

COMPREHENSIVE SERVICES

We offer competitive repair and calibration services, as well as easily accessible documentation and free downloadable resources.

SELL YOUR SURPLUS

We buy new, used, decommissioned, and surplus parts from every NI series. We work out the best solution to suit your individual needs.

 Sell For Cash  Get Credit  Receive a Trade-In Deal

OBSOLETE NI HARDWARE IN STOCK & READY TO SHIP

We stock **New**, **New Surplus**, **Refurbished**, and **Reconditioned** NI Hardware.



Bridging the gap between the manufacturer and your legacy test system.

 1-800-915-6216

 www.apexwaves.com

 sales@apexwaves.com

All trademarks, brands, and brand names are the property of their respective owners.

Request a Quote

 **CLICK HERE**

NI-9144

Getting Started

NI 9503 C Series Stepper Drive Modules and SoftMotion Module



Note If you are a new user of LabVIEW or are unfamiliar with LabVIEW, refer to the *Getting Started with LabVIEW* manual for information about LabVIEW and LabVIEW terminology.

This document explains how to use an NI 9503 C Series drive module with LabVIEW NI SoftMotion Module User-Defined Variable (UDV) axes, using an NI 9503 C Series drive module example to demonstrate concepts and programming best practices.



Tip If you encounter any problems during setup, refer to the [Tips and Troubleshooting](#) section for assistance.

Contents

What You Need to Get Started	2
Hardware	2
Software.....	3
SoftMotion Module Overview.....	4
Hardware and Software Installation	5
Step 1: Set Up the Real Time System.....	5
Step 2: Connect NI 9503 to the Stepper Motor	5
Step 3: Connect the NI 9503 to the NI PS-16 Power Supply	6
Step 4: Connect the System to AC Power	6
Step 5: Install Software on and Configure the NI RT Controller	6
Using NI 9503 with SoftMotion.....	7
SoftMotion UDV Axes and Configuration Data	7
SoftMotion Engine to FPGA Communication	8
Compile and Run the Example.....	10
Setting Up and Using Optional Hardware.....	12
Adding and Connecting Additional Modules.....	13
Additional UDVs and FPGA VI Loops.....	15
Tips and Troubleshooting.....	16
Drive Fault on Enable.....	16
Interactive Test Panel does not get updated	17
Where to Go Next.....	17
Worldwide Support and Services	18

What You Need to Get Started

You need the following items to get started.

Hardware

- NI 9503 C Series stepper drive module
- NI CompactRIO Real-Time controller and chassis
- 24 V power supply (such as the NI PS-15) for the CompactRIO controller (NI part number 781093-01)
- 24 V power supply (such as the NI PS-16) for the NI 9503 module



Note NI recommends the NI PS-16 power supply, which is designed for motor bus power, for use with the NI 9503 module. Refer to *Regeneration Consideration Using the NI C Series Drive Modules* at zone.ni.com for more information.

- Ethernet connection and cable for the CompactRIO controller
- NI or third-party stepper motor



Note NI offers NEMA 17 and NEMA 23 stepper motors compatible with the NI 9503. Go to ni.com for more information.

Optional Hardware

- NI or third-party encoder



Note NI offers encoders for NEMA 17 and NEMA 23 stepper motors. Go to ni.com for more information. Some NI stepper motors include integrated encoders.

- NI 9411 digital input module for encoder connections (NI part number 779005-01)
- NI 9935 15-pin D-SUB connector kit for connecting the NI 9411 (NI part number 779016-01)
- NI 9401 high-speed bidirectional digital I/O module for position compare and position capture operations (NI part number 779351-01)

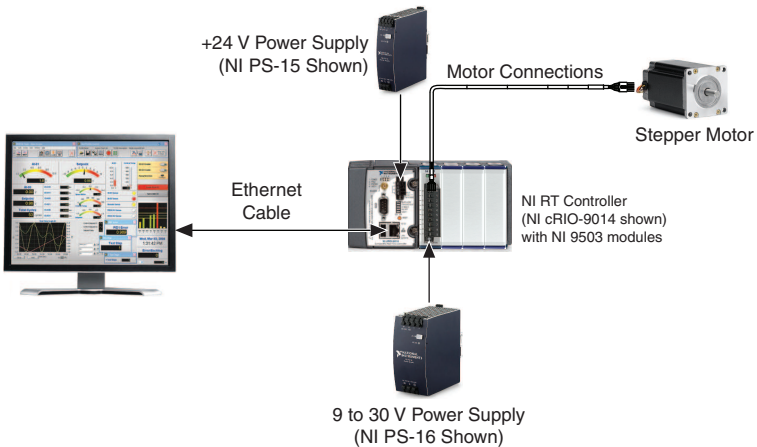
- ❑ NI 9924 25-pin D-SUB connector kit for connecting the NI 9401 (NI part number 781922-01)
- ❑ NI 9423 sinking digital input module for home, limit, and digital input connections (NI part number 779009-01)
- ❑ NI 9472 sourcing digital output module for digital output connections (NI part number 779004-01)

Software

- ❑ LabVIEW 2014 or later
- ❑ LabVIEW 2014 Real-Time Module or later
- ❑ LabVIEW 2014 FPGA Module or later
- ❑ LabVIEW 2014 SoftMotion Module or later
- ❑ NI-RIO Device Drivers 2014 or later

Figure 1 shows the system setup without optional hardware. The [Setting Up and Using Optional Hardware](#) section discusses optional hardware, including a connection diagram and example walkthrough of optional functionality.

Figure 1. SoftMotion Module with NI 9503 UDV Axis System Overview

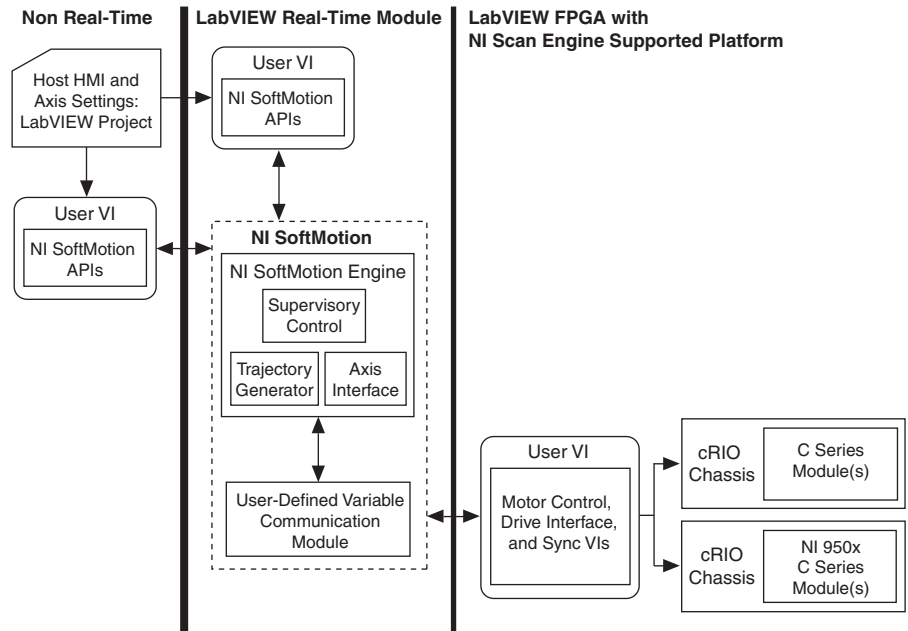


SoftMotion Module Overview

SoftMotion Module UDV axes allow you to implement an interface for communication between the SoftMotion Engine and the LabVIEW FPGA Module. This is achieved using user-defined variables that you add to the project, making it easier to use C Series modules in FPGA mode with the SoftMotion Module.

The following figure shows the SoftMotion architecture when you use the SoftMotion Module with UDV axes and the LabVIEW FPGA Module.

Figure 2. SoftMotion Module with UDV Axes



You use the LabVIEW Project to configure your axis settings and test your configuration. When your hardware configuration is complete, you use SoftMotion APIs to create move profiles.

Communication to the LabVIEW FPGA Module is handled through user-defined variables. You use the SoftMotion Drive Interface VIs to implement an interface for communication between the SoftMotion Engine and the LabVIEW FPGA Module. When you use the Drive Interface VIs with UDV axes you communicate using a predefined set of UDV's. Refer to *Adding User-Defined Variables for Use With a UDV Axis* in the *SoftMotion Module Help*, available by selecting **Help»LabVIEW Help** for information about the predefined UDV's. Refer to the [Using NI 9503 with SoftMotion](#) section for more information about the NI SoftMotion Drive Interface VIs.

Hardware and Software Installation

This section covers the hardware setup for the Real Time system and NI 9503 C Series drive module.

Step 1: Set Up the Real Time System

Complete the following steps to set up the Real Time system depending on your hardware.

1. Refer to the Getting Started guide included with the Real-Time Controller to assemble it, connect it to power, discover it on the network, and install the software in NI MAX.

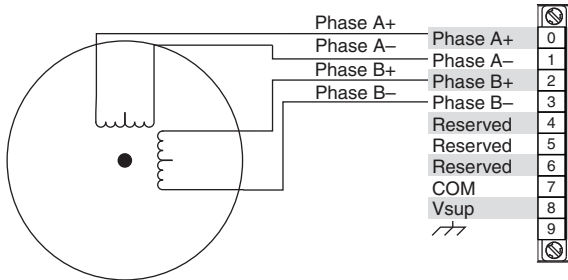


Note Older Model chassis, such as cRIO-902x, cRIO 907x, cRIO-908x, NI 9144, and NI 9148 have HSI support only on slots 1 through 4. Refer to your chassis documentation for more information about HSI support.

Step 2: Connect NI 9503 to the Stepper Motor

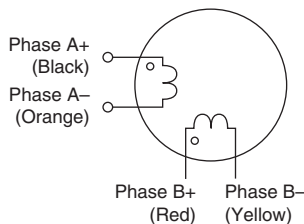
1. Connect the stepper motor to the NI 9503. Figure 3 shows a typical bipolar stepper motor connection. Refer to the *NI 9503 Operating Instructions and Specifications* for important connection information, including information about EMC compliance and connecting 6- or 8-wire stepper motors.

Figure 3. NI 9503 Bipolar Stepper Motor (2-Phase Type) Connection



NEMA 17 and NEMA 23 stepper motors from NI use the following wire color scheme.

Figure 4. Stepper Motor Wiring



Step 3: Connect the NI 9503 to the NI PS-16 Power Supply



Tip Refer to the *NI PS-16 Power Supply User Manual and Specifications* for more information about connecting and using the NI PS-16 power supply.

Complete the following steps to connect the NI 9503 module to the NI PS-16 power supply.



Tip Refer to the *NI 9503 Operating Instructions and Specifications* for more information about module power supply requirements.

1. Connect the NI 9503 Vsup (pin 8) to one of the two (+) terminals on the NI PS-16.
2. Connect the NI 9503 COM (pin 7) to one of the two (-) terminals on the NI PS-16.
3. Connect the power supply to AC power.

Step 4: Connect the System to AC Power

Complete the following steps to power on the system.

1. Connect the controller power supply (such as the NI PS-15) to AC power.

Step 5: Install Software on and Configure the NI RT Controller

This step covers installing and configuring the software for the NI 9503 stepper drive module. It assumes that all required software from the [What You Need to Get Started](#) section is installed on the host machine.

Complete the following steps to configure the controller and install software on it.



Note The NI Measurement & Automation Explorer (MAX) user interface may not match these steps exactly depending on which version of MAX you are using.

1. Launch Measurement & Automation Explorer (MAX) on the development computer by clicking the MAX icon on the desktop, or by selecting **Start»All Programs»National Instruments»NI MAX**.
2. Select the controller under **Remote Systems** in the **Configuration** pane. If you do not see the controller, you may need to disable the firewall on the development computer.
3. Verify that the **Serial Number** in the **Identification** section matches the serial number on the device.
4. Expand the controller item in the tree, right-click **Software**, and select **Add/Remove Software**.
5. Highlight your device.



Note If you do not see the controller, you may need to disable the firewall on the development computer. Go to ni.com/info and enter `RIOMAXTroubleshoot` for more information.

6. Verify that the **Serial Number** in the **System Settings** section matches the serial number on the device.
7. Select a recommended software set that includes NI CompactRIO 14.0 or later. Click **Help** if you need information about installing recommended software sets.
8. Click **Next**.
9. Select **LabVIEW SoftMotion Module** from the add-ons list.
10. Click **Next** to install the selected software on the controller.
11. Make a note of the IP address assigned to the controller, to use when adding the target in LabVIEW.
12. Close MAX.

Using NI 9503 with SoftMotion

The following tutorial walks you through using an NI 9503 UDV axis using the 9503 Stepper Drive (NI 9503) sample project. This project shows how to configure the NI 9503 for a UDV axis using the LabVIEW project and contains all required UDV's for use with the NI 9503.

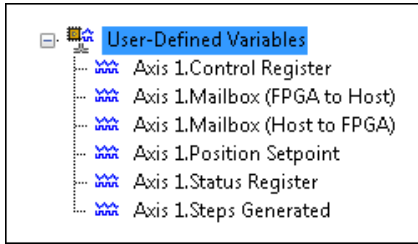
1. Select **File » Create Project» Sample Projects» SoftMotion » Stepper Drive (NI 9503)** to access the sample project provided for the NI 9503
2. Select **Position Profile** as the **Project Type** in the **Create Project** window and click **Finish**.
3. Right-click the **RT CompactRIO Target** item in the **Project Explorer** window and select **Properties** from the shortcut menu to open the real-time target properties dialog box.
4. On the **General** page, enter the IP address you configured in [Step 4: Connect the System to AC Power](#).
5. Click **OK**.
6. Right-click the target and select **Connect** from the shortcut menu. The RT target icon in the **Project Explorer** window changes to indicate a front panel connection with the RT target.

SoftMotion UDV Axes and Configuration Data

This section describes each UDV used in the example and explains how module configuration data is communicated from the LabVIEW Project to the LabVIEW FPGA Module.

1. Expand the **RTCompactRIO Target** item in the **Project Explorer** window.
2. Expand the **Chassis** item, then expand the **User-Defined Variables** item to display the UDV's used in the example. Figure 5 shows the UDV's displayed in Project Manager.

Figure 5. 9503 Stepper Drive (Getting Started) User-Defined Variables



The following table briefly describes each UDV used in the project. Refer to *Adding User-Defined Variables for Use With a UDV Axis* in the *SoftMotion Module Help* for more information about each UDV.

Table 1. Stepper Drive (Getting Started) UDV Descriptions

UDV Name	Description
Axis 1.Control Register	Contains information used to control the state and operating mode of the device.
Axis 1.Mailbox (FPGA to Host)	Contains information used to provide configuration and other data from FPGA to the SoftMotion Engine.
Axis 1.Mailbox (Host to FPGA)	Contains information used to provide configuration and other data from the SoftMotion Engine to FPGA.
Axis 1.Position Setpoint	Specifies the position setpoint.
Axis 1.Status Register	Contains information used to report status and operation mode information from the device to the system.
Axis 1.Steps Generated	Returns the current step count of the stepper generator taking into account the direction. This value is based on actual steps generated, not feedback position, and may not exactly match the feedback position.

SoftMotion Engine to FPGA Communication

Each User-Defined Variable communicates information between the SoftMotion Engine and the LabVIEW FPGA Module. These UDVs are used directly with the Drive Interface FPGA VIs in specific loops on the block diagram. Complete the following steps to open the FPGA VI and display the block diagram.

1. Expand the **FPGA Target** item in the LabVIEW Project Explorer window.
2. Double-click the **Stepper Drive (Getting Started) - FPGA.vi** item to open the VI.
3. Select **Window»Show Block Diagram** to open the FPGA VI block diagram.

The following table briefly describes each FPGA VI loop used in the project.

Table 2. Stepper Drive (Getting Started) Loop Descriptions
Table 3.

FPGA Loop Name	Description
Fault Monitoring Loop	The Fault Monitoring loop sends fault information, including user-defined faults, to the NI SoftMotion engine and sends the state machine implemented in the Control Status Loop into a fault state.
Control Status Loop	The Control Status Loop interprets the Control Register UDV and recognizes state changes, executes the appropriate action on a state change, and generates the Status Register UDV that returns information to the SoftMotion Engine.
Reset Monitoring Loop	The Reset Monitoring Loop latches the reset variable so that it only changes on a rising edge of the Scan Clock. This allows proper operation of the SoftMotion Motor Control VIs with a reset input.
Mailbox Loop	The Mailbox Loop transfers axis configuration and other data between the SoftMotion Engine and the LabVIEW FPGA Module. The transferred data is written to FPGA memory and accessed using the Read Motion Memory and Write Motion Memory Drive Interface VIs. This loop is required to be implemented as-is for proper operation
Synchronization Loop	The Synchronization Loop synchronizes the FPGA clock (slave) to the RT clock (master) to correct for drift and jitter. This is the preferred synchronization method to use with the NI SoftMotion Module. The Synchronization Loop is required to be implemented as-is for proper operation.
Position Loop and Current Loop	The Position Loop receives position setpoints from the SoftMotion trajectory generator and uses the Spline Interpolation VI to generate intermediate setpoints, resulting in smoother motion. It converts the position setpoints to an electrical angle, which is used to generate phase A and phase B current setpoints. The Position Loop sends current setpoints to the Current Loop
PWM Loop	The PWM Loop takes the A+, A-, B+ and B- duty cycles and converts them into digital signals that control H-bridges on the drive. The PWM Loop also triggers the Current Loop to run at the midpoint of the high phase of the PWM duty cycle.

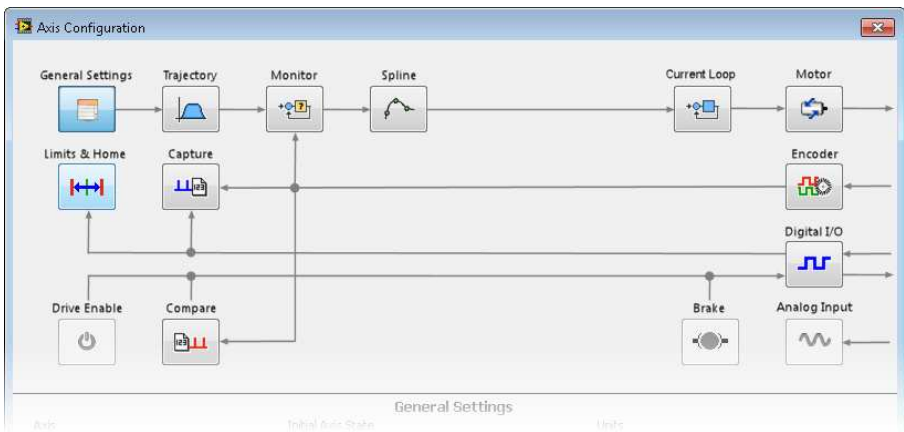
Compile and Run the Example

Complete the following steps to compile and run the example.

1. Right-click the axis in the Project Explorer window and select **Properties** from the shortcut menu to open the **Axis Configuration** dialog box. The **Axis Configuration** dialog box includes configuration options for stepper drive command signals, feedback devices, motion and digital I/O, trajectory, and axis setup.

Figure 6 shows the parts of the **Axis Configuration** dialog box for NI 9503 UDV axes. Refer to the *NI SoftMotion Module* section of the *LabVIEW Help* for detailed information about each configuration option.

Figure 6. Axis Configuration Dialog Box for NI 9503 UDV Axes





Note The **Axis Configuration** dialog box user interface may not match this image exactly depending on which version of the LabVIEW SoftMotion Module you are using.

2. For NI stepper motors, select the motor name from the drop down list. The motor parameters are included with SoftMotion and do not require customization. For third party stepper motors, set the Rated Phase Current and other motor parameters accordingly.
3. Click **OK** to close the **Axis Configuration** dialog box.

4. Right-click the **Chassis** item in the **Project Explorer** window and select **Deploy** from the shortcut menu.
5. Click the **Run** button on the 9503 Stepper Drive (Getting Started) - FPGA.vi. Clicking the **Run** button compiles the VI only if the VI or project has changed since you last compiled the VI.







Note The compilation process goes through several stages. Compiling FPGA VIs can take from a few minutes to a few hours. National Instruments recommends testing and debugging an FPGA VI before you compile it. Refer to *Introduction to Debugging FPGA VIs on an FPGA Target* in the *FPGA Module Help* for more information.

6. Verify that the FPGA VI is running. When a VI runs, the Run button () changes to a darkened arrow () to indicate that the VI is running. If the VI is not running, press the Run button.
7. Right-click the axis in the **Project Explorer** window and select **Interactive Test Panel** from the shortcut menu.



Note If the Scan Engine was not automatically transitioned from Configuration to Active mode, close the Interactive Test Panel and perform these steps: right click on the CompactRIO target in the project » Utilities » **Scan Engine Mode » Configuration, then repeat this step to change to Active. Once this is complete, the axis parameters will be sent to the FPGA VI and SoftMotion's engine will be activated.**

8. Click the **Enable** button () on the bottom of the dialog box to enable the drive.
9. Click the **Start** button () on the bottom of the dialog box to start the move with the configured options. If you encounter any errors or faults, refer to the [Tips and Troubleshooting](#) section for possible solutions.
10. Use the **Status** and **Plots** tabs to monitor the move while it is in progress.
11. Click the **Stop** button () to stop a move in progress.
12. Click the **Disable** button () on the bottom of the dialog box to disable the drive when you are finished testing it.

Setting Up and Using Optional Hardware

This section describes how to configure and use the NI 9503 with additional hardware to provide encoder feedback, limit and home inputs, digital I/O, and compare and capture operations. The Stepper Drive (with Encoder) example contains four additional modules and additional UDVs and FPGA loops to support these operations. Figure 7 shows the system setup with the additional hardware.

Figure 7. SoftMotion Module with NI 9503 UDV Axis System Overview

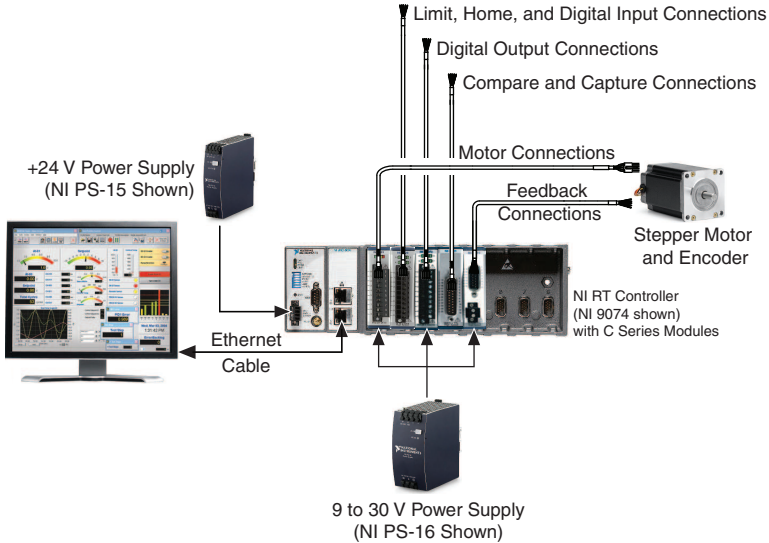


Table 4 shows the additional modules and what they are used for in the Stepper Drive (with Encoder) example.

Table 4. Additional C Series Modules Used in the Stepper Drive (with Encoder) Example

C Series Module	Slot Number	Purpose
NI 9423 Sinking Digital Input Module	2	Limits, Home, and Digital Inputs
NI 9472 Sourcing Digital Output Module	3	Digital Outputs
NI 9401 High-Speed Bidirectional Module	4	Position Compare and Position Capture
NI 9411 Digital Input Module	5	Encoder Inputs

Adding and Connecting Additional Modules

Add and Connect an NI 9423 Digital Input Module

1. Install and connect an NI 9423 digital input module in slot 2 of the chassis.
2. Connect the forward, reverse, and home switch to the NI 9423 as follows:

Table 5. NI 9411 Limit and Home Connections

NI 9423 Signal	Function
DI5	Reverse Limit
DI6	Forward Limit
DI7	Home Switch

3. Connect additional digital inputs to the following channels.

Table 6. NI 9411 Digital Input Connections

NI 9423 Signal	Function
DI0	Digital Input 0
DI1	Digital Input 1
DI2	Digital Input 2
DI3	Digital Input 3
DI4	Digital Input 4

Add and Connect an NI 9472 Digital Output Module

1. Install and connect an NI 9472 digital output module in slot 3 of the chassis.
2. Connect digital output devices to the NI 9472.
3. Connect the NI 9472 to the NI PS-16 power supply.
 - a. Connect an available NI 9472 Vsup terminal to one of the two (+) terminals on the NI PS-16.
 - b. Connect an available NI 9472 COM terminal to one of the two (-) terminals on the NI PS-16

Add and Connect an NI 9401 High-Speed Bidirectional Module

1. Install and connect an NI 9401 digital I/O module in slot 4 of the chassis.
2. Connect the position compare and position capture signals as follows:

Table 7. NI 9401 Position Capture and Position Compare Connections

NI 9401 Signal	Function
DIO0	Position Capture Input
DIO4	Position Compare Output

Add and Connect an NI 9411 Digital Input Module

1. Install an NI 9411 digital input module in slot 5 of the chassis.
2. Connect the encoder to the NI 9411. The NI 9411 also provides a +5 V supply for encoder power. The Stepper Drive (with Encoder) example uses the following NI 9411 signals for the corresponding encoder signals.

Table 8. NI 9411 Encoder Connections

NI 9411 Signal	Encoder Signal
DI0	Encoder Phase A
DI1	Encoder Phase B
DI2	Encoder Index

3. Connect the NI 9411 to the NI PS-16 power supply.
 - a. Connect the NI 9411 Vsup terminal to one of the two (+) terminals on the NI PS-16.
 - b. Connect the NI 9411 COM terminal to one of the two (-) terminals on the NI PS-16.

Additional UDVs and FPGA VI Loops

The Stepper Drive (with Encoder) example contains several additional UDVs and loops to implement the new functionality. In addition to the UDVs described in Table 1, the Stepper Drive (with Encoder) example uses the following new UDVs. Refer to *Adding User-Defined Variables for Use With a UDV Axis* in the *SoftMotion Module Help* for more information about each UDV.

Table 9. Stepper Drive (with Encoder) Additional UDV Descriptions


UDV Name	Description
Axis 1.DIO Control (Port A)	Contains the values of digital outputs 0 through 3 as well as information to clear input latches for limits, home, and digital inputs 0 through 3.
Axis 1.DIO Control (Port B)	<p>Contains the values of digital outputs 4 through 7 as well as information to enable position compare and position capture operations and clear input latches for digital inputs 4 through 7.</p> <p> Note Because the same digital input module is used for digital inputs and for home and limit connections, the Stepper Drive (with Encoder) example only uses digital inputs 0 through 4. Digital inputs 5 through 7 are not used in the example.</p>
Axis 1.DIO Status (Port A)	Contains information used to report value and latching information for limits, home, and digital inputs 0 through 3.
Axis 1.DIO Status (Port B)	Contains information used to report value and latching information for position capture, position compare, and digital inputs 4 through 7.
Axis 1.Position Feedback	Specifies the feedback position from the encoder.
Axis 1.Velocity Feedback	Returns the filtered encoder velocity.

Table 10. Stepper Drive (with Encoder) Additional FPGA Loop Descriptions
Table 11.

FPGA Loop Name	Description
Position Loop	When used with encoder feedback, the Position Loop calculates interpolated positions, filters the encoder velocity using the user-specified filter settings, and returns the feedback position and filtered velocity feedback information to the SoftMotion Engine.
Encoder Loop	The encoder loop uses the signals from the NI 9411 module to generate position and velocity feedback. Position Capture operations are included in the encoder loop to perform the Index capture operation for use with the SoftMotion Find Index routine.
DIO Config (Port A)	The DIO Config Port A loop manages the DIO contained in DIO Port A. This includes the Forward Limit, Reverse Limit, Home Switch, and Digital Inputs 0 through 3 from the NI 9423 C Series module, and Digital Outputs 0 through 3 that are sent to the NI 9472 C Series module.
DIO Config (Port B)	The DIO Config Port B loop manages the DIO contained in DIO Port B. This includes the Position Capture Input and Position Compare Output from the NI 9401 C Series module, Digital Inputs 4 through 7 from the NI 9423 C Series module, and Digital Outputs 4 through 7 that are sent to the NI 9472 C Series module.

Tips and Troubleshooting

Drive Fault on Enable

If you receive fault 7180 when you enable the NI 9503, verify that the **Rated Phase Current** setting is set to the appropriate value for your motor in Amps/Phase. Refer to Table 2 for information about how to determine this value.

Complete the following steps to correct the setting:

1. Set the **Rated Phase Current** in the **Axis Configuration** dialog box and click **OK** when you are done.
2. Right-click the axis in the **Project Explorer** window and select **Deploy** from the shortcut menu to deploy the updated setting.

Interactive Test Panel does not get updated

If the Scan Engine is not transitioned from Configuration to Active mode after the FPGA VI is run, SoftMotion will display a number of errors.

1. Make sure the FPGA VI is running either in Interactive mode or started using the Open FPGA VI Reference VI.
2. Transition the Scan Engine from Configuration to Active mode. If the Scan Engine was not automatically transitioned from Configuration to Active mode, close the Interactive Test Panel and perform the following steps:
 - a. Right Click on the CompactRIO target in the project.
 - b. Select Utilities » Scan Engine Mode » Configuration.
 - c. Repeat this step to change the mode to Active. **Once this is complete, the axis parameters will be sent to the FPGA VI and SoftMotion's engine will be activated.**
3. Launch the Interactive Test Panel.

Where to Go Next

The following documents contain additional information that you may find helpful. All referenced documents ship with the product and are available at ni.com/manuals.

- Operating instructions for the controller
- *NI 9503 Operating Instructions and Specifications*—Use this document to learn how to use the National Instruments 9503, including specifications and pin assignments for the NI 9503.
- *NI 9411 Operating Instructions and Specifications*—Use this document to learn how to use the National Instruments 9411, including specifications and pin assignments for the NI 9411.
- *LabVIEW SoftMotion Module Help*—Use this help file to learn about using the NI SoftMotion Module in LabVIEW including information about function blocks and using the SoftMotion Module with the LabVIEW Project. To access this help file from LabVIEW, select **Help»LabVIEW Help**, then expand the *LabVIEW SoftMotion Module* book on the **Contents** tab.
- *LabVIEW Help*—Use the *LabVIEW Help* to access information about LabVIEW programming concepts, step-by-step instructions for using LabVIEW, and reference information about LabVIEW VIs, functions, palettes, menus, tools, properties, methods, events, dialog boxes, and so on. The *LabVIEW Help* also lists the LabVIEW documentation resources available from National Instruments. Access the *LabVIEW Help* by selecting **Help»LabVIEW Help**.
- *NI PS-16 Power Supply User Manual and Specifications*—Use this document to learn about the features and specifications of the NI PS-16 power supply and information about installing the power supply.

Worldwide Support and Services

The National Instruments website is your complete resource for technical support. At ni.com/support you have access to everything from troubleshooting and application development self-help resources to email and phone assistance from NI Application Engineers.

Visit ni.com/services for NI Factory Installation Services, repairs, extended warranty, and other services.

Visit ni.com/register to register your National Instruments product. Product registration facilitates technical support and ensures that you receive important information updates from NI.

A Declaration of Conformity (DoC) is our claim of compliance with the Council of the European Communities using the manufacturer's declaration of conformity. This system affords the user protection for electromagnetic compatibility (EMC) and product safety. You can obtain the DoC for your product by visiting ni.com/certification. If your product supports calibration, you can obtain the calibration certificate for your product at ni.com/calibration.

National Instruments corporate headquarters is located at 11500 North Mopac Expressway, Austin, Texas, 78759-3504. National Instruments also has offices located around the world. For telephone support in the United States, create your service request at ni.com/support or dial 1 866 ASK MYNI (275 6964). For telephone support outside the United States, visit the Worldwide Offices section of ni.com/niglobal to access the branch office websites, which provide up-to-date contact information, support phone numbers, email addresses, and current events.

Information is subject to change without notice. Refer to the *NI Trademarks and Logo Guidelines* at ni.com/trademarks for more information on NI trademarks. Other product and company names mentioned herein are trademarks or trade names of their respective companies. For patents covering NI products/technology, refer to the appropriate location: **Help»Patents** in your software, the `patents.txt` file on your media, or the *National Instruments Patents Notice* at ni.com/patents. You can find information about end-user license agreements (EULAs) and third-party legal notices in the readme file for your NI product. Refer to the *Export Compliance Information* at ni.com/legal/export-compliance for the NI global trade compliance policy and how to obtain relevant HTS codes, ECCNs, and other import/export data. NI MAKES NO EXPRESS OR IMPLIED WARRANTIES AS TO THE ACCURACY OF THE INFORMATION CONTAINED HEREIN AND SHALL NOT BE LIABLE FOR ANY ERRORS. U.S. Government Customers: The data contained in this manual was developed at private expense and is subject to the applicable limited rights and restricted data rights as set forth in FAR 52.227-14, DFAR 252.227-7014, and DFAR 252.227-7015.

© 2014–2018 National Instruments. All rights reserved.