

## ADA4571 End of Shaft Evaluation Board

### FEATURES

- USB 2.0 interface
- Jumper for temperature compensation mode enable
- Jumper for power down mode enable
- Measurement test points and coaxial connectors

### EVALUATION KIT CONTENTS

- ADA4571 magnetic stimulus:
  - Dipole magnet
  - Brushed or brushless dc motor with integrated control electronics
- Evaluation software CD-ROM (Windows® 7 32-bit and 64-bit compatible GUI)

### ADDITIONAL EQUIPMENT NEEDED

- Customer supplied 6 V to 12 V bench supply
- SDP interface board
- USB cable (supplied with SDP interface board)

### GENERAL DESCRIPTION

The end of shaft evaluation system is composed of a Windows LabVIEW® GUI software, an ADA4571 motherboard, a magnetic stimulus mounted on top of a brushless dc motor, a daughter board with ADA4571 in its SOIC package, and a USB interface and controller board, the SDP-S.

The motherboard features an on-board 5 V regulator, a 2-channel simultaneous sampling ADC and jumpers for enabling the temperature compensation and power-down modes within the ADA4571. The motherboard also features test points and unpopulated coaxial connectors for the three outputs of the device.

The daughter board features the ADA4571 mounted above the magnetic stimulus as well as test points for the three outputs of the device.

The SDP board is used to control the ADC on the motherboard and interface with the GUI.

### EVALUATION BOARD CONNECTION DIAGRAM

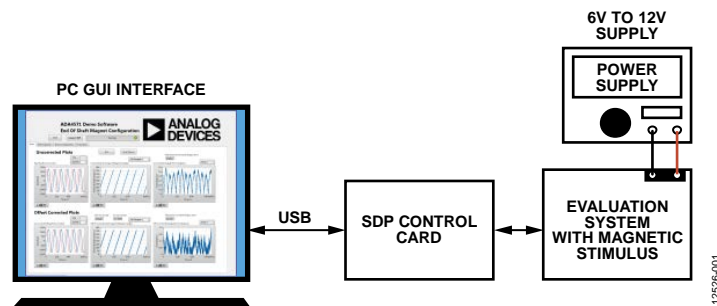


Figure 1. ADA4571 End of Shaft Evaluation System

## TABLE OF CONTENTS

|   |   |  |    |
|---|---|--|----|
| Features .....                            | 1 | Evaluation Board Hardware.....               | 4  |
| Evaluation Kit Contents.....              | 1 | Jumper Configuration .....                   | 4  |
| Additional Equipment Needed.....          | 1 | DUT Outputs .....                            | 4  |
| General Description .....                 | 1 | How to Use the Software .....                | 5  |
| Evaluation Board Connection Diagram ..... | 1 | Starting Up the Evaluation GUI.....          | 5  |
| Revision History .....                    | 2 | Overview of the Main GUI Window .....        | 6  |
| Getting Started .....                     | 3 | Evaluation Board Schematics and Artwork..... | 12 |
| Software Installation Procedures.....     | 3 | Related Links.....                           | 13 |

## REVISION HISTORY

10/14—Revision 0: Initial Version

# GETTING STARTED

## SOFTWARE INSTALLATION PROCEDURES

There are two pieces of software to install: the Windows GUI and the SDP drivers.

### Windows GUI Installation

Use the following steps to install the GUI.

1. Before connecting the USB cable or powering the board, insert the ADA4571-EBZ setup CD and from the installer directory, run the installer **Setup.exe**.
2. When the **Destination Directory** screen appears (see Figure 2), click **Next**. Optionally, you may change the destination folder by clicking **Browse**, selecting a different destination folder, and clicking **Next**.

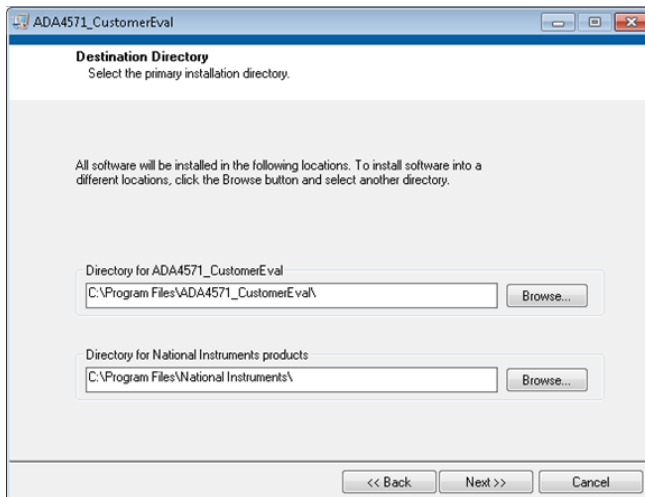


Figure 2. Choose Destination Location

3. When the **Start Installation** window appears click **Next** to continue with the installation (see Figure 3).

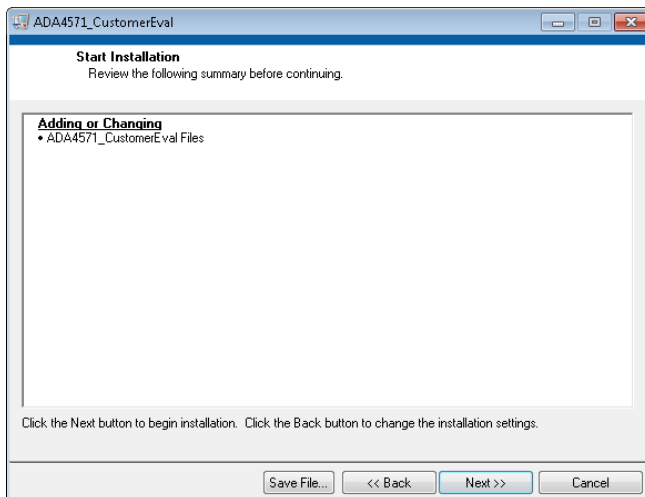


Figure 3. Review Installation

4. Click **Next** to complete installation of the Windows LabVIEW GUI.

### SDP Installation

Next, install the Analog Devices, Inc., SDP driver. This driver allows the SDP control board to interface with the LabVIEW GUI.

1. When the SDP drivers setup wizard appears, click **Next** (see Figure 4).



Figure 4. SDP Driver Installation

2. When the **Choose Install Location** screen appears (see Figure 5), click **Next**. Optionally, you may change the destination folder by clicking **Browse**, selecting a different destination folder, and clicking **Next**.

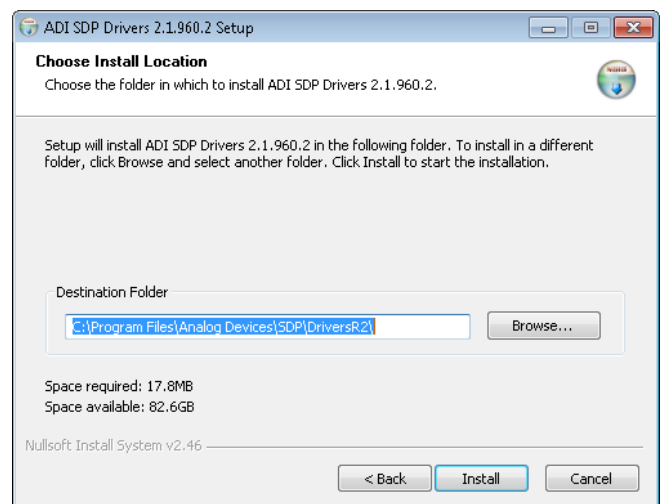


Figure 5. Choose Install Location

3. Click **Finish** to complete the installation of the SDP drivers.
4. Connect the SDP control card to the motherboard and plug the SDP control card into the PC with the supplied USB cable. The computer now recognizes the SDP control board and the LabVIEW GUI may be opened to continue.

## EVALUATION BOARD HARDWARE

The [ADA4571](#) end of shaft demo evaluation system comprises of two boards ([ADA4571](#) motherboard and [ADA4571](#) daughter board) and a brushless dc motor.

The [ADA4571](#) evaluation system can be powered directly from the host PC USB or from an external bench supply. For maximum performance, it is recommended that an external bench power supply be used.

When supplied directly from the host PC USB, the applied voltage is approximately 5 V. However, due to errors in the regulated USB voltage this value will vary and introduce extra errors into the system.

To power the motherboard by an external bench supply, apply 6 V to 12 V to P7, the red terminal. When supplied by an external bench supply, the applied voltage is regulated to 5 V on the motherboard resulting in a better performance than powering directly from the host PC USB. If the bench supply features current-limiting, it is recommended to set the current limit to 100 mA, as a precaution.

To power the motor by an external bench supply, 3 V to 9 V can be applied to P6, the blue terminal. The ground is shared with the ground of the motherboard. The speed of the brushless dc motor providing the magnetic stimulus to the [ADA4571](#) is proportional to the voltage applied at this terminal. The attached motor provides a more constant rotational speed at lower applied voltages. Due to the LabVIEW GUI measuring the linearity of the outputs from the device, a more constant rotational speed is necessary to see the true performance of the [ADA4571](#). See the Angular Error (Linearity) section for more information on motor performance.

## JUMPER CONFIGURATION

Refer to the [ADA4571](#) motherboard schematic (see Figure 15) or the configuration panel to understand the purpose of each jumper.

Configure the motherboard default jumper as follows (see Figure 15):

- Install the P9 and P10 jumpers in the standard position to connect the motor and board power to the external supply terminals.
- Install the P3 jumper connecting GC to VDD. This enables the gain control mode of the part. When P3 connects GC to GND, gain control mode is disabled.
- Install the P2 jumper connecting PD to GND. This disables the power-down mode of the part. When P2 connects PD to VDD, power-down mode is enabled and the [ADA4571](#) outputs are put into a high impedance state.

## DUT OUTPUTS

The outputs of the [ADA4571](#) may be monitored at the test points located on the daughter board or the motherboard. The VSIN, VCOS, and VTEMP pins are all accessible on both of the boards.

## HOW TO USE THE SOFTWARE

### STARTING UP THE EVALUATION GUI

For maximum performance when the evaluation board is first powered up, control both the motor and the board using an external bench power supply. The jumper settings for P9 and P10 should be set for **Ext Motor** and **Ext +5V** as indicated on the board.

Plug the positive supply for the board into the red terminal, P7, on the motherboard. This terminal requires 6 V to 12 V which is then regulated to 5 V on the motherboard using the on-board [ADP3336](#). This supply powers both the on-board ADC, [AD7866](#), as well as the daughter board containing the [ADA4571](#).

Plug the positive supply for the motor into the blue terminal, P6, on the motherboard. Due to mechanical nonlinearities of the dc motor, such as cogging during coil commutating, extra errors are introduced to the system at higher rotational velocities. For best performance, apply 3 V to **Ext Motor** terminal. If the motor supplied is a brushless dc motor; 3 V results in rotational speeds of approximately 2,000 RPM. Speeds up to 10,000 RPM are possible with a supply voltage of 12 V applied to this terminal. If the motor supplied is a brushed dc motor, 3 V results in rotational speeds of approximately 200 RPM.

The nonidealities of the motor result in a higher reported nonlinearity of the device. This is an artifact of the motor and not the [ADA4571](#). With an ideal magnetic stimulus, the [ADA4571](#) has the same angular error performance regardless of rotational velocity.

**OVERVIEW OF THE MAIN GUI WINDOW**

Figure 6 shows the main GUI window, as it appears, after launching the GUI.

When the program is first launched the SDP controller board must be recognized by the GUI before proceeding. Pressing **Connect SDP** reads the EEPROM ID of the motherboard to ensure the correct program is being used. If the SDP controller board is not connected or if the drivers are not installed correctly an error message will be shown. Ensure that the drivers are installed correctly if this occurs.

After the SDP control board is properly connected and the program recognizes the motherboard, the **Instructions** tab appears. Click the **Read** tab to begin.

Initially all of the figures will be blank. To begin press **Run** (see Figure 6). The various output graphs are explained in detail in the following sections.

There are two different categories of output waveforms as indicated by the GUI. The waveforms on the top of each tab, indicated as **Uncorrected Plots**, are without any post processing to correct for output offset before calculations are done on the raw data. In the case of the bottom waveforms, indicated as **Offset Corrected Plots**, the offset of each channel is subtracted from the raw data before completing any further calculations. These differences are discussed in further detail for each waveform in the Raw Waveforms section.

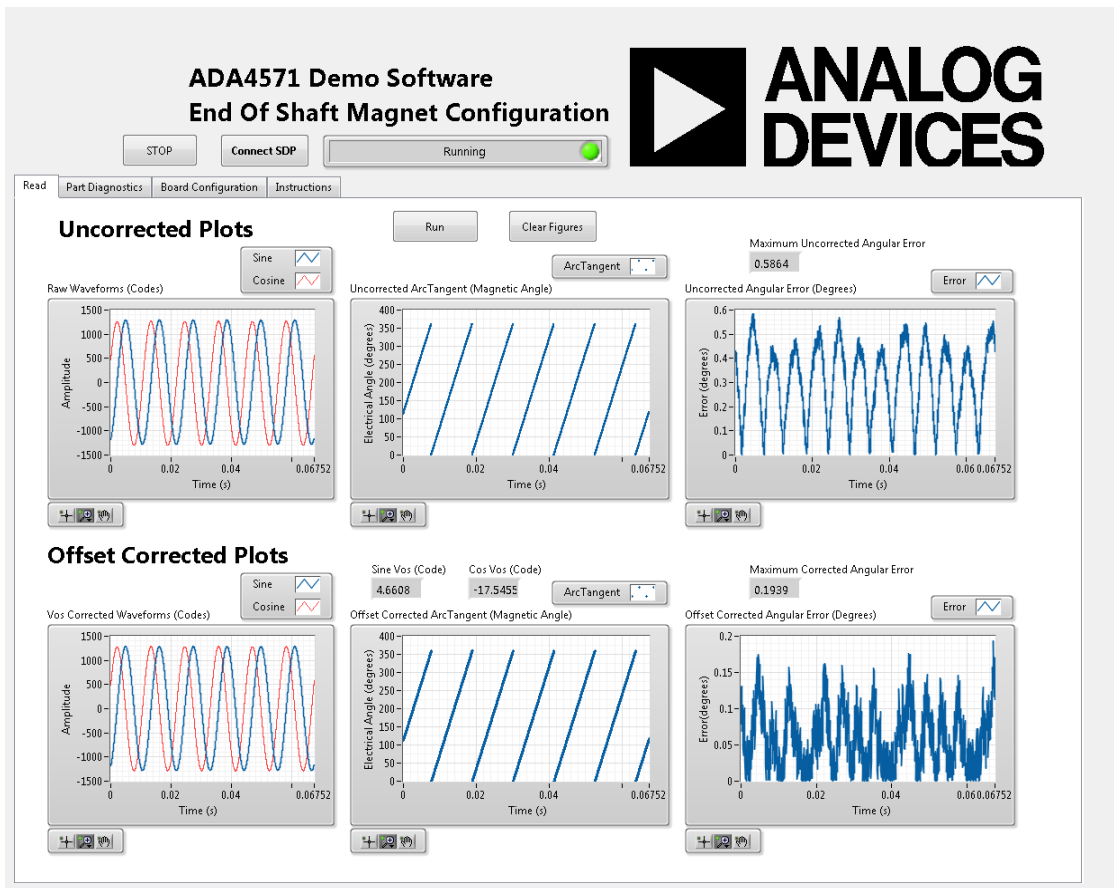


Figure 6. ADA4571 Main Window

**Raw Waveforms**

The first figure is labeled **Raw Waveforms** (see Figure 11). This figure shows the sampled ADC raw data as the motor is spinning. The amplitude is shown in 12-bit code. The dual channel AD7866 simultaneously samples the sine and cosine channels at 100,000 samples per second. The internal 2.5 V reference of the AD7866 has been subtracted in hardware as the readout of the ADC is in twos complement. Therefore, the two signals are centered around zero in the raw waveform plot. The magnetic stimulus is sampled over many rotations and then cropped to three mechanical revolutions or six electrical revolutions. It is important that these two channels are simultaneously sampled or extra errors will be introduced from the phase delay between the sampling of the individual channels.

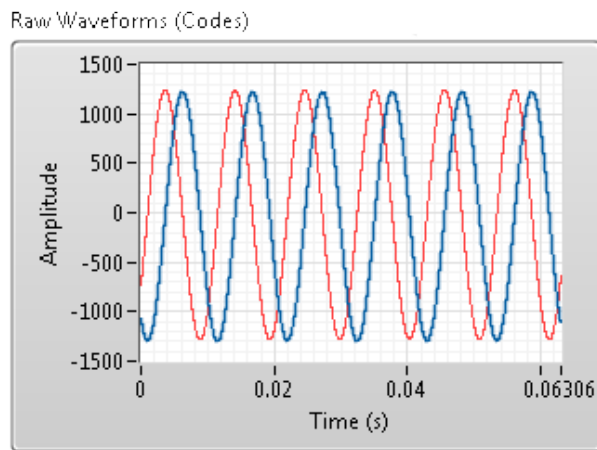


Figure 7. Raw Sine and Cosine Waveform

There are two different figures shown depicting these sine and cosine waveforms. The uncorrected figure has not had any post processing applied and shows the absolute raw data from the sensor. For the offset corrected figure, the full three mechanical revolutions are averaged independently for both the sine and cosine channels giving the offset for the channel. These offset values are then subtracted from their respective channel to give the end waveform centered perfectly about zero.

Note that when powering the board through a USB instead of by an external power supply there will be some variation in the supply voltage of the ADA4571. Due to the readout of the AD7866 being in twos complement form with respect to the internal 2.5 V reference, the offset of these waveforms will be higher than the inherent offset of the ADA4571.

**ArcTangent2 (Magnetic Angle)**

The second set of figures are labeled **ArcTangent (Magnetic Angle)** (see Figure 8). These figures depict the calculated electrical angle of the ADA4571. This calculation is performed by the following equation:

$$Angle = ArcTangent2(V_{SIN}/V_{COS})$$

Because the two AMR bridges are deposited at a 45° relative angle, the sine and cosine outputs are 90° out of phase. This constant 90° phase difference results in the calculated angle over a constant rotary speed as a straight line.

Normally the ArcTangent function will have a range of (-90° to +90°). However, if quadrant information is kept and corrected for after the calculation the second and third quadrant can be distinguished from the first and fourth. The function ArcTangent2 has this quadrant information and therefore the range is extended to (-180° to +180°). The program then zeros this waveform and therefore shows the angle between (0° and 360°).

Uncorrected ArcTangent (Magnetic Angle)

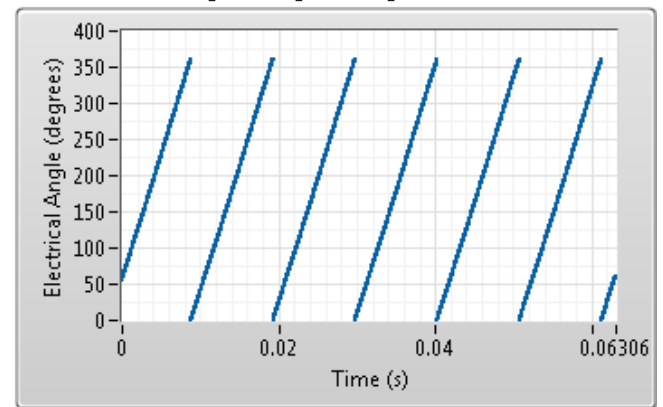


Figure 8. ArcTangent Calculation Plot

The electrical angle period will repeat for every sinusoidal period of the sine and cosine outputs from the ADA4571. Just like the raw waveform data, three mechanical revolutions or six electrical revolutions are used for calculations. This results in six periods of angle information shown.

The **Uncorrected ArcTangent (Magnetic Angle)** plot will have a slight bowed shape to it due to the sensor offset in the raw waveform. The **Offset Corrected ArcTangent (Magnetic Angle)** plot shows the angle information after the offset is nulled from each individual channel. This offset correction to the raw waveforms before the ArcTangent calculation results in a much more linear output plot.

**Angular Error (Linearity)**

There are two different motors that may be supplied with your demo board: a brushless dc motor or a brushed dc motor. The brushed dc motor will introduce extra errors into the system due to cogging of the motor during rotation. To fully evaluate the performance of the sensor, an externally applied magnetic stimulus that has a smoother rotational velocity should be used with the supplied LabVIEW GUI.

The third set of figures are labeled **Angular Error (Degrees)** (see Figure 6). This figure shows the linearity of the ArcTangent plot discussed in the Arc Tangent2 (Magnetic Angle) section. There is no encoder attached to the magnetic stimulus on the board and therefore the program cannot compare the calculated angle to the actual position of the magnet. Therefore, this plot is calculating the linearity of both the ADA4571 and the brushless dc motor providing the magnetic stimulus.

Due to the nonidealities of the brushless dc motor providing the magnetic stimulus, the reported angular error will always be higher than the actual error of the ADA4571. The motor provides a more constant rate of speed at lower rotational velocities and therefore the reported linearity will be lower at slower speeds. These extra errors are not indicative of the bandwidth of the ADA4571 as the part can handle motor rotational speeds as high as 50,000 RPM.

Figure 9 shows the **Uncorrected Angular Error (Degrees)** plot. When powered by the host PC USB supply this waveform reports higher error than when powered by an external supply. This increased error is because the internal 2.5 V reference is subtracted in hardware from each ADC channel resulting in a higher inherent offset of the sensor if the supply voltage is not exactly 5 V. When powered by an external power source the ADA4571 supply is regulated to 5 V and, therefore, the ADC introduces no extra offset or errors to the system.

Uncorrected Angular Error (Degrees)

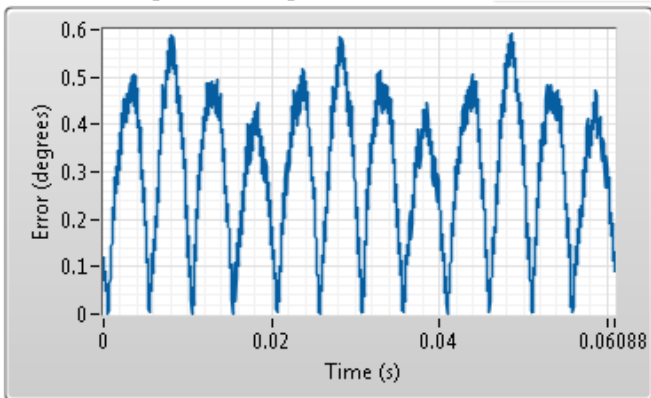


Figure 9. Uncorrected Linearity Error Plot

Figure 10 shows the **Offset Corrected Error (Degrees)** plot. Large spikes appear in this plot due to the nonidealities of the magnetic stimulus. When the motor commutes, there is a kick from the excitation coils resulting in a higher reported linearity error at these points. The sensor measures the position of the magnetic stimulus and so these kicks during commuting will show up as an error from an ideal linear plot. This nonideality from the magnetic stimulus is more prevalent at higher speeds but is not a result of the sensor. The included motor is very smooth at lower speeds and, therefore, these spikes will not appear in the error plot.

Offset Corrected Angular Error (Degrees)

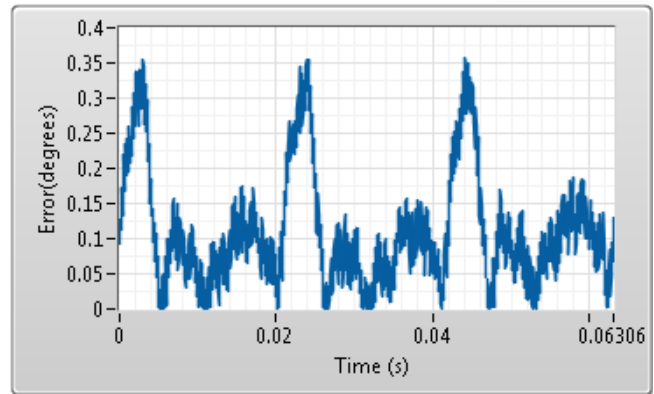


Figure 10. Offset Corrected Linearity Error Plot



**Fourier Transform**

The fourth set of figures are labeled **Fourier Transform**. These figures show the spectral analysis of the two independent output signals. The fundamental frequency corresponds to the motor speed. Harmonics from the sensor are also depicted in this plot. The y-axis of this plot shows the magnitude of the frequency components. This value is the root mean squared (RMS), magnitude in 12-bit code of that specific frequency.

The x-axis is shown in hertz. The fundamental frequency shown depicts the electrical frequency. This will be two times the mechanical frequency. An example calculation for motor speed in RPM from a 100 Hz fundamental electrical frequency is shown as,

$$100 \text{ Hz} \times (1 \text{ electrical cycle}) / (2 \text{ mechanical cycles}) \times (60 \text{ seconds}) / (1 \text{ minute}) = 3,000 \text{ RPM}$$

Uncorrected Fourier Transform

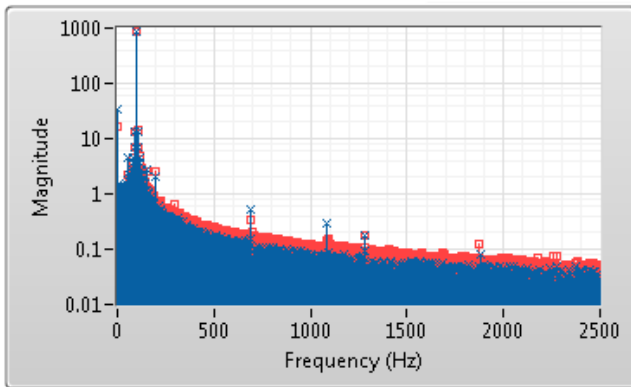


Figure 11. Spectral Output for Sine and Cosine Channels

Due to the layout of the AMR bridge odd harmonics which are usually present in the output of sensors, such as third and fifth, are suppressed.

Spectral analysis of the sensor can be useful for debugging purposes. Even harmonics appear in this plot when there is gross misalignment between the center of the AMR sensor and the magnetic stimulus.

**Radius Plot**

The fifth set of figures are labeled **Radius Check** (see Figure 12). This figure plots the sine channel on the y-axis and the cosine channel on the x-axis. Both axes are shown in 12-bit codes. Due to the sinusoidal nature of the two channels and the 90° phase delay between the sine and cosine channels the plot is circular in nature.

The radius of this plot is constant throughout the entire rotation of the magnetic stimulus. The exact radius of this plot is inversely proportional to the temperature of the ADA4571. At lower device temperatures, the radius increases while at higher device temperatures the radius decreases; when held at a constant temperature the radius will also be constant.

Offset Corrected Radius Check

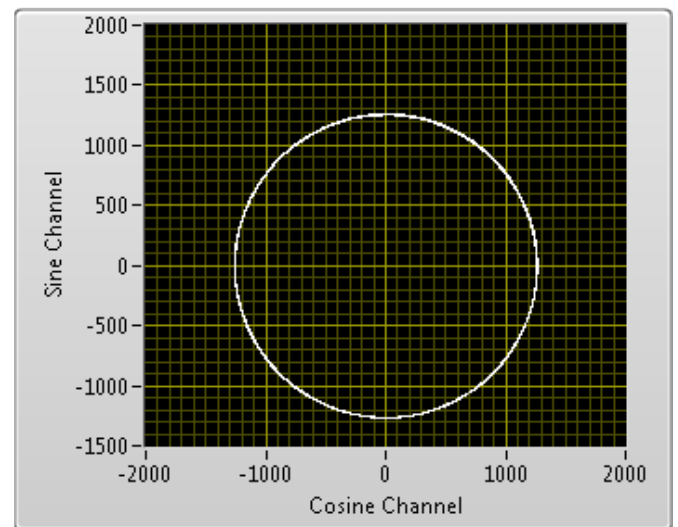


Figure 12. Radius Plot of Output Waveforms

The temperature dependent variation in output amplitude of the AMR bridge is due to the reduced change in resistance of the AMR film at higher temperatures. The ADA4571 provides an internal regulated voltage to the AMR bridge supply. By enabling the temperature compensation mode of the ADA4571, this regulated supply voltage varies with temperature. At higher temperatures, the regulator provides a higher bridge supply voltage, thus increasing the output amplitude of the device. Using this mode, the output amplitude and, therefore, radius in this plot will be more consistent over the wide temperature range of -40°C to 150°C.

This mode is enabled by default by an internal pull-up resistor on the GC pin. Moving Jumper P3 to the correct position as outlined in Figure 14 and Figure 15 will disable the temperature compensation mode of the device. There is an internal temperature sensor on the ADA4571 that is used to adjust the bridge supply voltage. The internal temperature sensor voltage is available to the end user and can be monitored on the daughter board or the motherboard as outlined in Figure 14 and Figure 15.

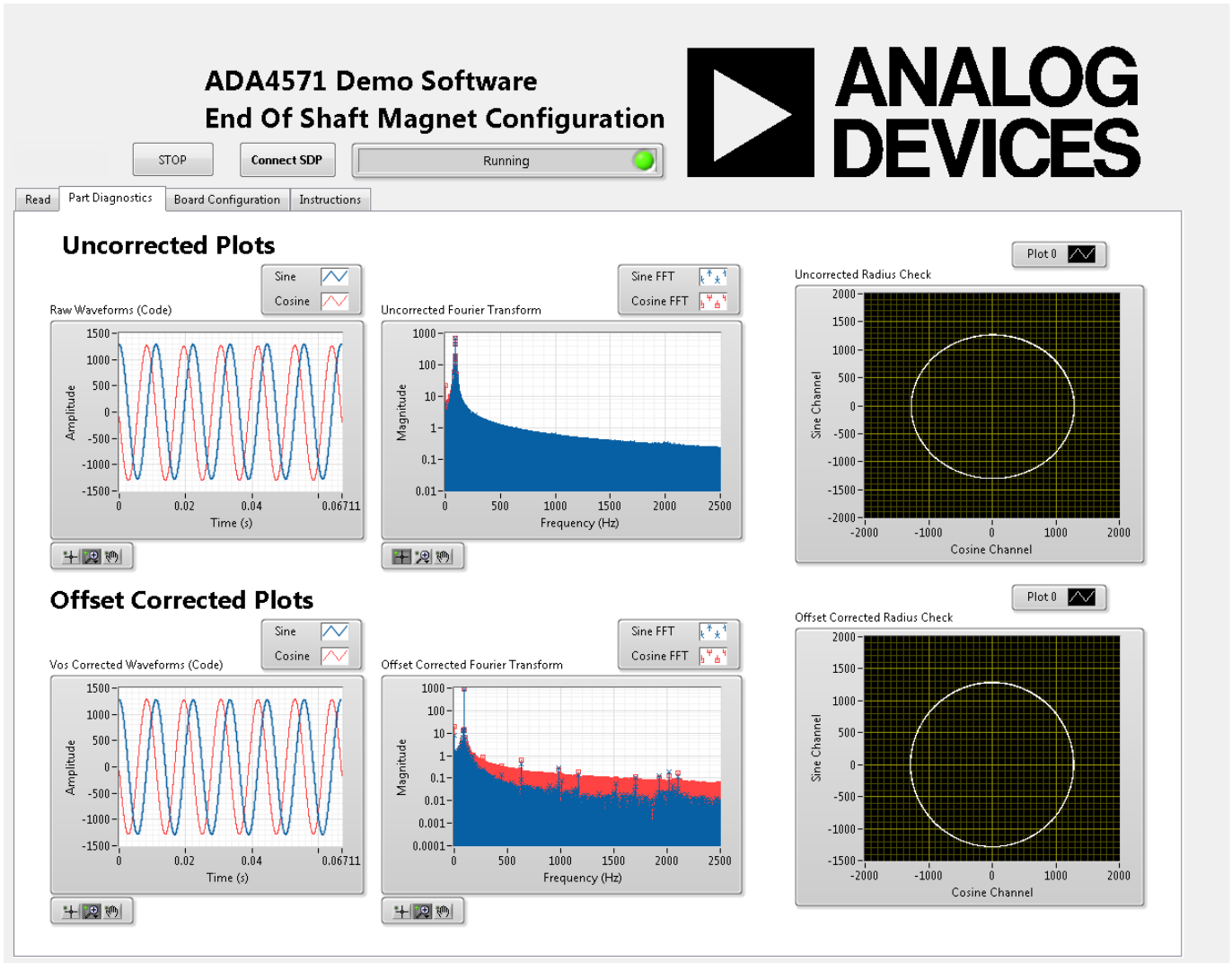


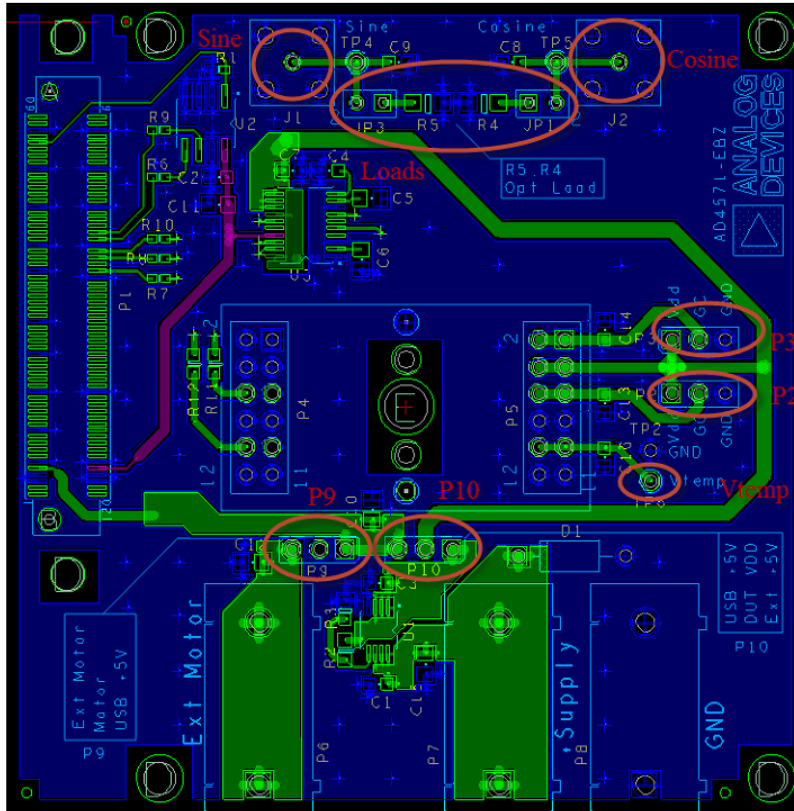
Figure 13. ADA4571 Part Diagnostics Tab

**ADA4571 Demo Software**  
**End Of Shaft Magnet Configuration**



STOP    Connect SDP    SDP Board Ready ●

Read    Part Diagnostics    Board Configuration    Instructions



**DUT Outputs (Sine and Cosine)**

The raw analog output signals from the ADA4571 are available for probing on the board. The pinned out signals include both the Sine and Cosine channels as well as the on chip coarse temperature sensor. Optional loads may be installed in footprints R4 and R5. These resistor loads should be matched or extra errors will result.

**Motor Power Supply (P9)**

The attached motor can be powered by either an external power supply or directly by the USB +5V supply. Externally applying the motor power to P6 will allow the user to vary the motor speed by varying the voltage. This is recommended to avoid switching noise coupling into the rest of the system. The motor is rated at +6V, but can be supplied with +12V to increase speed while reducing the lifetime.

**Dut Power Supply (P10)**

The board should be powered by an external supply of +7V. However, the board can either be powered by an external power supply regulated on board to +5V or directly by the USB +5V supply. The on board +5V regulation circuit will be more accurate than USB and can be slightly altered if other supply voltages are desired.

**Power-down mode (P2)**

The Power-down mode can be activated by switching pin PD to VDD. Within this mode, the device shutdown and its output pins are set to high impedance to avoid current consumption across the load resistors. An internal pull down resistor ensures that the device remains active if PD pin is left floating.

**Gain Control mode (P3)**

The GC enable mode can be activated by switching pin GC to VDD. Within this mode the MR bridge sensor amplitude outputs are compensated for temperature degradation. If the Gain Control pin is left floating then a weak pull up resistor ensures that the Gain Control mode is enabled as a default condition.

Figure 14. ADA4571 Board Configuration Tab



**RELATED LINKS**

| Resource                | Description   |
|-------------------------|---|
| <a href="#">ADA4571</a> | Product Page, ADA4571 Integrated AMR Angle Sensor and Signal Conditioner                              |
| <a href="#">ADP3336</a> | Product Page, High Accuracy Ultralow I <sub>o</sub> , 500 mA anyCAP® Adjustable Low Dropout Regulator |
| <a href="#">AD7866</a>  | Product Page, Dual 1 MSPS, 12-Bit, 2-Channel SAR ADC with Serial Interface                            |



**ESD Caution**

**ESD (electrostatic discharge) sensitive device.** Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

**Legal Terms and Conditions**

By using the evaluation board discussed herein (together with any tools, components documentation or support materials, the "Evaluation Board"), you are agreeing to be bound by the terms and conditions set forth below ("Agreement") unless you have purchased the Evaluation Board, in which case the Analog Devices Standard Terms and Conditions of Sale shall govern. Do not use the Evaluation Board until you have read and agreed to the Agreement. Your use of the Evaluation Board shall signify your acceptance of the Agreement. This Agreement is made by and between you ("Customer") and Analog Devices, Inc. ("ADI"), with its principal place of business at One Technology Way, Norwood, MA 02062, USA. Subject to the terms and conditions of the Agreement, ADI hereby grants to Customer a free, limited, personal, temporary, non-exclusive, non-sublicensable, non-transferable license to use the Evaluation Board FOR EVALUATION PURPOSES ONLY. Customer understands and agrees that the Evaluation Board is provided for the sole and exclusive purpose referenced above, and agrees not to use the Evaluation Board for any other purpose. Furthermore, the license granted is expressly made subject to the following additional limitations: Customer shall not (i) rent, lease, display, sell, transfer, assign, sublicense, or distribute the Evaluation Board; and (ii) permit any Third Party to access the Evaluation Board. As used herein, the term "Third Party" includes any entity other than ADI, Customer, their employees, affiliates and in-house consultants. The Evaluation Board is NOT sold to Customer; all rights not expressly granted herein, including ownership of the Evaluation Board, are reserved by ADI. CONFIDENTIALITY. This Agreement and the Evaluation Board shall all be considered the confidential and proprietary information of ADI. Customer may not disclose or transfer any portion of the Evaluation Board to any other party for any reason. Upon discontinuation of use of the Evaluation Board or termination of this Agreement, Customer agrees to promptly return the Evaluation Board to ADI. ADDITIONAL RESTRICTIONS. Customer may not disassemble, decompile or reverse engineer chips on the Evaluation Board. Customer shall inform ADI of any occurred damages or any modifications or alterations it makes to the Evaluation Board, including but not limited to soldering or any other activity that affects the material content of the Evaluation Board. Modifications to the Evaluation Board must comply with applicable law, including but not limited to the RoHS Directive. TERMINATION. ADI may terminate this Agreement at any time upon giving written notice to Customer. Customer agrees to return to ADI the Evaluation Board at that time. LIMITATION OF LIABILITY. THE EVALUATION BOARD PROVIDED HEREUNDER IS PROVIDED "AS IS" AND ADI MAKES NO WARRANTIES OR REPRESENTATIONS OF ANY KIND WITH RESPECT TO IT. ADI SPECIFICALLY DISCLAIMS ANY REPRESENTATIONS, ENDORSEMENTS, GUARANTEES, OR WARRANTIES, EXPRESS OR IMPLIED, RELATED TO THE EVALUATION BOARD INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANTABILITY, TITLE, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS. IN NO EVENT WILL ADI AND ITS LICENSORS BE LIABLE FOR ANY INCIDENTAL, SPECIAL, INDIRECT, OR CONSEQUENTIAL DAMAGES RESULTING FROM CUSTOMER'S POSSESSION OR USE OF THE EVALUATION BOARD, INCLUDING BUT NOT LIMITED TO LOST PROFITS, DELAY COSTS, LABOR COSTS OR LOSS OF GOODWILL. ADI'S TOTAL LIABILITY FROM ANY AND ALL CAUSES SHALL BE LIMITED TO THE AMOUNT OF ONE HUNDRED US DOLLARS (\$100,000). EXPORT. Customer agrees that it will not directly or indirectly export the Evaluation Board to another country, and that it will comply with all applicable United States federal laws and regulations relating to exports. GOVERNING LAW. This Agreement shall be governed by and construed in accordance with the substantive laws of the Commonwealth of Massachusetts (excluding conflict of law rules). Any legal action regarding this Agreement will be heard in the state or federal courts having jurisdiction in Suffolk County, Massachusetts, and Customer hereby submits to the personal jurisdiction and venue of such courts. The United Nations Convention on Contracts for the International Sale of Goods shall not apply to this Agreement and is expressly disclaimed.

©2014 Analog Devices, Inc. All rights reserved. Trademarks and registered trademarks are the property of their respective owners.  
UG12526-0-10/14(0)



www.analog.com