ADA4570 Diagnostic Information

INTRODUCTION

The ADA4570 is an anisotropic magnetoresistive (AMR) sensor with integrated signal conditioning amplifiers and analog-to-digital converter (ADC) drivers. The ADA4570 produces four analog outputs that indicate the angular position of the surrounding magnetic field combined to form a single sensing channel.

The ADA4570 consists of two die within one package, an AMR sensor, and a fixed gain instrumentation amplifier. The ADA4570 delivers clean and amplified differential cosine and sine output signals related to the angle of the rotating magnetic field. The output voltage range is ratiometric to the supply voltage. The on-chip temperature sensor is used to correct for sensor variation over temperature. See the ADA4570 data sheet for the functional block diagram and further details on the ADA4570.

The ADA4570 application note must be read in conjunction with the following documents:

- The ADA4570 data sheet
- The ADA4570 pin failure mode and effects analysis (contact Analog Devices, Inc., sales for additional information)
- (FMEA) The ADA4570 FMD Report, which is available under a nondisclosure agreement (NDA) from Analog Devices sales

Note that, it is assumed that the ADA4570 use conditions comply with the Analog Devices, Inc., recommendations in the ADA4570 data sheet.

SCOPE

The diagnostic information in this application note describes the available diagnostics at a system level, and how to use the ADA4570 to analyze and diagnose the angle sensor portion of the system. The diagnostic methods recommended in this application note can indicate a potential failure at points in the signal processing chain, including the ADA4570. System errors caused by a fault in the user ADC and/or incorrect application of the calibration can be detected with the diagnostic methods discussed in this application note.

The ADA4570 was developed with a standard automotive development flow. Information provided in this application note is for user reference only and does not guarantee any level of fault coverage at the system level. Fault coverage must be assessed by the user for their system implementation.

TARGET APPLICATIONS

The ADA4570 can be used in various applications including those that require an absolute position measurement (linear angle and linear), for example, brushless dc (BLDC) motor control and positioning, actuator control, contactless angular measurement, and magnetic angular position sensing. For recommended application diagrams, refer to the ADA4570 data sheet.

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REVISION HISTORY

8/2021 —Revision 0: Initial Version

INTERNAL DIAGNOSTIC FEATURES

This section outlines the diagnostic features internal to the ADA4570.

DIAGNOSTIC BANDS

The output levels of the ADA4570 were designed to be within the linear region shown in the diagnostic band figure shown in the ADA4570 data sheet during normal operation. Validate that the output levels are within the appropriate operating band. If any, or all, of the VSIN+, VSIN−, VCOS+, and VCOS− outputs are in the diagnostic bands, this result must be treated at the system level as an indication of a potential fault.

Some of the IC faults detectable from analysis of the diagnostic bands are shown in Table 1. The differential nature of the VSIN and VCOS signal outputs from the ADA4570 can lead to different diagnostic outcomes depending on whether single-ended or differential conversions are completed on these outputs.

BROKEN BOND WIRE DETECTION

The ADA4570 includes the ability to detect broken bond wires between the AMR sensor and the application specific IC (ASIC). When this circuitry detects that the signal nodes are outside the normal operating region, the device pulls the VSIN+, VSIN−, VCOS+, and VCOS− analog output pins to ground. Monitor the voltage level of the analog signals to verify that the output level does not fall within the short-circuit diagnostic band as shown in the diagnostic band figure in the ADA4570 data sheet. If the outputs fall within the diagnostic band, the user must take the appropriate action.

Table 1. ADA4570 Diagnostic Band Fault Detection Features

		Fault Indication	
Fault Description	**Output Conditions**	**Single-Ended Configuration**	**Differential Configuration**
Broken Bond Wire Between the Internal AMR Sensor and the ASIC	Broken bond wire detection activated, and VSIN+, VSIN−, VCOS+, and VCOS− pulled to ground	Diagnostic band (low) for VSIN+, VSIN−, VCOS+, and VCOS−	Diagnostic band (low) for VSIN+, VSIN−, and VCOS+, and VSIN and VCOS amplitudes to 0 V
Output Short to Ground	Shorted output pulled toward ground	Diagnostic band (low) for affected output	Possible radius check limit violation in full rotation
Output Short to VDD	Shorted output pulled toward VDD	Diagnostic band (high) for affected output	Possible radius check limit violation in full rotation

SYSTEM LEVEL DIAGNOSTIC CHECKS

This section outlines the possible diagnostic checks that can be implemented at a system level to validate the functional operation of the ADA4570. These checks may additionally cover aspects of the conversion and calibration of the outputs of the ADA4570 carried out within the system.

This application note discusses the following checks:

- Diagnostic band monitor
- Radius
- Channel offset
- Channel amplitude
- Amplitude synchronism
- Supply current
- VTEMP

DIAGNOSTIC BAND MONITOR CHECK

In the Broken Bond Wire Detection section, diagnostics for detecting a broken bond wire between the AMR and ASIC sensor are discussed. It is also possible to detect a broken bond wire from the ASIC to the pins of the device or a bad connection between the device pins and printed circuit board (PCB). The detection of a bad or broken pin connection to the PCB can be achieved by the utilization of pull-up and pull-down resistors to pull the node voltage levels into the diagnostic band shown in the diagnostic bands figure in the ADA4570 data sheet. It is recommended that a pull-down resistance of 200 kΩ is connected at the analog output pins to ensure that the output goes into a known state in the event of a failure of a bond wire or pin connection. Monitor these nodes to determine if the nodes are outside of the normal operating region and take the appropriate action.

RADIUS CHECK

The differential sine and cosine outputs from the ADA4570 can be used to calculate a radius of the circle at any angle of the applied magnetic field as shown in the radius values figure in the ADA4570 data sheet. VRAD is equal to the vector sum of VCOS and VSIN. Due to the constant phase difference of 90° between the differential VSIN (VSIN+ − VSIN−) and the differential VCOS (VCOS+ − VCOS−) measurements, VRAD is constant over an entire magnetic revolution for a constant temperature and supply. The radius varies with AMR sensor sensitivity, supply voltage, and temperature. These variations are detailed in the ADA4570 data sheet specifications around amplitude specification and sensor sensitivity.

During normal operation, VRAD is equal to

$$\sqrt{VSIN^2 + VCOS^2}$$

See the ADA4570 data sheet for the V_{AMP} valid range of VSIN and VCOS to determine the valid range of VRAD for the temperature that the system is operating at.

As shown in the radius values figure in the ADA4570 data sheet, the VRAD varies with operating temperature. Calibration of VSIN and VCOS at room temperature as an initial system action can be used to adjust for sensor output variation and, therefore, allow tighter limits to be applied to VRAD. Calibration across the expected operating temperature range can allow a further tightening of the limits.

Steps to implement a radius check include the following:

1. Measure VTEMP, VSIN, and VCOS
2. Apply the relevant calibration to VSIN/VCOS as described in the ADA4570 data sheet
3. Calculate the radius, VRAD, by using the previous equation.
4. Verify that VRAD falls within the expected range

The radius check can be a powerful method to diagnose faults for static and continuous rotary operation. The radius check is not a completely comprehensive test when used in a static application due to the phase mismatch between the radius error and the angular error.

A radius check showing a radius outside expected limits may be an indication of an offset error on the sine or cosine signal path, or a gain mismatch between the sine and cosine signal path. It is also possible that a supply out of range can lead to a radius that is out of specification.

The radius check can also be used as a secondary diagnostic check on the power supply level when VDD is not used as the ADC reference voltage, or as a check on the internal AMR bridge driver levels within the ADA4570.

CHANNEL OFFSET

An offset on one or both channels may lead to an unacceptable angular error. An offset on one or both channels may affect the radius check results by moving the center of the circle away from the origin. If the user determines that extra offset coverage is required in addition to that provided by the radius check, implement the following steps:

- Measure the offset over a mechanical period
- Compare limits with the ADA4570 data sheet

When the temperature of the system is varying slowly compared to the speed of rotation, monitor and compare the offsets of the output signals to the data sheet limits.

Also, compare individual offsets of VSIN and VCOS with previously recorded offsets because these values match closely, as specified in the ADA4570 data sheet.

SYSTEM LEVEL DIAGNOSTIC CHECKS

CHANNEL AMPLITUDE CHECK

The channel amplitude check covers similar potential failures to those covered by the radius check: a change in amplitude on one, or both, of the sine or cosine paths affects the radius. The user may decide that the radius check provides diagnostic coverage for all potential failures covered by the channel amplitude check and that both checks are unnecessary.

Take the following steps to implement the channel amplitude check:

1. Measure the peak-to-peak differential amplitudes (V_{AMP}) of VSIN and VCOS over a mechanical period.
2. Measure VTEMP.
3. Compare V_{AMP} to the ADA4570 data sheet limits with the VTEMP output comparison.

The V_{AMP} of the VSIN and VCOS channel depends on the temperature of the ADA4570. During continuous fast operation, where temperature is changing slowly compared to the frequency of the output signals, VTEMP can be used to calculate the operating temperature, and the expected level of V_{AMP} can be verified to ensure that the device is operating within the limits specified the ADA4570 data sheet. Figure 1 shows the typical variation in V_{AMP} vs. the ambient temperature.

Figure 2 shows the valid range for V_{AMP} of the VSIN and VCOS when compared to the VTEMP output. Measure V_{AMP} over the entire magnetic rotation at a single temperature.

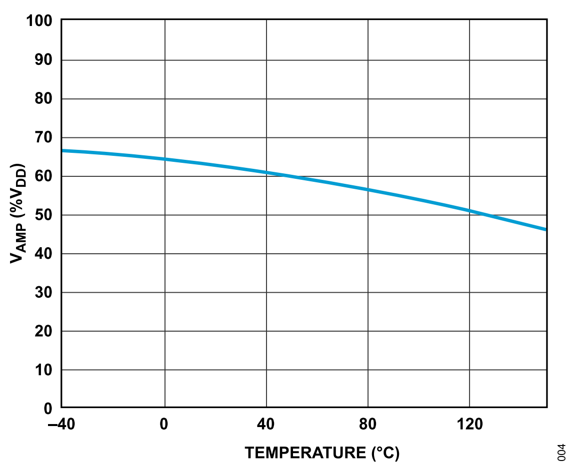

Figure 1. Typical Output Differential Amplitude vs. Ambient Temperature

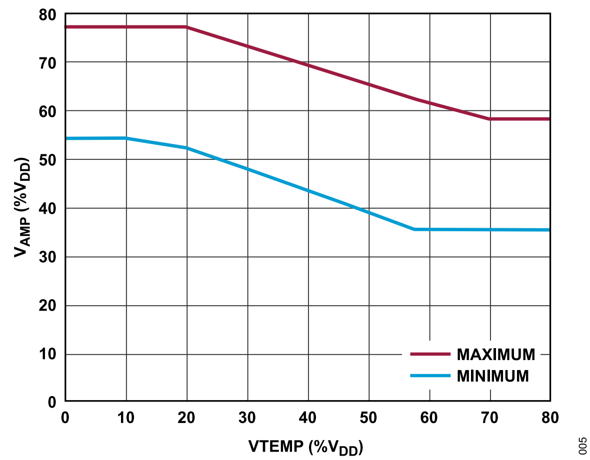

Figure 2. Valid Output Differential Amplitude Range vs. VTEMP Output Voltage

AMPLITUDE SYNCHRONISM CHECK

The amplitude synchronism check covers similar potential failures to those covered by the radius check. Due to the tight specifications on amplitude synchronism, tighter limits are applied vs. the radius check. The amplitude synchronism check enables a change in amplitude on the sine path relative to the cosine path to be detected.

The user may decide that the radius check provides diagnostic coverage for all potential failures covered by the amplitude synchronism check, and that both checks are unnecessary.

The sine and cosine signal paths, including correction and digitization can be verified by using the amplitude synchronism check. The steps to implement the dynamic amplitude synchronism check are as follows:

1. Measure the VSIN amplitude through an entire magnetic rotation.
2. Measure the VCOS amplitude through an entire magnetic rotation.
3. Calculate the amplitude synchronism as described in the ADA4570 data sheet.
4. Compare the amplitude synchronism with the ADA4570 data sheet limit.

An amplitude synchronism value outside the ADA4570 data sheet limits may indicate a potential fault in the signal chain including the ADA4570. This result assumes that the temperature is relatively constant during the magnetic rotation, and that this temperature is understood and monitored in the system.

SYSTEM LEVEL DIAGNOSTIC CHECKS

SUPPLY CURRENT CHECK

An unexpected supply current can indicate a potential problem in either the ADA4570 or the components connected to the device on the system. To use the diagnostic capabilities of the supply current, to implement a supply current check take the following steps:

- Measure the supply current.
- Compare the current value to the ADA4570 data sheet limits while also including the effect of the load resistance, which is drawing additional current.

Supply current can be monitored to ensure proper operation of the ADA4570. However, it is important to note that this supply current changes depending on the load of the device and the temperature. Quiescent supply current is specified in the ADA4570 data sheet.

VTEMP CHECK

The VTEMP output can be used to optimize the accuracy of the radius check and the diagnostic resolution of the radius check. In addition, monitor this output to ensure that the ADA4570 is within its specified operating range for valid outputs. Diagnostic information around potential faults can be obtained from the following temperature checks:

1. Measure the VTEMP output on the ADA4570.
2. Monitor the rate of change of VTEMP.
3. Compare the VTEMP output with an external temperature sensor within the system.
4. Compare the rate of change of the VTEMP output with the rate of change of an external temperature sensor

A VTEMP result outside the limits on the ADA4570 data sheet indicates a potential fault. For a system with known thermal properties, the following are indicators of a potential fault and allow the diagnosis of the existence of a potential fault within or associated with the ADA4570:

- A faster than expected rate of change of VTEMP.
- A larger than expected delta between the temperature indicated by VTEMP when compared to another independent temperature sensor on the system.
- A rate of change on VTEMP that is significantly higher or lower than that on another independent temperature sensor on the system.

SUMMARY

By making use of the internal diagnostic capabilities of the ADA4570 and implementing system level monitoring, significant diagnostics are available to detect faults.

The level of diagnostic information achievable depends on an understanding of the variation of the amplitude of VSIN and VCOS outputs. The outputs vary due to

- Operating temperature and voltage supplies
- The level of system calibration