BROADCOM®

White Paper

Magnetic Encoders

Increasing Demand on High-Performance Magnetic Encoders with Robust Self-Correcting Angular Error Detection Systems

Abstract

Over the years, magnetic encoders have gained popularity for their durability in harsh environments compared to optical encoders. When any fine dust particles or debris accidentally enters the housing of encoders, it could result in catastrophic faults or failure for optical encoders, but that is not so for magnetic encoders. By using magnetic flux as a medium of detection, as opposed to the more sensitive light waves, magnetic encoders can completely disregard any potential dust or debris that interferes with an optical encoder's medium of detection and operate as normal. Although using magnetic flux as a medium of detection may make magnetic encoders less precise, their advantage in harsh environments more than makes up for this disadvantage.

Although magnetic encoders are highly resilient against the dust and debris introduced from harsh environments, they are not without their setbacks. Similar to optical encoders, their precision is limited by the mechanical misalignment of components, which leads to angular error. This angular error is more evident in actual field applications of magnetic encoders because during their lifetime of use in harsh environments, their mechanical misalignment can be far more exaggerated than a regular optical encoder.

This document briefly discusses how Broadcom integrates a system of internal self-correction that compensates for the mechanical misalignment of the line of magnetic encoders.

Introduction

Conventional methods to address this mechanical misalignment include complex system calibrations or expensive mechanical redesigns, increasing cost, and integration complexity. Broadcom addresses these challenges with the AEAT-99xx series by featuring an integrated self-correcting system that automatically detects angular errors imposed by mechanical misalignment to improve precision while reducing setup.

The AEAT-99xx series are high-resolution magnetic encoders that are equipped with a state-of-the-art, self-correcting angular error detection system. This system compensates for errors in detected positions caused by mechanical misalignment, reducing the overall complexity of user designs and systems while achieving the ultimate goal of cost reduction.

The AEAT-9955/AEAT-9966 series are automotive grade in compliance with IATF-16949 and are qualified to Grade 1 AEC-Q100 automotive reliability up to 125°C.

Applications

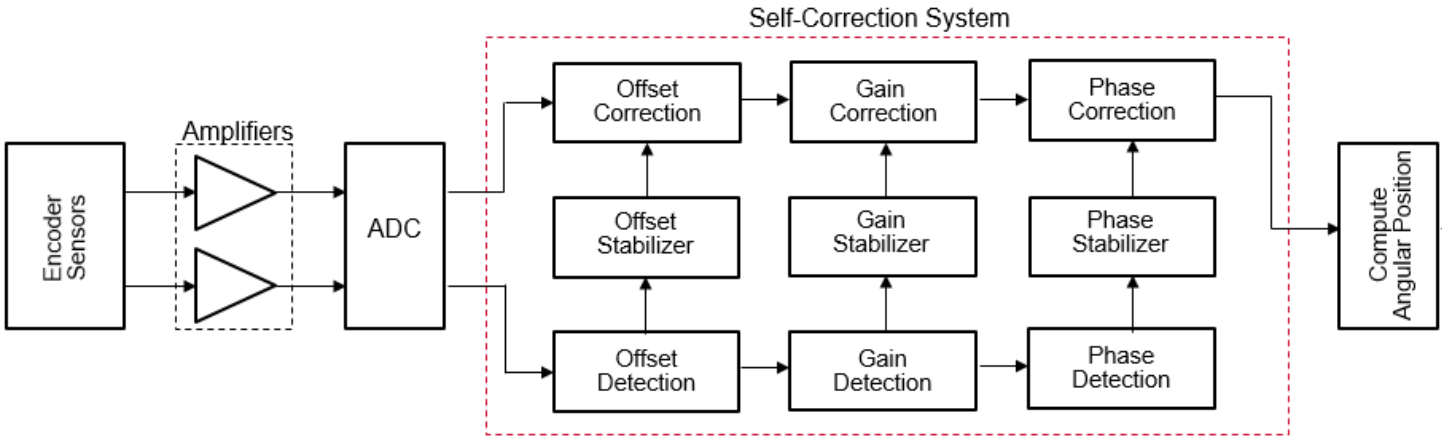
- Robotics
- Medical applications
- Brushless DC motors and stepper motors
- Resolver and potentiometer replacement
- Industrial automation
- Industrial sewing machines and textile equipment
- Light detection and ranging (LiDAR)
- Vending machines
- Liquid level monitoring

Self-Correcting Angular Error Detection System

The Broadcom® Self-Correcting Angular Error Detection System implemented within the AEAT-99xx series is seamlessly integrated into the encoder such that all the corrections are done without user intervention. Once the encoder is in operation, if the exciter magnet is in rotation, the system actively detects the imperfections generated by any form of mechanical misalignment that occurs in real time—and then corrects them.

Figure 1 shows the block diagram of the Self-Correcting Angular Error Detection System. Any X/Y/Z mechanical misalignment that occurs in the system is detected by the encoder sensors and is then amplified before it is digitized by the system's analog-to-digital converter (ADC). The correction is done digitally but is first separated into correcting the offset, the gain mismatch, and the phase mismatch incurred by the mechanical misalignment in selectable sequences based on the application. Figure 1 shows only one of the default settings that is commonly used.

Figure 1: Block Diagram of the Broadcom Self-Correcting Angular Error Detection System



As per Figure 1, the system functions through consistent detection of the offset, gain, and phase mismatches as part of its data path, and then it constantly corrects them before an angular position is computed. This ensures that any signal that is outputted to the user is already filtered and corrected to its most optimal condition for the lowest angular error possible.

The offset, gain, and phase stabilizers are user-adjustable settings provided by the Broadcom AEAT-99xx series. They are normally used to control the speed or rate at which the correction system compensates for the errors.

Figure 2: Self-Correcting Angular Error Detection Magnetic Encoder System

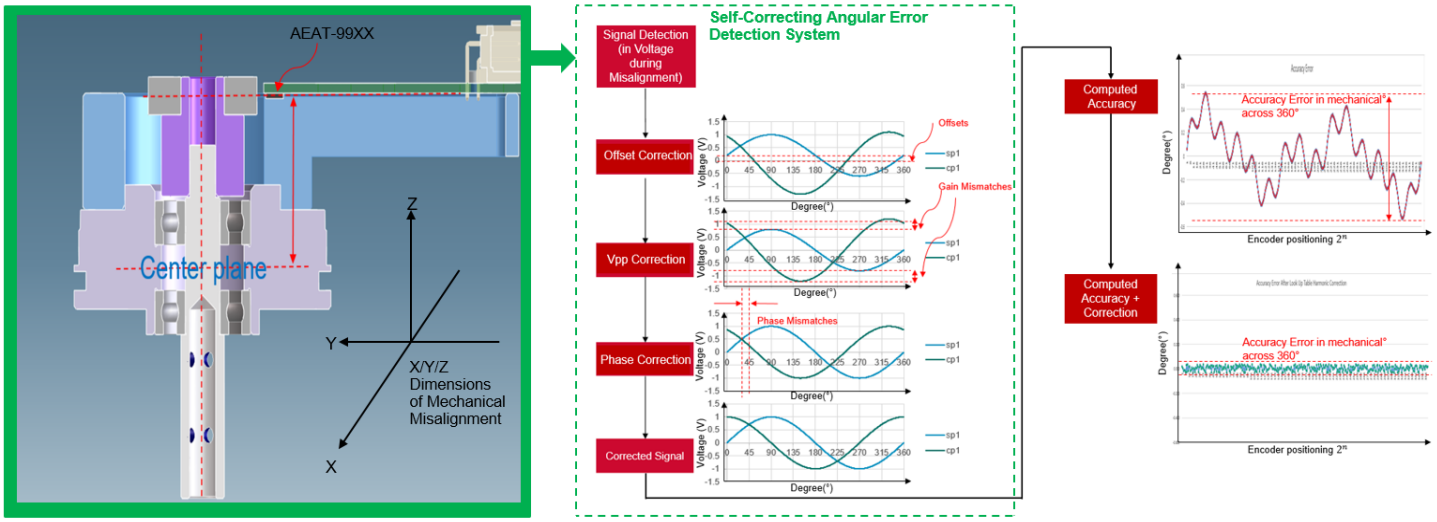


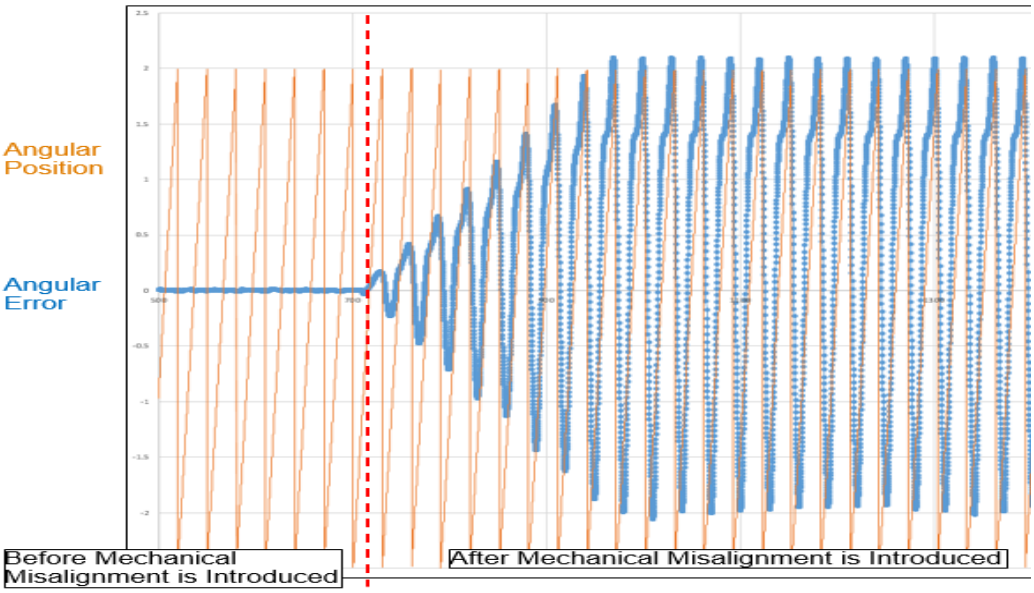
Figure 2 shows a magnetic encoder system with the Broadcom AEAT-99xx series mounted next to a shaft that houses the magnet. This simplified magnetic encoder system makes up most of the magnetic encoder systems found across the market.

To illustrate the impact of mechanical misalignment, look at the center plane of the shaft housing as illustrated in Figure 2 (left), and imagine the impact that could occur when any sudden jerk, movement, or permanent displacement occurs with respect to the center plane (X/Y/Z dimension) when used in harsh environments.

Any shift in the X/Y/Z dimension introduces a variation in the magnetic flux signal as detected by the sensors. These variations can be offsets, gain mismatches, or phase mismatches within the sine/cosine signals that are detected within the AEAT-99xx, as illustrated in Figure 2 (center to right section). These are the known main parameters and errors introduced during mechanical misalignments and are the parameters that the AEAT-99xx detects and corrects to obtain its most optimal precision.

To further elaborate on the impact of an exaggerated mechanical misalignment, Figure 3 illustrates what exactly occurs to a magnetic encoder's angular error when a mechanical misalignment is suddenly introduced into the system during rotation.

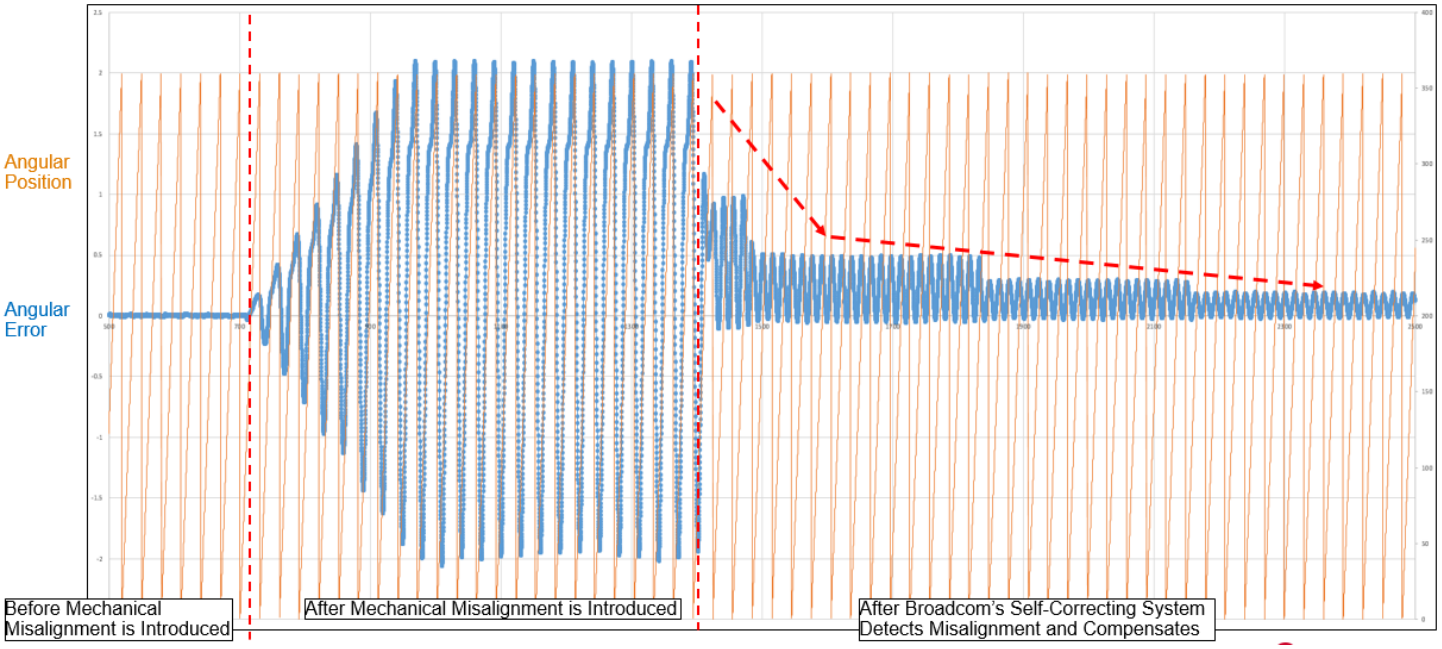
Figure 3: Angular Accuracy Deviation during Mechanical Misalignment



Note that the angular error (center section of the graph) will persist throughout the encoder's operation if no correction is introduced in the system. When such a large mechanical misalignment occurs within other magnetic encoder systems in the market, the standard go-to method of correction is to stop the motor to either realign the system or reperform an encoder calibration. This correction, however, is very costly and time-consuming because it disrupts operation. To avoid this disruption, users generally design the mechanical system with a precise bearing to be much more rigid and have a tighter tolerance, such that when a mechanical misalignment occurs, it is not as exaggerated as shown in Figure 3. This additional rigidity and precision, again, increase costs on the user end.

Figure 4 displays what occurs when the Broadcom AEAT-99xx system is subjected to the same misalignment.

Figure 4: Broadcom's Angular Accuracy Deviation during Mechanical Misalignment



The right section of the graph in Figure 4 illustrates what automatically occurs to the encoder's angular error as the magnet rotates. The Broadcom AEAT-99xx series automatically compensates for the mechanical misalignment without any user intervention. The rate of correction and change is gradual and can be adjusted within the Broadcom system such that it accommodates the needs of various users.

Encoder Selection Principle: Using the 5W 1H Principle to Determine Encoder Selection

Who to choose:

Broadcom Inc. is a global infrastructure technology leader built on 50 years of innovation, collaboration, and engineering excellence. With roots in the rich technical heritage of AT&T/Bell Labs, Lucent, and Hewlett-Packard/Agilent, Broadcom Inc. focuses on technologies that connect the world. Through the combination of industry leaders LSI, Broadcom Corporation, Brocade, CA Technologies, VMware, and Symantec, the company has the size, scope, and engineering talent to lead the industry into the future.

Why choose Broadcom:

Broadcom is one of the leading global encoder makers and has an extensive portfolio of encoder-related intellectual property ranging from optical encoders to magnetic encoders.

Where to find Broadcom encoder products:

Easy access to Broadcom encoder product details is available at https://www.broadcom.com/products/motion-control-encoders.

What types of encoder to choose:

- Optical absolute encoders
- Optical incremental encoders
- Optical absolute with incremental output encoders
- Magnetic absolute with incremental output encoders

When to choose:

Choose encoders for a new project or ongoing manufacturing products that require better performance, safety requirements, a consistent supply chain, and cost savings.

How to choose:

Know the design requirements and consult with a Broadcom sales representative for recommendations.

Conclusion

Broadcom magnetic encoders are built with an integrated self-correcting system that runs seamlessly in the background to ensure that they are always running at the most optimal precision without the need for user interference nor the need for a complex, expensive, mechanical bearing system that is catered for harsh environments. Broadcom magnetic encoders are not only durable and precise, they are also designed for ease of use and are cost competitive.

The AEAT-9955 and AEAT-9966 series encoders are automotive grade in compliance with IATF-16949 and are qualified to Grade 1 AEC-Q100 automotive reliability up to 125°C. They are a drop-in solution for automotive/industrial parts.

Product Summary

	AEAT-8811	AEAT-9922	AEAT-9933	AEAT-9955	AEAT-9966	AEAT-9988
Voltage	3.3V to 5V (±10%)					4.5V to 5V (±10%)
Magnet Track Type	Single Track					Dual Track
Package Size	5 mm × 5 mm	4 mm × 4 mm	4 mm × 4 mm	5 mm × 5 mm		8.2 mm × 5 mm
Automotive Ready[a]	X	X	X	√	√	X
Temperature Rating	–40°C to 125°C	–40°C to 125°C	–40°C to 125°C	–40°C to 125°C	–40°C to 125°C	–40°C to 125°C
ABI Output	√	√	√	√	√	√
UVW Output	√	√	√	√	√	√
ABI Differential Output	X	X	X	X	X	√
UVW Differential Output	X	X	X	X	X	√
PWM Output	√	√	√	√	√	√
RS485 Protocol	X	X	X	X	X	√
BiSSC Protocol	X	X	X	X	X	√
SSI2 Protocol	X	√	√	√	√	√
SSI3 Protocol	√	√	√	√	√	√
SPI3 Protocol	√	√	√	√	√	√
SPI4 Protocol	X	X	X	X	X	√
Standby Mode	X	X	X	√	√	√
Resolution (Selectable)	10/12/14/16b	10b to 18b	10b to 14b	10b to 18b	10b to 18b	16b to 23b
Accuracy	±0.35	±0.10				±0.015
Latency (Typical)	80 ns					
Spatial Tolerance	±250 µm					
Calibration Required	√					
Max. Digital Output(AB) Interpolation (Selectable)	32 to 4,096	1 to 10,000	1 to 1,024	1 to 20,000		1 to 65,536
Max. Digital Output(UVW) Pole-Pair (Selectable)	1 to 8	1 to 32				
Status Pin	X	X	X	√	√	√

a. The manufacturing/quality management system is compliant with automotive IATF-16949.
The AEAT-9955 and AEAT-9966 (production status) are qualified to Grade 1 AEC-Q100 automotive reliability 125°C.

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