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**cRIO-9014**

# Getting Started with the NI 9502 Brushless Servo Drive Module and NI AKM Motors



**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 install and configure the NI 9502 C Series brushless servo drive module for use with the NI AKM motors, and provides a walkthrough for both Trapezoidal and Field Oriented Control commutation modes.



**Tip** If you encounter any problems during setup, refer to the *Tips and Troubleshooting* section for assistance.

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## NI 9502 Overview

The NI 9502 is a brushless servo motor drive that provides outputs to drive a brushless servo motor, inputs for Hall Effect sensors, and power connections. Depending on software settings, the NI 9502 can operate in either Trapezoidal or Field Oriented Control (FOC) commutation mode. Table 1 shows the hardware and software differences between the NI 9502 commutation modes.

**Table 1.** NI 9502 Commutation Options

	<b>Trapezoidal Commutation</b>	<b>Field Oriented Control Commutation</b>
NI AKM Motor Direct Connectivity	Yes	Yes
Torque Ripple	Up to 15%	Negligible
High-Speed Performance	Limited	Full motor capability
Feedback Required	Velocity control—No Position control—Yes	Velocity control—Yes Position control—Yes
Optimized Current Loop Gains Provided for NI AKM Motors	No	Yes
NI SoftMotion Module Requirement	None	NI SoftMotion Module Premium
Hall Phasing	Manual configuration	Automatic configuration (using NI SoftMotion Module provided example)
Trajectory Generator	User-supplied setpoints or velocity control	NI SoftMotion Module trajectory generator

## NI 9502 Commutation Mode

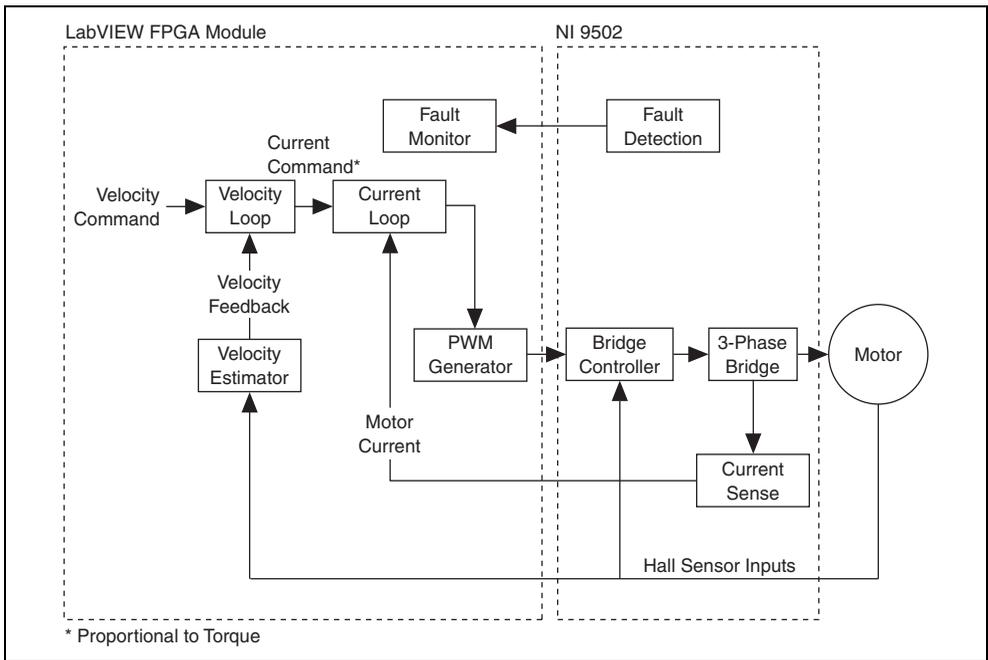
Specify the NI 9502 commutation mode in the **C Series Module Properties** dialog box, available by right-clicking the NI 9502 C Series module in the **Project Explorer** window and selecting **Properties** from the shortcut menu. The I/O nodes available to the module change depending on which commutation mode is selected.

### Trapezoidal Commutation

Trapezoidal commutation involves sending current through two of the three motor phases at any time. The phase transitions are controlled by the Hall Effect sensor state changes. With trapezoidal commutation, one electrical revolution is divided into six steps of 60 degrees each.

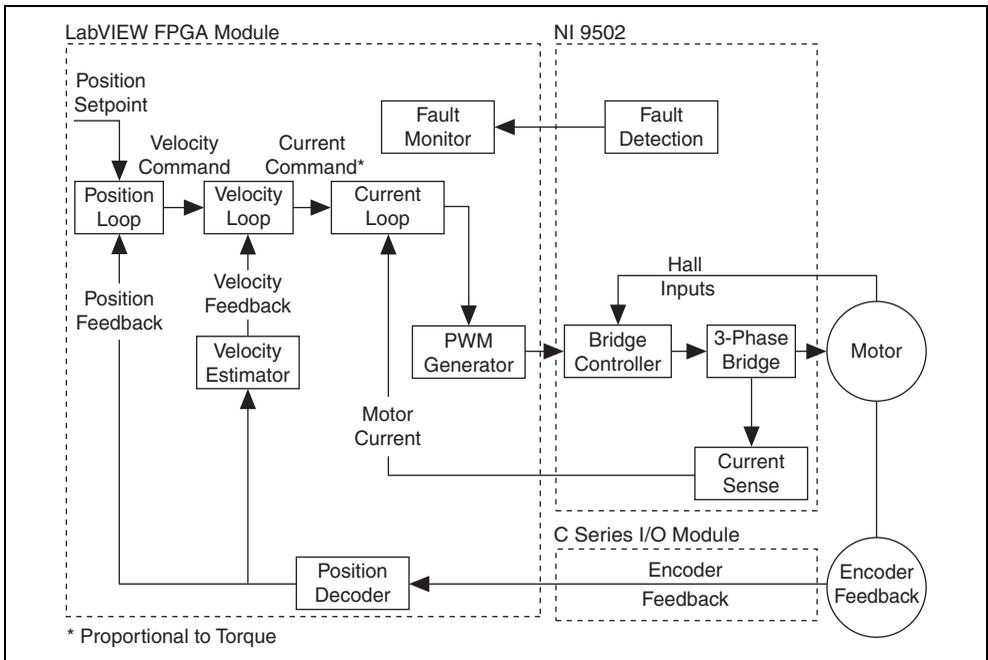
The NI 9502 performs trapezoidal commutation based on the Hall Effect sensor inputs. For proper phase switching to occur, the Hall Effect sensors from the motor must be connected to the correct Hall inputs on the NI 9502 module. The Hall Effect sensor phase sequence is motor-dependent, so selecting the correct inputs requires manual testing. Refer to the [Connecting and Using the NI 9502 in Trapezoidal Commutation Mode](#) section for a detailed walkthrough using an example VI for assistance in determining the proper Hall input connections to the NI 9502 module.

Figure 1 shows the NI 9502 module block diagram when it is used in Trapezoidal commutation mode for velocity control.



**Figure 1.** NI 9502 Trapezoidal Commutation Mode Block Diagram

If your application requires position feedback you can also use an additional I/O module, such as the NI 9411, for encoder feedback as shown in Figure 2.



**Figure 2.** NI 9502 Trapezoidal Commutation Mode Block Diagram with Encoder Feedback

Trapezoidal commutation produces a torque ripple of up to 15% at slow speeds, which is not the case with Field Oriented Control commutation.

## Field Oriented Control

Field Oriented Control (FOC) commutation mode uses a more advanced algorithm that allows smooth motion at slow speeds and better efficiency at high speeds. LabVIEW NI SoftMotion Module Premium provides VIs and example programs that provide quick setup and application development when using the NI 9502 with FOC commutation mode. Your LabVIEW Platform DVD includes a free 30-day evaluation of NI SoftMotion Module Premium that you can install to evaluate using the NI 9502 in FOC commutation mode.

Figure 3 shows the NI 9502 module block diagram when it is used in FOC commutation mode.

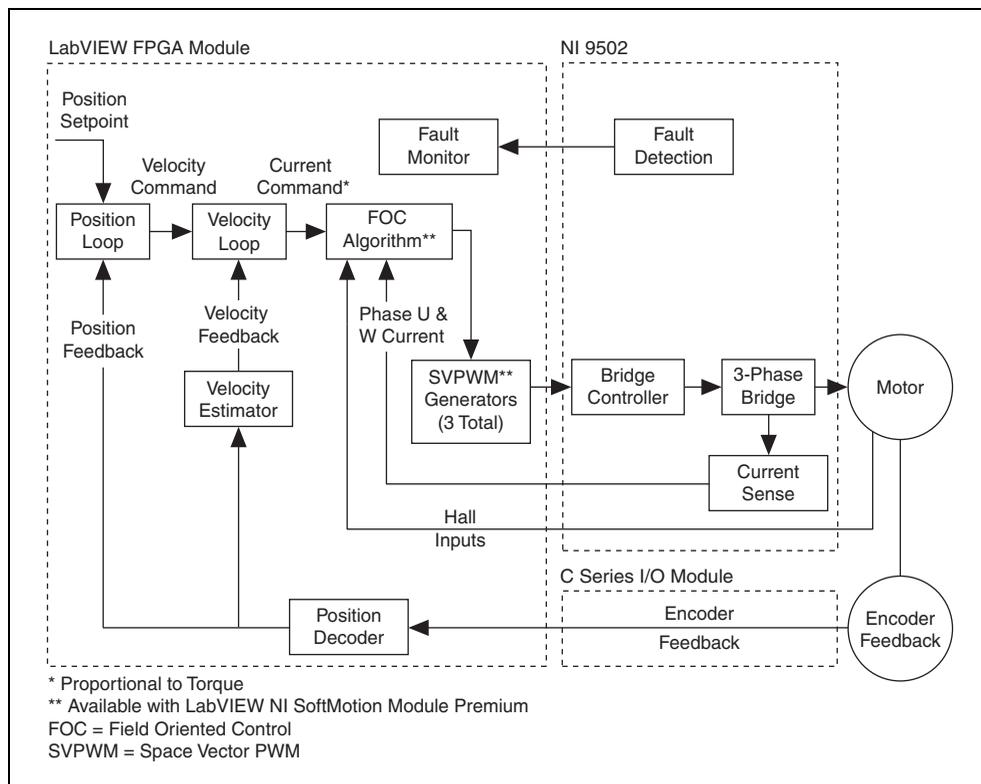


Figure 3. NI 9502 FOC Commutation Mode Block Diagram

## NI 9502 Connections

The NI 9502 has a 10-terminal detachable screw-terminal connector that provides connections for the brushless servo motor signals, Hall Effect sensors, a 9 to 30 VDC power supply, COM, and chassis ground. Refer to Figure 4 for the pin assignments.

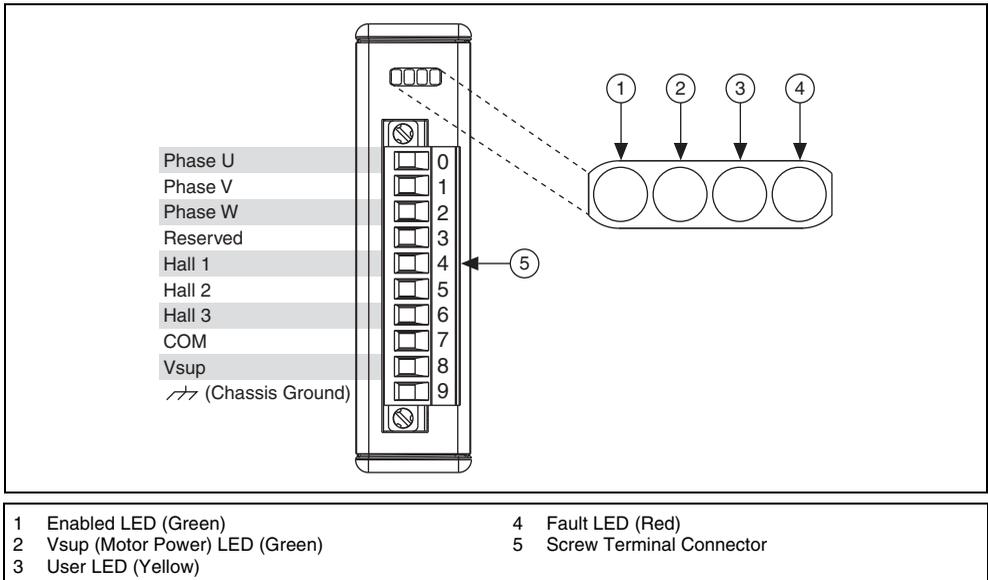
The NI 9502 requires a 9 to 30 VDC power supply connection, provided on the screw-terminal connector. Refer to the *NI 9502 Operating Instructions and Specifications* for power supply requirements and other important information.



**Caution** To ensure EMC compliance, special considerations are required for all cable connections. Refer to the *Cable Requirements for EMC Compliance* section in the *NI 9502 Operating Instructions and Specifications* for more information.



**Caution** Do not turn on or plug in the motor DC power supply until the screw-terminal connector is fully inserted and the two connector flange screws are tightened.



**Figure 4.** NI 9502 Screw Terminal Connector and LEDs

## NI 9502 to AKM Cable

The NI 9502 to AKM Cable kit connects an NI 9502 C Series brushless servo motor drive module to an NI AKM servo motor available from National Instruments. The kit consists of two cables, one for motor power and one for Hall Effect sensor and encoder feedback, with motor connectors on one end and pigtail connectors to the NI 9502 C Series module and a separate encoder module on the other end. The required cable connections differ depending on the NI 9502 commutation mode. Refer to the [Connecting and Using the NI 9502 in Trapezoidal Commutation Mode](#) or [Connecting and Using the NI 9502 in Field Oriented Control Commutation Mode](#) section for cable information.

# Connecting and Using the NI 9502 in Trapezoidal Commutation Mode

---

This section explains how to connect and use the NI 9502 module in Trapezoidal commutation mode, using an installed example to help you set up and configure your system.

## What You Need to Get Started

You need the following items to get started.

### Hardware

- NI 9502 C Series brushless servo drive module
- NI CompactRIO real-time controller
- 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 9502 module (NI part number 781094-01)



**Note** NI recommends the NI PS-16 power supply, which is designed for motor bus power, for use with the NI 9502 module. Refer to *Regeneration Consideration Using the NI C Series Drive Modules* at [zone.ni.com](http://zone.ni.com) for more information.

- 5 V power supply (such as the NI PS-6) for the Hall Effect sensors (NI part number 780577-01)



**Note** If you are connecting the optional encoder and using an NI 9411 C Series module for encoder connections, you can use the +5 V output on the NI 9411 module to power the encoder and Hall Effect sensors on the NI AKM motor.

- Ethernet connection and cable for the CompactRIO controller
- NI 9502 to AKM Cable (NI part number 153108-03)
- NI AKM servo motor
- (Optional) NI 9411 C Series module for encoder connections and +5 V output (NI part number 779005-01)
- (Optional) NI 9935 15pin D-Sub connector kit for connecting the NI 9411 (NI part number 779016-01)

### Software

- LabVIEW 2011 or later
- LabVIEW 2011 Real-Time Module or later
- NI-RIO 4.0.0 or later with CompactRIO Module Support 4.0.1 installed
- (Optional) LabVIEW NI SoftMotion Module 2011 f1 or later



**Note** LabVIEW NI SoftMotion Module Premium provides FPGA Motor Control VIs that you can use with the NI 9502. Your LabVIEW Platform DVD includes a free 30-day evaluation of NI SoftMotion Module Premium that you can install. Refer to [ni.com/info](http://ni.com/info) and enter `nismpkg` for more information about the NI SoftMotion Module.

Figure 5 shows the hardware connections when the NI 9502 is used in Trapezoidal commutation mode for velocity control.

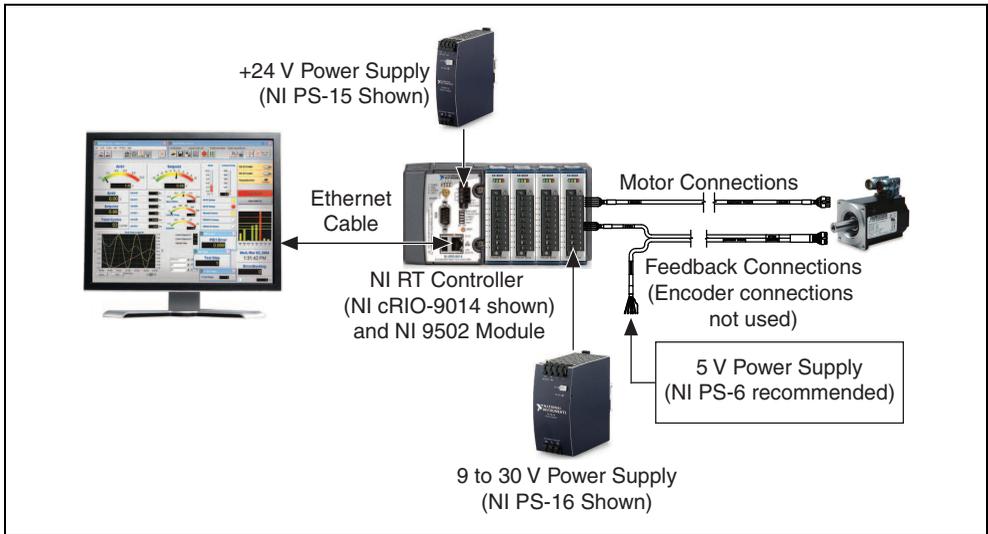


Figure 5. NI 9502 Trapezoidal Commutation Connections

## Hardware Installation and Configuration

This section covers the hardware setup for the CompactRIO system, NI 9502 C Series servo drive module, and NI AKM brushless servo motor.

### Step 1: Set Up the CompactRIO System

Complete the following steps to set up the CompactRIO hardware.

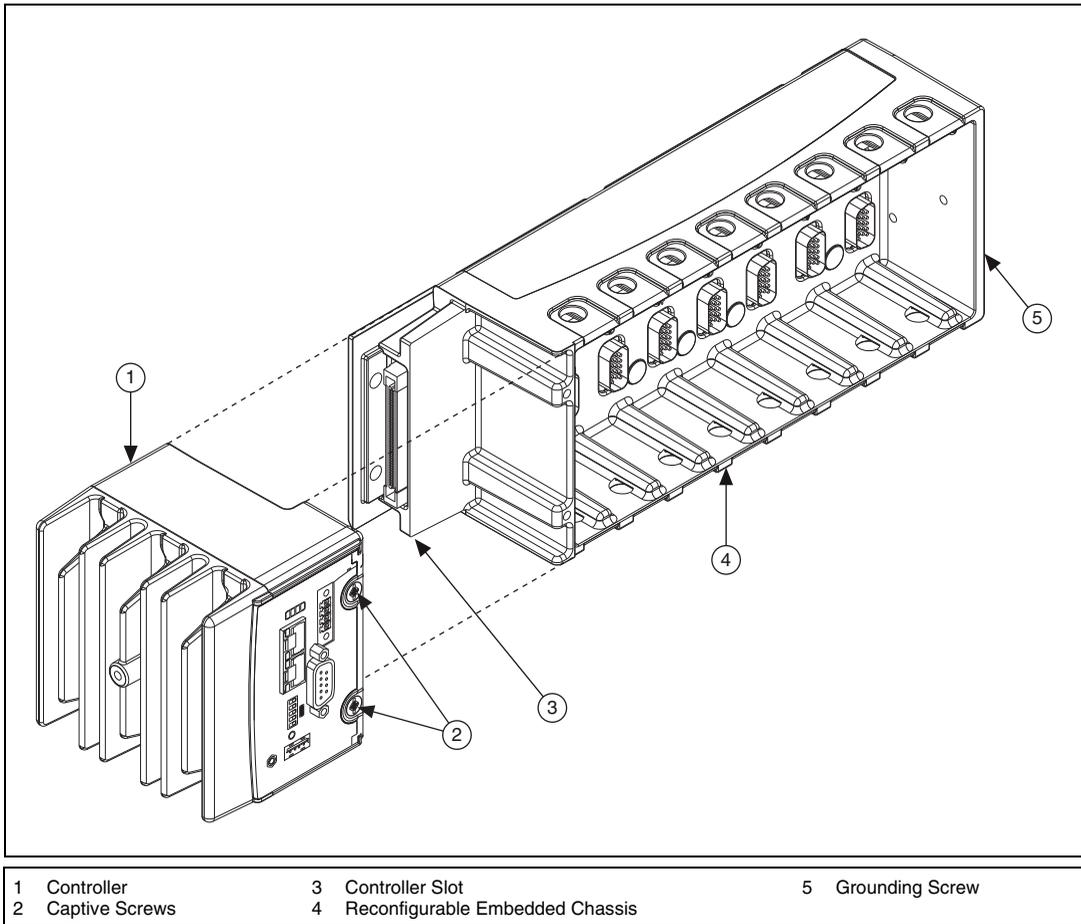
1. Install the real-time CompactRIO controller on the chassis if you are not using an integrated controller and chassis.



**Note** Write down the controller serial number before installing the controller onto the chassis. You will be unable to read the serial number after you install the controller.

- a. Make sure that no power is connected to the controller or the chassis.

- b. Align the controller with the chassis as shown in Figure 6.



**Figure 6.** Installing the Controller on the Chassis (Eight-Slot Chassis Shown)

- c. Slide the controller onto the controller slot on the chassis. Press firmly to ensure the chassis connector and the controller connector are mated.
- d. Using a number 2 Phillips screwdriver, tighten the two captive screws on the front of the controller.
2. Connect the controller to a power supply and an Ethernet network on the same subnet as the development computer. Refer to the controller operating instructions for information about wiring the controller to the power supply and Ethernet network.



**Note** Do not plug in or turn on any power to the system until after all hardware connections are complete.

3. Install the NI 9502 module in slot 1 of the chassis, if available.



**Note** The NI 9502 example programs are configured for slot 1. If the NI 9502 module is installed in a different slot, modify the examples accordingly.

4. (Optional) Install an NI 9411 module for encoder feedback, if using.

## Step 2: Connect the NI 9502 to the NI AKM Motor

Connect the NI AKM motor to the NI 9502 C Series module using the NI 9502 to AKM Motor Cables. Figure 7 shows the NI 9502 to AKM Motor Cable connectors.

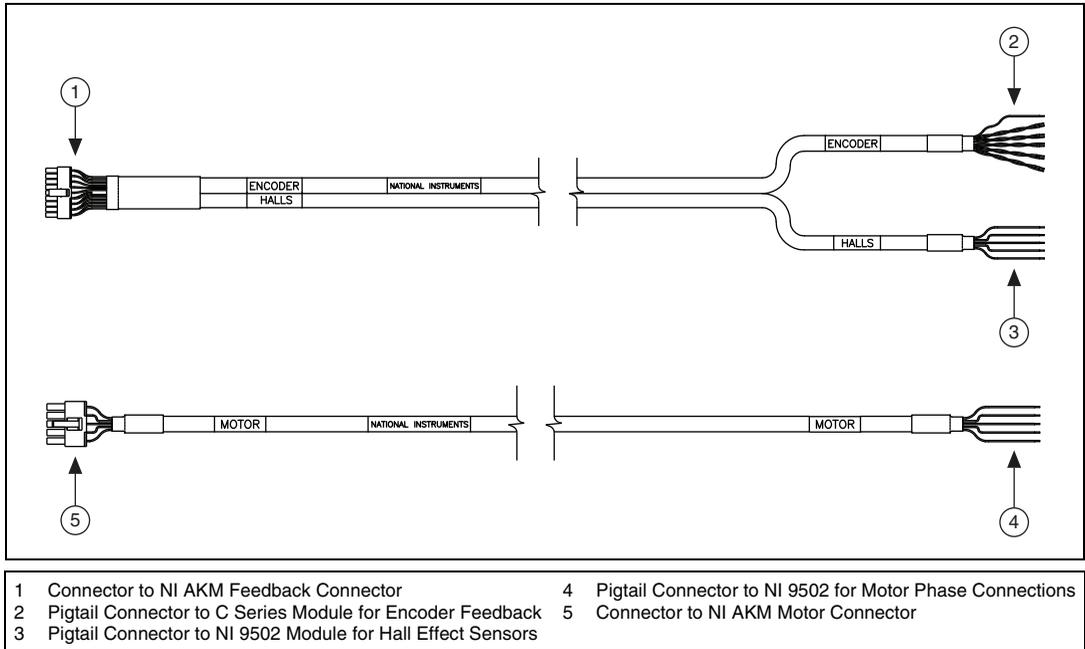


Figure 7. NI 9502 to NI AKM Motor Cables



**Note** Encoder feedback is optional when using the NI 9502 in trapezoidal commutation mode for velocity control applications and required when using the NI 9502 in FOC commutation mode. Refer to the [Connecting and Using the NI 9502 in Field Oriented Control Commutation Mode](#) section for connecting an NI 9411 C Series module for encoder feedback.

Tables 2, 3, and 4 provide the NI 9502 to AKM Motor cable screw terminal lead descriptions for the motor, encoder, and Hall Effect sensor connections, respectively. Tables 2 and 4 show NI 9502 connections, and Table 3 shows an example NI 9411 connection.

**Table 2.** NI 9502 to AKM Motor Connector Screw Terminal Lead Descriptions

NI 9502 Connection	Wire Color	Signal Name	Signal Description
0	Black	Phase U	Motor Phase U.
1	White	Phase V	Motor Phase V.
2	Red	Phase W	Motor Phase W.
7	Green	COM	Motor COM.
—	Clear	Drain	Connected to the NI AKM motor case. NI recommends leaving the drain wire disconnected; some applications may find it beneficial to connect the drain wire to the NI 9502 chassis ground to improve EMC immunity or emissions.

**Table 3.** NI 9502 to AKM Feedback Cable Screw Terminal Lead Descriptions (Encoder Portion)

NI 9411 Connection (NI 9411 Signal Name)	Wire Color	Signal Name	Signal Description
1 (DI0a)	White/Orange Stripes	Encoder Phase A	Differential encoder Phase A/A– signals.
9 (DI0b)	Orange/White Stripes	Encoder Phase A–	
2 (DI1a)	White/Blue Stripes	Encoder Phase B	Differential encoder Phase B/B– signals.
10 (DI1b)	Blue/White Stripes	Encoder Phase B–	
3 (DI2a)	White/Green Stripes	Encoder Index	Differential encoder Index/Index– signals.
11 (DI2b)	Green/White Stripes	Encoder Index–	
12 (COM)	White/Brown Stripes	COM	Encoder ground.
4 (Supply (+5 Vout))	Brown/White Stripes	+5 V	+5 V supply for encoder and Hall Effect sensors.

**Table 3.** NI 9502 to AKM Feedback Cable Screw Terminal Lead Descriptions (Encoder Portion) (Continued)

NI 9411 Connection (NI 9411 Signal Name)	Wire Color	Signal Name	Signal Description
—	White/Grey Stripes	NI AKM Motor Thermal Sensor	Internal thermistor connection within the motor which you can connect to an external device for monitoring. Under normal operating conditions at a motor winding temperature of 140 °C or lower, the resistance is less than or equal to 100 Ω. When the motor winding temperature exceeds the NI AKM thermal trip point of 140 °C the resistance rapidly increases. Refer to the <a href="#">Tips and Troubleshooting</a> section for more information.
—	Grey/White Stripes	NI AKM Motor Thermal Sensor	
—	Clear	Drain	Connected to the ground of the encoder inside the NI AKM motor. NI recommends connecting this drain wire to the COM terminal on the NI 9411; some applications may find it beneficial to disconnect the drain wire from the NI 9411 to improve EMC immunity or emissions.

**Table 4.** NI 9502 to AKM Feedback Cable Screw Terminal Lead Descriptions (Halls Portion)

NI 9502 Connection	Wire Color	Signal Name	Signal Description
4	Red	Hall 1	Hall Effect sensor 1.
5	Green	Hall 2	Hall Effect sensor 2.
6	White	Hall 3	Hall Effect sensor 3.
7	Black	COM	Hall Effect sensor COM.
—	Clear	Drain	Connected to the ground of the Hall Effect sensor case inside the NI AKM motor. NI recommends connecting this drain wire to the COM terminal on the NI 9502; some applications may find it beneficial to disconnect the drain wire from the NI 9502 to improve EMC immunity or emissions.

Complete the following steps to connect the NI 9502 to the NI AKM motor.

1. Connect the motor connector on the cable to the NI AKM motor connector.
2. Connect the motor Phase U, Phase V, and Phase W, and COM wires to the NI 9502.
3. Connect the feedback connector on the cable to the NI AKM feedback connector.
4. Connect the Hall 1, Hall 2, Hall 3, and COM wires from the Halls portion of the cable to the NI 9502.
5. Connect the +5 V and COM wires from the encoder portion of the cable to a 5 V power supply.
6. Connect the COM from the 5 V power supply to the NI 9502 COM, to provide a common reference.

## Software Installation and Configuration

This section covers installing and configuring the software for the NI 9502 servo drive module. It assumes that all required software from the [What You Need to Get Started](#) section is installed.

### Step 1: Install Software on and Configure the NI RT Controller

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



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»Measurement & Automation**.
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. If you do not want to format the disk on the controller, eliminating all installed software and files, power on the controller and skip to step 12.
5. Set the **Safe Mode** switch on the controller to the **On** position.
6. Power on the controller. If it is already powered on, press the **Reset** button on the controller to reboot it.
7. Right-click the controller under **Remote Systems** in the **Configuration** pane and select **Format Disk**. Click **Yes** on the dialog box that appears.
8. When MAX finishes formatting the disk, set the **Safe Mode** switch to the **Off** position and press the **Reset** button on the controller to reboot it.
9. Select the **System Settings** tab and type a descriptive name for the system in the **Name** field.
10. (Optional) Complete this step only if the target has an empty IP address (0.0.0.0). Select the **Network Settings** tab and select **DHCP or Link Local** from the **Configure IPv4 Address** list to assign an IP address or select the **Static** to specify a static IP address in the **IPv4 Address** section.
11. Click **Save** on the toolbar and let MAX reboot the system.
12. When the new system name appears under **Remote Systems**, expand the controller item in the tree, right-click **Software**, and select **Add/Remove Software**.
13. Select a recommended software set that includes NI-RIO 4.0 or later.
14. Click **Next**.
15. (Optional) Select **LabVIEW NI SoftMotion Module 11.0.1** or later from the add-ons list.
16. Click **Next** to install the selected software on the controller. Click **Help** if you need information about installing recommended software sets.
17. Close MAX.

## Step 2: Configuring Hall Effect Sensors and Tuning the Motor

For proper phase switching to occur during Trapezoidal commutation mode, the Hall Effect sensors from the motor must be connected to the correct Hall inputs on the NI 9502 module. The Hall Effect sensor phase sequence is motor-dependent, so selecting the correct inputs requires manually testing the motor wiring.

The following tutorial walks you through the Hall Effect sensor connections for the NI 9502 using the 9502 Trapezoidal Commutation example installed in the `labview\examples\CompactRIO\Module Specific\NI 9502\Trapezoidal Commutation` directory. This example shows how to operate the NI 9502 module in Trapezoidal commutation mode using velocity and current control loops.

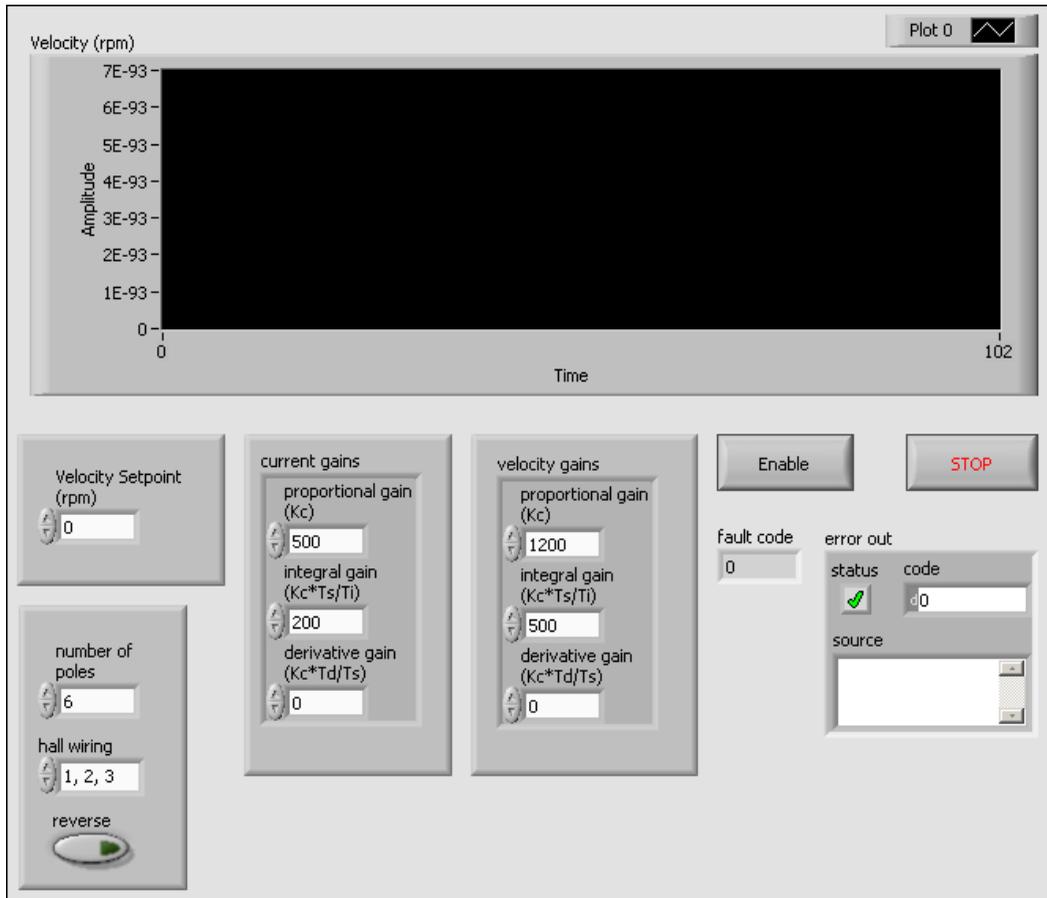
1. Connect the motor and Hall Effect sensor inputs to the drive, but do not connect the motor to a load.
2. Open the `9502 Trapezoidal Commutation` example.
3. Configure the example to work with your hardware:
  - a. Add your CompactRIO device to the LabVIEW project by right-clicking the **Project:9502 Trapezoidal Commutation.lvproj** item in the LabVIEW **Project Explorer** window and selecting **New»Targets and Devices**.
  - b. Select your target from the **Add Targets and Devices** dialog box.
  - c. Click **OK**.
  - d. Select **LabVIEW FPGA Interface** from the **Select Programming Mode** dialog box.
  - e. Click **Continue**.
  - f. Click **Discover** in the **Discover C Series Modules?** dialog box, if it appears.
  - g. Locate the FPGA VI and move it from the example FPGA target to the FPGA target under your device.
  - h. Select the example target and remove it from the project.
  - i. Rename the FPGA target from `FPGA Target 2` to `FPGA Target`.
  - j. Right-click the NI 9502 module item in the **Project Explorer** window and select **Properties** to open the **C Series Module Properties** dialog box.
  - k. Change the **Commutation Mode** from **Field Oriented Control** to **Trapezoidal**.
  - l. (Optional) Remove the unavailable I/O nodes from under the NI 9502 item the **Project Explorer** window.
  - m. If the NI 9502 is not in slot 1 of the CompactRIO chassis, update the I/O nodes in the FPGA VI to point to the correct location.
4. Compile the `9502 Trapezoidal Commutation FPGA VI`.
5. Open the `9502 Trapezoidal Commutation` desktop VI and run the VI.



**Note** If the VI is not executable, right-click the Open FPGA VI reference function and select **Configure Open FPGA VI Reference** from the shortcut menu, then browse to the FPGA VI and click **OK**.

6. With the **hall wiring** property set to the default of **1, 2, 3**, enter a small positive velocity (such as 20 RPM) in the **Velocity Setpoint (rpm)** control.
7. Click the **Enable** button to enable the drive and move the motor.

- Record the highest velocity returned in the **Positive Velocity** column in Table 5. The velocity is returned in the **Velocity (rpm)** graph on the front panel:



**Figure 8.** 9502 Trapezoidal Commutation Front Panel



**Note** If the motor moves erratically or not at all, place an X in both velocity columns in Table 5, as this wiring scheme can be eliminated.

- Click the **Enable** button again to disable the drive and stop the motor.
- Enter the same velocity as a negative number in the **Velocity Setpoint** control.
- Click the **Enable Drive** button to enable the drive and move the motor.
- Record the highest velocity returned in the **Negative Velocity** column in Table 5.
- Click the **Enable Drive** button again to disable the drive and stop the motor.
- Repeat steps 8 through 15 for the other five possible wiring combinations.
- Stop the VI using the **Stop** button.

**Table 5.** Hall Wiring Property Results

Hall Wiring Property Setting	Positive Velocity	Negative Velocity
1, 2, 3		
1, 3, 2		
2, 1, 3		
2, 3, 1		
3, 1, 2		
3, 2, 1		

16. Look for the **hall wiring** value in Table 5 where the velocities in both directions were closest to the setpoint. This is the setting to use for your system. If these steps did not provide a conclusive result, repeat the test with a higher **Velocity Setpoint**.
17. Set **hall wiring** to the correct value, if necessary.
18. Connect a load to the system and tune the velocity gains using the 9502 Trapezoidal Commutation VI. Refer to the [Tips and Troubleshooting](#) section for tuning tips.
19. (Optional) Tune the current gains using the same principles in the [Tips and Troubleshooting](#) section used to tune the velocity loop.

# Connecting and Using the NI 9502 in Field Oriented Control Commutation Mode

This section explains how to connect and use the NI 9502 module in Field Oriented Control (FOC) commutation mode, using an installed example to help you set up and configure your system.

## What You Need to Get Started

You need the following items to get started.

### Hardware

- NI 9502 C Series brushless servo drive module
- NI CompactRIO real-time controller
- 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 9502 module (NI part number 781094-01)



**Note** NI recommends the NI PS-16 power supply, which is designed for motor bus power, for use with the NI 9502 module. Refer to *Regeneration Consideration Using the NI C Series Drive Modules* at [zone.ni.com](http://zone.ni.com) for more information.

- Ethernet connection and cable for the CompactRIO controller
- NI 9502 to AKM Cable (NI part number 153108-03)
- NI AKM servo motor
- NI 9411 C Series module for encoder connections and +5 V output (NI part number 779005-01)
- (Optional) NI 9935 15pin D-Sub connector kit for simplified NI 9411 connections (NI part number 779016-01)

### Software

- LabVIEW 2011 or later
- LabVIEW 2011 Real-Time Module or later
- NI-RIO 4.0.0 or later with CompactRIO Module Support 4.0.1 installed
- LabVIEW NI SoftMotion Module 2011 f1 or later



**Note** LabVIEW NI SoftMotion Module Premium provides VIs and example programs that make it easier to use the NI 9502 in FOC commutation mode. Your LabVIEW Platform DVD includes a free 30-day evaluation of NI SoftMotion Module Premium that you can install. Refer to [ni.com/info](http://ni.com/info) and enter `nismpkg` for more information about the NI SoftMotion Module.

Figure 5 shows the hardware connections when the NI 9502 is used in FOC commutation mode.

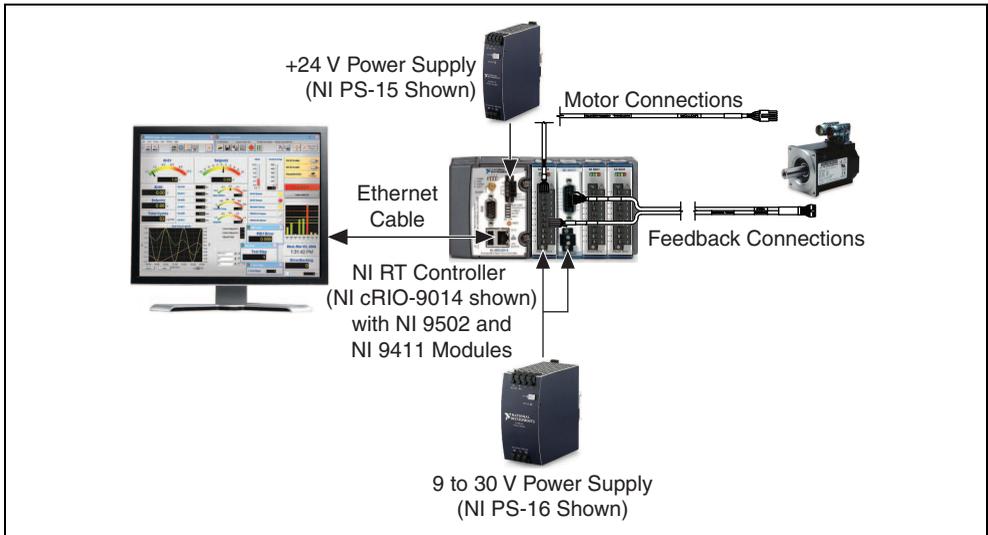


Figure 9. NI 9502 FOC Commutation Connections

## Hardware Installation and Configuration

This section covers the hardware setup for the CompactRIO system, NI 9502 C Series servo drive module, and NI AKM brushless servo motor.

### Step 1: Set Up the CompactRIO System

Complete the following steps to set up the CompactRIO hardware.

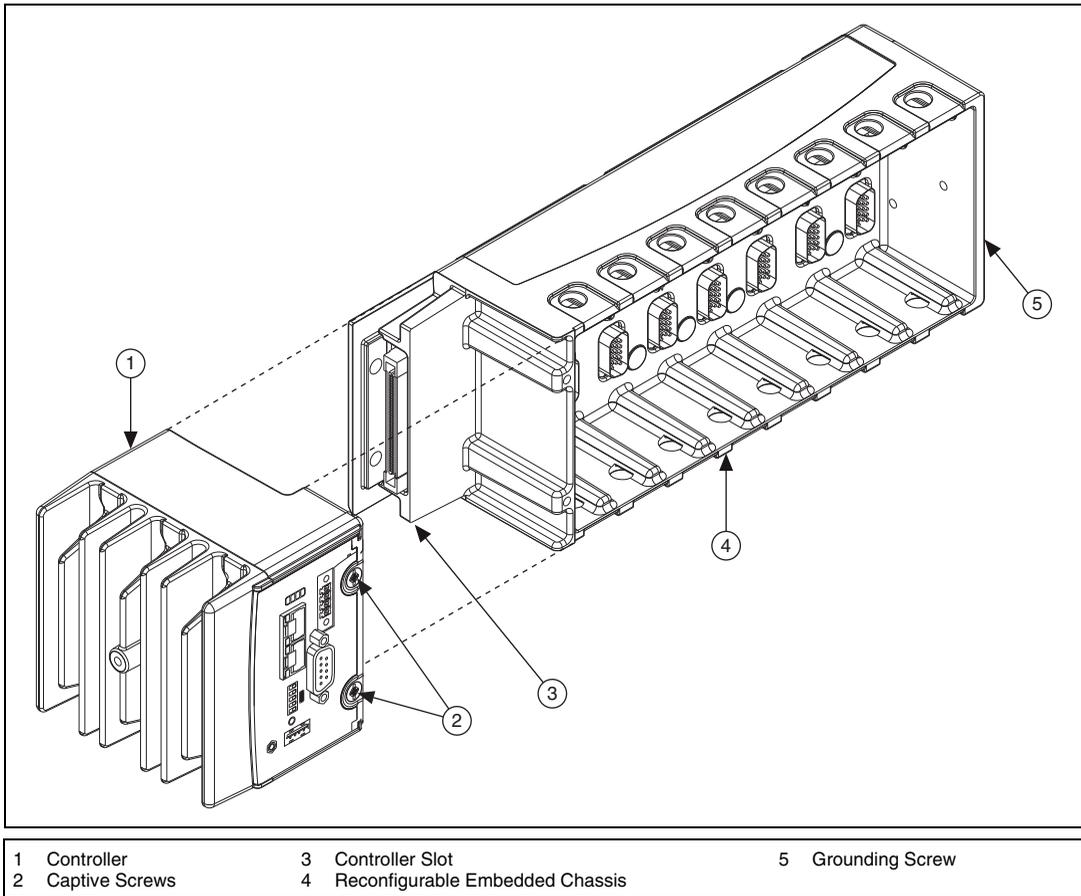
1. Install the real-time CompactRIO controller on the chassis if you are not using an integrated controller and chassis.



**Note** Write down the controller serial number before installing the controller onto the chassis. You will be unable to read the serial number after you install the controller.

- a. Make sure that no power is connected to the controller or the chassis.

- b. Align the controller with the chassis as shown in Figure 10.



**Figure 10.** Installing the Controller on the Chassis (Eight-Slot Chassis Shown)

- c. Slide the controller onto the controller slot on the chassis. Press firmly to ensure the chassis connector and the controller connector are mated.
- d. Using a number 2 Phillips screwdriver, tighten the two captive screws on the front of the controller.
2. Connect the controller to a power supply and an Ethernet network on the same subnet as the development computer. Refer to the controller operating instructions for information about wiring the controller to the power supply and Ethernet network.



**Note** Do not plug in or turn on any power to the system until after all hardware connections are complete.

3. Install the NI 9502 module in slot 1 of the chassis, if available.

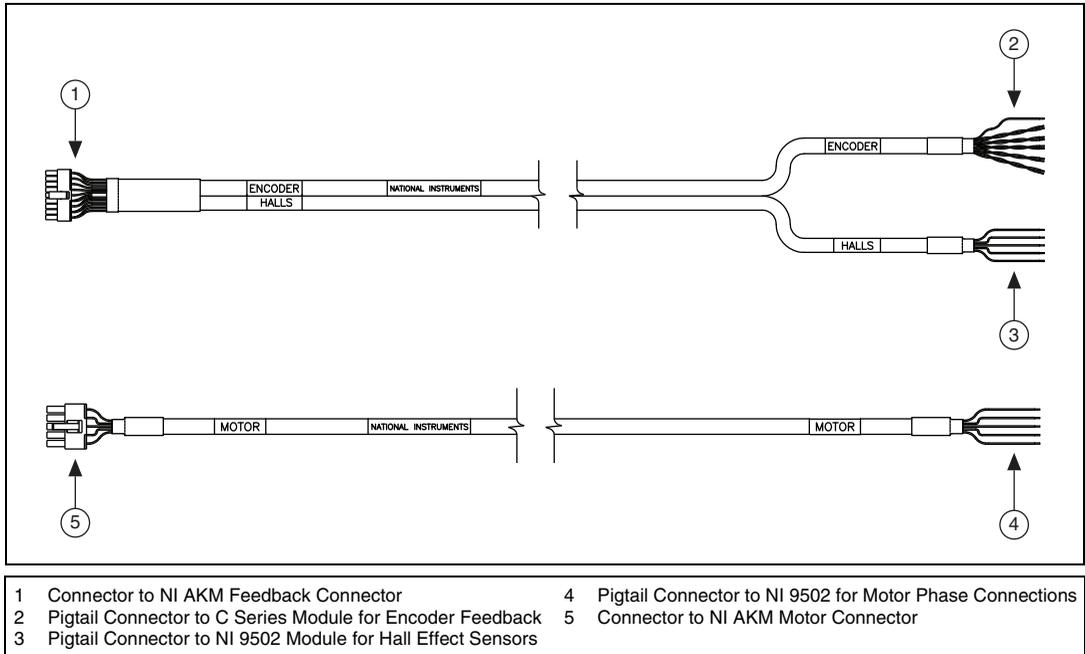


**Note** The NI 9502 example programs are configured for slot 1. If the NI 9502 module is installed in a different slot, modify the examples accordingly.

4. Install an NI 9411 module for encoder feedback, and to provide 5 V power for the encoder and Hall Effect sensors.

## Step 2: Connect the NI 9502 and NI 9411 to the NI AKM Motor

Connect the NI AKM motor to the NI 9502 and NI 9411 C Series modules using the NI 9502 to AKM Motor Cables. Figure 7 shows the NI 9502 to AKM Motor Cable connectors.



**Figure 11.** NI 9502 to AKM Motor Cables

Tables 6, 7, and 8 provide the NI 9502 to AKM Motor cable screw terminal lead descriptions for the motor, encoder, and Hall Effect sensor connections, respectively.

**Table 6.** NI 9502 to AKM Motor Connector Screw Terminal Lead Descriptions

NI 9502 Connection	Wire Color	Signal Name	Signal Description
0	Black	Phase U	Motor Phase U.
1	White	Phase V	Motor Phase V.
2	Red	Phase W	Motor Phase W.
7	Green	COM	Motor COM.
—	Clear	Drain	Connected to the NI AKM motor case. NI recommends leaving the drain wire disconnected; some applications may find it beneficial to connect the drain wire to the NI 9502 chassis ground to improve EMC immunity or emissions.

**Table 7.** NI 9502 to AKM Feedback Cable Screw Terminal Lead Descriptions (Encoder Portion)

NI 9411 Connection (NI 9411 Signal Name)	Wire Color	Signal Name	Signal Description
1 (DI0a)	White/Orange Stripes	Encoder Phase A	Differential encoder Phase A/A– signals.
9 (DI0b)	Orange/White Stripes	Encoder Phase A–	
2 (DI1a)	White/Blue Stripes	Encoder Phase B	Differential encoder Phase B/B– signals.
10 (DI1b)	Blue/White Stripes	Encoder Phase B–	
3 (DI2a)	White/Green Stripes	Encoder Index	Differential encoder Index/Index– signals.
11 (DI2b)	Green/White Stripes	Encoder Index–	
12 (COM)	White/Brown Stripes	COM	Encoder ground.
4 (Supply (+5 Vout))	Brown/White Stripes	+5 V	+5 V supply for encoder and Hall Effect sensors.
—	White/Grey Stripes	NI AKM Motor Thermal Sensor	Internal thermistor connection within the motor which you can connect to an external device for monitoring. Under normal operating conditions at a motor winding temperature of 140 °C or lower, the resistance is less than or equal to 100 Ω. When the motor winding temperature exceeds the NI AKM thermal trip point of 140 °C the resistance rapidly increases. Refer to the <i>Tips and Troubleshooting</i> section for more information.
—	Grey/White Stripes	NI AKM Motor Thermal Sensor	
—	Clear	Drain	Connected to the ground of the encoder inside the NI AKM motor. NI recommends connecting this drain wire to the COM terminal on the NI 9411; some applications may find it beneficial to disconnect the drain wire from the NI 9411 to improve EMC immunity or emissions.

**Table 8.** NI 9502 to AKM Feedback Cable Screw Terminal Lead Descriptions (Halls Portion)

NI 9502 Connection	Wire Color	Signal Name	Signal Description
4	Red	Hall 1	Hall Effect sensor 1.
5	Green	Hall 2	Hall Effect sensor 2.
6	White	Hall 3	Hall Effect sensor 3.
7	Black	COM	Hall Effect sensor COM.
—	Clear	Drain	Connected to the ground of the Hall Effect sensor case inside the NI AKM motor. NI recommends connecting this drain wire to the COM terminal on the NI 9502; some applications may find it beneficial to disconnect the drain wire from the NI 9502 to improve EMC immunity or emissions.

Complete the following steps to connect the NI 9502 to the NI AKM motor.

1. Connect the motor connector on the cable to the NI AKM motor connector.
2. Connect the motor Phase U, Phase V, and Phase W, and COM wires to the NI 9502.
3. Connect the feedback connector on the cable to the NI AKM feedback connector.
4. Connect the Hall 1, Hall 2, Hall 3, and COM wires from the Halls portion of the cable to the NI 9502.
5. Connect the encoder Phase A/A–, Phase B/B–, and Index/Index– signals, and the +5 V and COM wires from the encoder portion of the cable to the NI 9411 module.

## Software Installation and Configuration

This section covers installing and configuring the software for the NI 9502 servo drive module. It assumes that all required software from the *What You Need to Get Started* section is installed.

### Step 1: Install Software on and Configure the NI RT Controller

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



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»Measurement & Automation**.
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. If you do not want to format the disk on the controller, eliminating all installed software and files, power on the controller and skip to step 12.
5. Set the **Safe Mode** switch on the controller to the **On** position.

6. Power on the controller. If it is already powered on, press the **Reset** button on the controller to reboot it.
7. Right-click the controller under **Remote Systems** in the **Configuration** pane and select **Format Disk**. Click **Yes** on the dialog box that appears.
8. When MAX finishes formatting the disk, set the **Safe Mode** switch to the **Off** position and press the **Reset** button on the controller to reboot it.
9. Select the **System Settings** tab and type a descriptive name for the system in the **Name** field.
10. (Optional) Complete this step only if the target has an empty IP address (0.0.0.0). Select the **Network Settings** tab and select **DHCP or Link Local** from the **Configure IPv4 Address** list to assign an IP address or select the **Static** to specify a static IP address in the **IPv4 Address** section.
11. Click **Save** on the toolbar and let MAX reboot the system.
12. When the new system name appears under **Remote Systems**, expand the controller item in the tree, right-click **Software**, and select **Add/Remove Software**.
13. Select a recommended software set that includes NI-RIO 4.0 or later.
14. Click **Next**.
15. Select **LabVIEW NI SoftMotion Module 11.0.1** or later from the add-ons list.
16. Click **Next** to install the selected software on the controller. Click **Help** if you need information about installing recommended software sets.
17. Close MAX.

## Step 2: Configure and Test the Drive using LabVIEW

This section uses the `Velocity FOC` example installed in the `labview\examples\motion\Primitives\HW\FOC Velocity Control (9502)` directory to configure the motor and Hall Effect sensor phasing values, then provides a tuning panel for determining velocity gains for your system. Complete the following steps to configure and test the drive using this example.

1. Open the `Velocity FOC` example.
2. Configure the example to work with your hardware:
  - a. Add your CompactRIO device to the LabVIEW project by right-clicking the **Project:Velocity FOC.lvproj** item in the LabVIEW **Project Explorer** window and selecting **New»Targets and Devices**.
  - b. Select your target from the **Add Targets and Devices** dialog box.
  - c. Click **OK**.
  - d. Select **LabVIEW FPGA Interface** from the **Select Programming Mode** dialog box.
  - e. Click **Continue**.
  - f. Click **Discover** in the **Discover C Series Modules?** dialog box, if it appears.
  - g. Locate the FPGA VI and move it from the example FPGA target to the FPGA target under your device.
  - h. Select the example target and remove it from the project.
  - i. Rename the FPGA target from `FPGA Target 2` to `FPGA Target`.
  - j. If the NI 9502 is not in slot 1 and the NI 9411 is not in slot 2 of the CompactRIO chassis, update the I/O nodes in the FPGA VI to point to the correct location.
3. Compile the `Velocity FOC FPGA VI`.



**Note** You do not need to run the FPGA VI directly. The other VIs use the FPGA VI to communicate with the NI 9502 module. Refer to the NI SoftMotion Module help for more information about the field-oriented control (FOC) algorithm and autophasing.

4. Run the 1 - AutoPhasing VI. This VI calculates the motor settings and Hall Effect sensor phasing values by turning the motor once at low speed to detect the Hall Effect sensor transitions.



**Note** If the VI is not executable, right-click the Open FPGA VI reference function and select **Configure Open FPGA VI Reference** from the shortcut menu, then browse to the FPGA VI and click **OK**.

5. Select the NI AKM motor you are using from the **Preset Motor** list.



**Note** This VI also allows you to manually enter motor values for autophasing with a third-party motor.

6. Navigate to the **Run** tab and click the **Run** button to start the autophasing routine.
7. After the autophasing routine completes successfully, save the information to the file specified in the **Output File** section of the **Run** tab.
8. Connect the load to the motor.
9. Run the 2 - Tune Velocity VI, load the configuration data saved in step 7, and follow the instructions to tune the velocity loop. Refer to the *Tips and Troubleshooting* section for tuning tips.



**Note** The default current gains for the Velocity FOC example are preconfigured for the NI AKM motors.

10. Run the 3 - Velocity Run VI, load the configuration data saved in step 7, and enter the velocity loop gains found in step 9.
11. Select different velocities to test the system with the load attached.

## Tips and Troubleshooting

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### I/O Nodes Are Broken or Unavailable

Verify the commutation mode, which controls the available I/O nodes and properties for the NI 9502. If any I/O nodes from the unselected mode are present on the block diagram the nodes are broken and the VI does not compile. Complete the following steps to change the commutation mode:

1. Right-click the NI 9502 module item in the **Project Explorer** window and select **Properties** to open the **C Series Module Properties** dialog box.
2. Change the **Commutation Mode** to the required mode for your application.
3. (Optional) Remove the unavailable I/O nodes from under the NI 9502 item the **Project Explorer** window by selecting them and pressing <Delete>.

## Motor Responds Poorly

The NI 9502 example programs are configured with basic gains that may not work well for your system. This section contains some tuning best practices, but does not cover all aspects of tuning a system from scratch.



**Note** Go to [ni.com/info](http://ni.com/info) and enter `MotorTuning` for more information about tuning principles.

### Tuning Using the Trapezoidal Commutation Example

The 9502 `Trapezoidal Commutation` example VI allows you to adjust the current and velocity gains during execution to observe the effect of different gains on the system. The following steps will help you get started with tuning your system.

1. Connect a load to the motor.
2. Set the **integral gain** in the **velocity gains** section to 0.
3. Set the **proportional gain** in the **velocity gains** section to a low number, and slowly increase the value until the velocity returned begins to oscillate around the velocity setpoint.

The proportional gain ( $K_p$ ) determines the contribution of restoring force that is directly proportional to the position error. This restoring force functions in much the same way as a spring in a mechanical system. A system with too small a value of  $K_p$  is unable to hold position and is very soft. Increasing  $K_p$  stiffens the axis and improves its disturbance torque rejection. However, too large a value of  $K_p$  often results in instability.

4. Keeping the proportional gain value set at the value determined in the previous step, set the **integral gain** to a low number, and slowly increase until the velocity returned is the same as the velocity setpoint, with little oscillation.

The integral gain ( $K_i$ ) determines the contribution of restoring force that increases with time, ensuring that the static position error in the servo loop is forced to zero. This restoring force works against constant torque loads to help achieve zero position error when the axis is stopped.

In applications with small static torque loads, this value can be left at its default value of zero (0). For systems having high static torque loads, this value should be tuned to minimize position error when the axis is stopped.

Although non-zero values of  $K_i$  cause reduced static position error, they tend to cause increased position error during acceleration and deceleration. This effect can be mitigated through the use of the Integration Limit parameter. Too high a value of  $K_i$  often results in servo loop instability.

5. If necessary, tune the current loop using the same tuning principles as for the velocity loop.

## Tuning Using the Field Oriented Control Commutation Example

The `Velocity FOC` example project provides a tuning VI with a step response that spins the motor at low velocity and high velocity for the specified number of samples to evaluate the step response of the system. The following steps will help you get started with tuning your system.



**Note** The default current gains for the `Velocity FOC` example are preconfigured for the NI AKM motors.

1. Run the 2 - Tune Velocity VI.
2. Load the file obtained from executing the 1 - AutoPhasing VI.
3. Connect a load to the motor.
4. Set **Ki** to 0.
5. Set the **Kp** to a low number, and click the **Step** button.
6. Observe the step response and slowly increase the value of **Kp** until the step response begins to oscillate around the velocity setpoint.

The proportional gain (**Kp**) determines the contribution of restoring force that is directly proportional to the position error. This restoring force functions in much the same way as a spring in a mechanical system. A system with too small a value of **Kp** is unable to hold position and is very soft. Increasing **Kp** stiffens the axis and improves its disturbance torque rejection. However, too large a value of **Kp** often results in instability.

7. Keeping the proportional gain value set at the value determined in the previous step, set **Ki** to a low number, and slowly increase until the velocity returned is the same as the velocity setpoint, with little oscillation.

The integral gain (**Ki**) determines the contribution of restoring force that increases with time, ensuring that the static position error in the servo loop is forced to zero. This restoring force works against constant torque loads to help achieve zero position error when the axis is stopped.

In applications with small static torque loads, this value can be left at its default value of zero (0). For systems having high static torque loads, this value should be tuned to minimize position error when the axis is stopped.

Although non-zero values of **Ki** cause reduced static position error, they tend to cause increased position error during acceleration and deceleration. This effect can be mitigated through the use of the Integration Limit parameter. Too high a value of **Ki** often results in servo loop instability.

8. If necessary, tune the current loop using the same tuning principles as for the velocity loop.

## NI AKM Motor Specifications

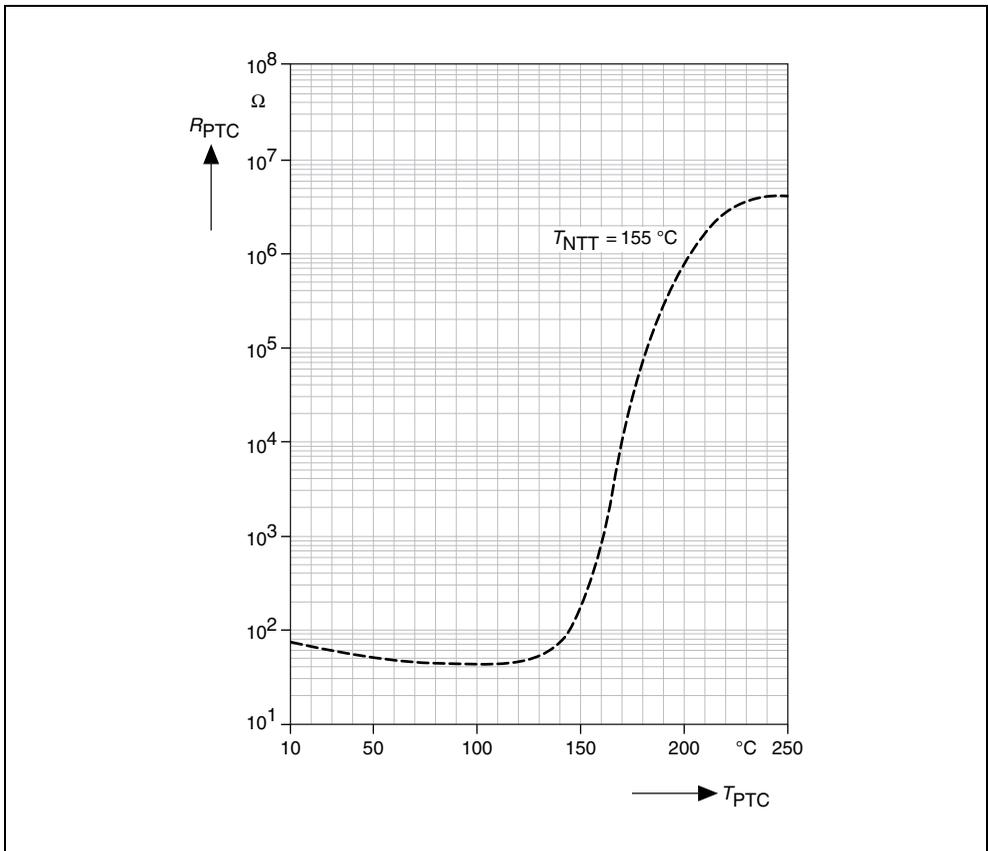
The NI AKM motors contain labels listing specifications for the motors. However, these numbers may be incorrect. The following figure lists the correct specifications for each motor.

<p>Model: AKM11F-ANMN2-00</p> <p>Ics           4   A / 2.8   ARMS Ipk           8   A / 5.6   ARMS Tcs        0.128   Nm Vs           24   VDC           IP54 Nrtd       4057   RPM Prtd       0.054   kW Rm         1.80   <math>\Omega</math> (L-L) @ 25 °C CLASS F            AMBIENT 40 °C</p>	<p>Model: AKM11E-ANMN2-00</p> <p>Ics           4   A / 2.8   ARMS Ipk           8   A / 5.6   ARMS Tcs        0.180   Nm Vs           24   VDC           IP54 Nrtd       2002   RPM Prtd       0.038   kW Rm         3.11   <math>\Omega</math> (L-L) @ 25 °C CLASS F            AMBIENT 40 °C</p>
<p>Model: AKM21I-ANMN2-02</p> <p>Ics           4   A / 2.8   ARMS Ipk           8   A / 5.6   ARMS Tcs        0.197   Nm Vs           24   VDC           IP54 Nrtd       3270   RPM Prtd       0.067   kW Rm         0.80   <math>\Omega</math> (L-L) @ 25 °C CLASS F            AMBIENT 40 °C</p>	<p>Model: AKM21G-ANMN2-00</p> <p>Ics           4   A / 2.8   ARMS Ipk           8   A / 5.6   ARMS Tcs        0.29   Nm Vs           24   VDC           IP54 Nrtd       1958   RPM Prtd       0.059   kW Rm         1.44   <math>\Omega</math> (L-L) @ 25 °C CLASS F            AMBIENT 40 °C</p>
<p>Model: AKM21F-ANMN2-00</p> <p>Ics           4   A / 2.8   ARMS Ipk           8   A / 5.6   ARMS Tcs        0.35   Nm Vs           24   VDC           IP54 Nrtd       1300   RPM Prtd       0.048   kW Rm         2.29   <math>\Omega</math> (L-L) @ 25 °C CLASS F            AMBIENT 40 °C</p>	<p>Model: AKM21E-ANMN2-00</p> <p>Ics           4   A / 2.8   ARMS Ipk           8   A / 5.6   ARMS Tcs        0.45   Nm Vs           24   VDC           IP54 Nrtd       721   RPM Prtd       0.034   kW Rm         3.42   <math>\Omega</math> (L-L) @ 25 °C CLASS F            AMBIENT 40 °C</p>

Figure 12. NI AKM Motor Specifications

## NI AKM Motor Thermal Sensor PTC Resistance Versus Temperature Curve

The following figure shows the NI AKM motor thermal sensor PTC (positive temperature coefficient) resistance versus temperature response.



**Figure 13.** NI AKM Motor Thermal Sensor Resistance Versus Temperature Curve

## Related Documentation

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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](http://ni.com/manuals).

- *NI 9502 Operating Instructions and Specifications*—Use this document to learn additional information about the NI 9502 including detailed specifications and important safety information.
- Operating instructions for the real-time controller.
- *LabVIEW NI SoftMotion Module Help*—Use this help file to learn about using the NI SoftMotion Module in LabVIEW including information about the Motor Control VIs and using the NI SoftMotion Module with the LabVIEW Project. To access this help file from LabVIEW, select **Help»LabVIEW Help**, then expand the *LabVIEW NI SoftMotion Module* book on the **Contents** tab.

## Worldwide Support and Services

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