

- **Hardware Reference Database**—A searchable database containing brief hardware descriptions, mechanical drawings, and helpful images of jumper settings and connector pinouts.

- **Application Notes**—A library with more than 100 short papers addressing specific topics such as creating and calling DLLs, developing your own instrument driver software, and porting applications between platforms and operating systems.

Software-Related Resources

- **Instrument Driver Network**—A library with hundreds of instrument drivers for control of standalone instruments via GPIB, VXI, or serial interfaces. You also can submit a request for a particular instrument driver if it does not already appear in the library.

- **Example Programs Database**—A database with numerous, non-shipping example programs for National Instruments programming environments. You can use them to complement the example programs that are already included with National Instruments products.

- **Software Library**—A library with updates and patches to application software, links to the latest versions of driver software for National Instruments hardware products, and utility routines.

Worldwide Support

National Instruments has offices located around the globe. Many branch offices maintain a Web site to provide information on local services. You can access these Web sites from `www.natinst.com/worldwide`.

If you have trouble connecting to our Web site, please contact your local National Instruments office or the source from which you purchased your National Instruments product(s) to obtain support.

For telephone support in the United States, dial 512 795 8248. For telephone support outside the United States, contact your local branch office:

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

A

A	amperes
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)
A/D	analog-to-digital
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

ID	identification
in.	inches
index	marker between consecutive encoder revolutions
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
interlock	5 V bus interlock voltage

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.

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 a the motion control board
PWM	Pulse Width Modulation—a method of controlling the average current in a motors phase windings 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	The 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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