BROADCOM®

White Paper

Reflective Encoder

Increasing Demand for Low-Profile, High-Performance Miniature Encoders for Robotic and Bionic Hands

Abstract

In the mobile robotics world, robotic hands are capable of performing amazing functions mimicking human hands, therefore offering high flexibility to perform specific tasks.

Multiple linear actuator driven systems integrate in a robotic hand to provide dexterity and grasping force. Low-profile encoders and small-sized encoders are required to provide accurate positioning feedback to linear actuator systems.

Introduction

In robotics, accuracy and dependability are crucial for robots to perform tasks with the same skill and control as human hands. Robotic hands incorporate advanced mechanisms such as linkage-driven systems and multiple linear actuators to mimic natural hand movements. These actuators depend on precise feedback for accurate control of motion and force.

The Broadcom® AEDR-98xx/AEDR-99xx series encoders are designed to address this need, combining compact design, high resolution, and automotive-grade reliability to support applications in robotics, medical devices, industrial automation, and more. These encoders are suitable for both rotary and linear feedback applications, making them versatile and cost effective.

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 Range (LiDAR)
- Vending machines
- Liquid level monitoring

Encoder Selection Principle

Using the 5W 1H Principle to Determine Encoder Selection

Who to choose:

Broadcom is a global infrastructure technology leader built on 50 years of innovation, collaboration, and engineering excellence. With roots based in the rich technical heritage of AT&T/Bell Labs, Lucent, and Hewlett-Packard/Agilent, Broadcom focuses on technologies that connect our world. Through the combination of industry leaders Broadcom, 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 encoder makers globally and has an extensive portfolio of encoder-related intellectual property, ranging from optical to magnetic encoders.

Where to find Broadcom encoder products:

Refer to broadcom.com/products/motion-control-encoders/ for additional encoder product details and descriptions.

What types of encoder to choose:

Broadcom offers a wide range of motion control optical encoders and magnetic encoders:

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

When to choose:

Choose Broadcom encoders for new projects or ongoing manufacturing products that require better performance, safety requirements, consistent supply chains, and cost savings.

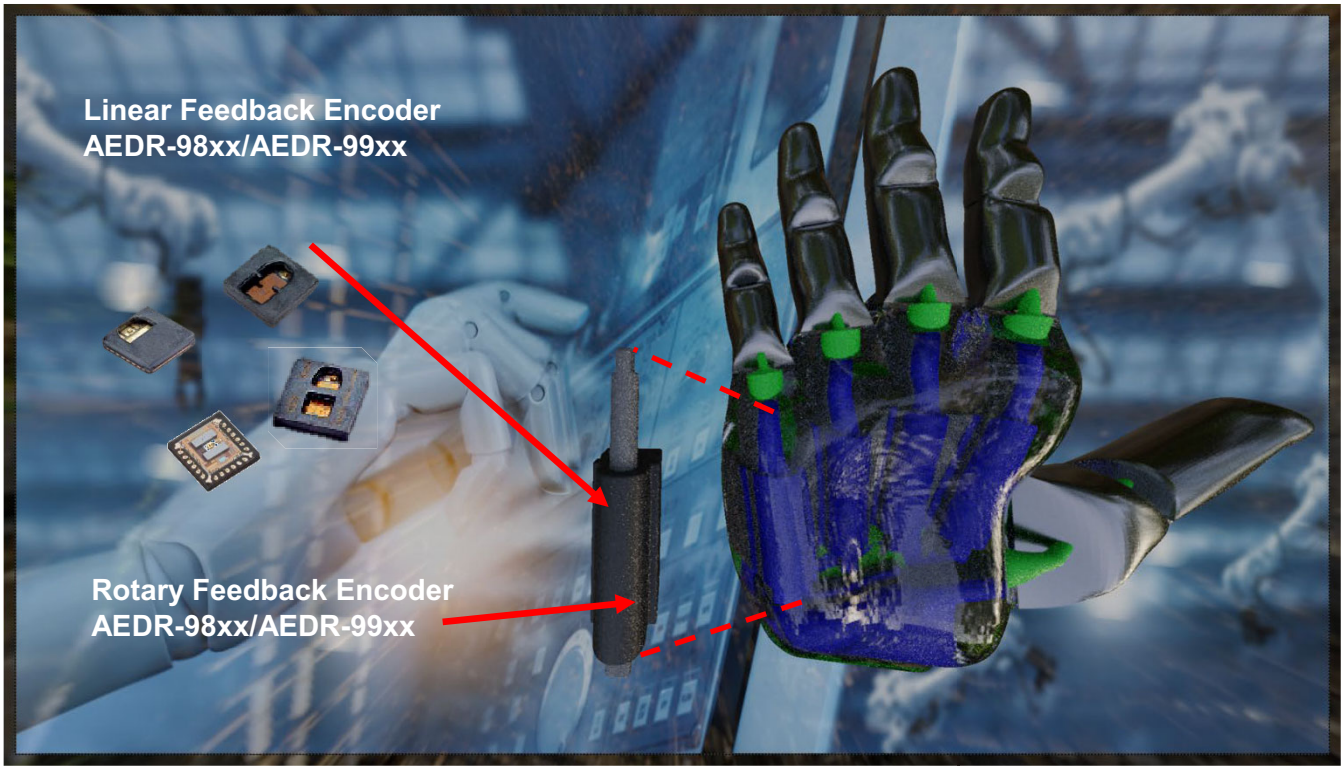
How to choose:

Examine your design requirements and contact your Broadcom sales representative for recommendations.

Robotic Hands and Bionic Hands

Robotic and bionic hands have a variety of different design mechanisms. One of these mechanisms is a linkage-driven design. In this design, robotic hands facilitate joint movement in the desired direction through mechanical structures in combination through several links, transmitting power from linear actuators.

Bidirectional joint control using linear actuators provides multiple degrees of freedom with high dexterity. Linear actuators with linear encoders on the linear shaft or rotary encoders on the linear actuator motor provide higher movement accuracy control.



Reflective encoders play a crucial role in these applications by providing precise feedback for motion control. The preceding figure illustrates how reflective encoders pair with linear actuators to achieve high dexterity and accuracy. Each finger's movement is individually monitored and adjusted using encoder feedback, ensuring precise operation. A total of five linear actuators are integrated on the palm. Each linear actuator controls one finger, providing individual control on each finger. For multi-axis controls to move the finger sideways, the linear actuator may be designed with dual shaft or three shaft to control the side movement axis. Other than the linear actuator, the other type of design involves using strings to control the fingers. The string type of design typically is in the form of a rotary placed at the forearm. Multiple strings are linked to fingers to control the axis of finger movement.

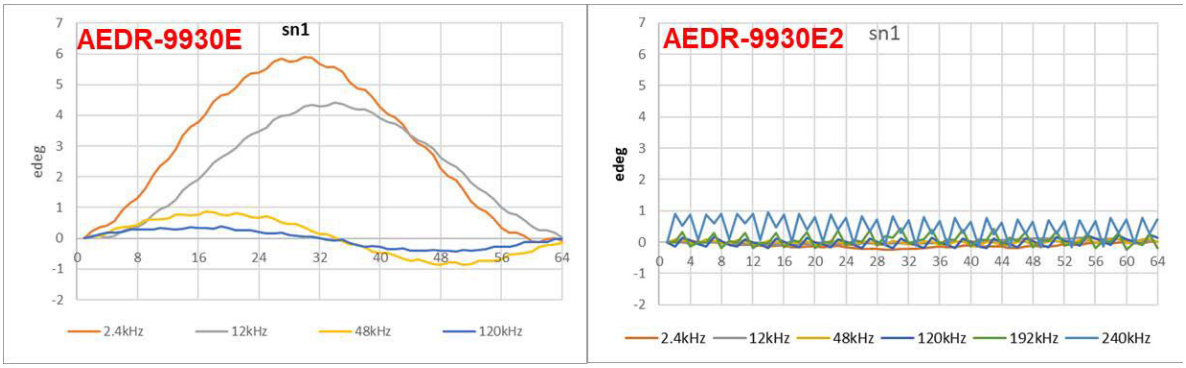
Encoder Selection Guide

Selecting the right encoder is critical for achieving optimal performance in your system. Broadcom offers a range of encoders designed for specific needs.

Performance-Driven Applications

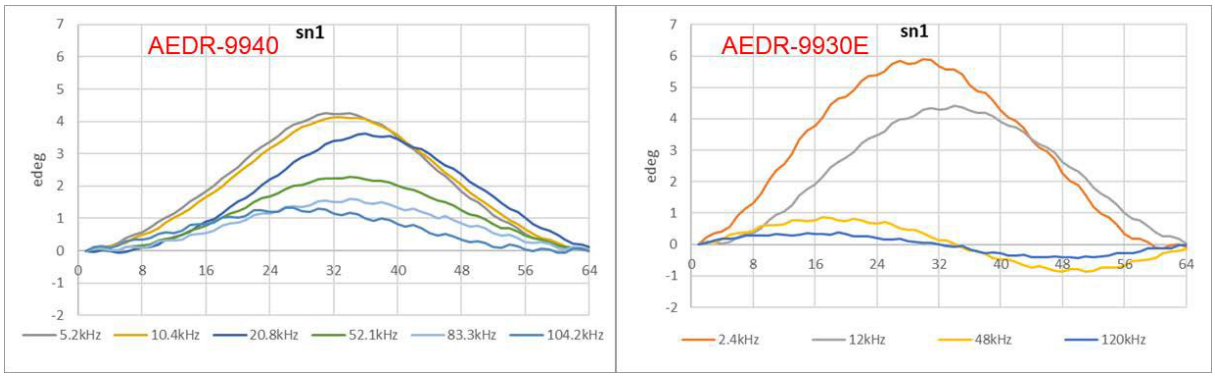
The AEDR-9930E2/E2L and AEDR-9940 encoders are the best choices for performance-driven applications. The AEDR-9930E2/E2L has the best performance with its raw pitch of 397 LPI (64 µm) in comparison to other products. Furthermore, the AEDR-9930E2/E2L has integrated autocalibration that is not only able to calibrate the raw signals but also calibrate the subgrating errors generated from the raw material (codewheel or codestrip). These corrections will significantly improve the speed accuracy on the system. On the other hand, the AEDR-9940 has a pitch of 198 LPI (128 µm), double that of the AEDR-9930E2/E2L, but it is less sensitive to codewheel or codestrip pitch errors while providing high interpolation to match the AEDR-9930E2/E2L. For example, with detection of 0.1 µm, you can use the AEDR-9940 with 320x interpolation or AEDR-9930E2/E2L with 160x interpolation.

Figure 1: Comparison between AEDR-9930E (without) vs. AEDR-9930E2 (with) Subgrating Correction



The AEDR-9930E subgrating errors are generated from the codewheel or codestrip mismatch. At higher frequencies, the AEDR-9930E is better because of the cross-averaging effect. The AEDR-9930E2, on the other hand, is integrated with subgrating error correction. It will correct the mismatch during the calibration process. Therefore, the subgrating error is largely suppressed to relatively 1 edeg. (Note that edeg = electrical degree; 1 pitch = 360 edeg.)

Figure 2: Comparison between AEDR-9940 vs. AEDR-9930E without Subgrating Correction



The AEDR-9940 pitch is half of the AEDR-9930E pitch. Although the pitch size is larger, it is less sensitive to codewheel or codestrip mismatch; therefore, the subgrating errors is less.

Cost and Temperature

The AEDR-98xx series provides a better cost and higher temperature rating up to 125°C with an automotive part number. The AEDR-9830 has a higher LPI compared to the AEDR-9820, meaning that with the same size, it will provide higher signal feedback frequency on the same movement speed.

Robustness in Linear Application

The AEDR-9920 will provide the most robustness, especially for a linear application, because it is designed with single track detection. Single track detection means both the incremental AB signals and the Index are on the same track, so the radial shift will not be impacted on linear application.

Ease of Maintenance

The AEDR-9940 provides an ease of maintenance that other products are not capable of. The AEDR-9940 is covered with a silicon coating, allowing a cleaning process with lab grade isopropyl alcohol (IPA).

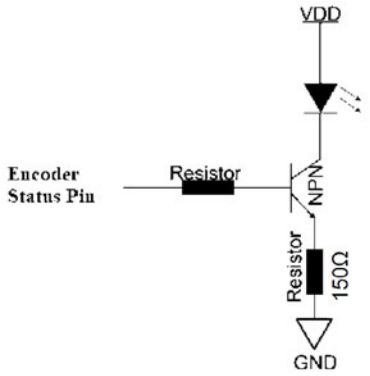
Latency

The AEDR-98xx series has the lowest raw latency because it is a pure analog device while the AEDR-99xx series is a mix analog and digital devices. For applications that require live response and faster power-up timing, the AEDR-98xx series is the best choice. The shortest power-up timing for the AEDR-99xx series is ~110 ms.

Status Pin

The AEDR-9930E2/E2L and AEDR-9940 provide an additional status pin controlling an external LED or MCU that serves as an early indicator, allowing you to perform maintenance or change the overtime degraded parts.

Figure 3: AEDR-9930E2/E2L and AEDR-9940 Encoder Status Pin



Summary

The Broadcom AEDR-98xx/99xx series encoders set a benchmark for precision and reliability in robotic and industrial feedback systems. These encoders provide the following:

- High resolution and accuracy for complex tasks.
- Cost-effective solutions with built-in interpolators.
- Automotive grade reliability with compliance to IATF-16949 and Grade 1 AEC-Q100 standards.

Whether for robotics hands, medical devices, or industrial automation, Broadcom encoders deliver performance and versatility, ensuring seamless integration into various applications.

Product Summary

Parameter	AEDR-9820/A	AEDR-9830/A	AEDR-9830DP	AEDR-9920	AEDR-9930E/EA	AEDR-9930EL/ELA	AEDR-9940
Product Image							
Voltage	3.3V to 5V (±10%)						
Track Type	Dual Track			Single Track	Dual Track		Dual Track
Package Size	4 mm × 4 mm				5 mm × 5 mm		4 mm × 4 mm
LED Type	Infrared (840 nm ~ 860 nm)						660 nm
Automotive Ready[a]	X / √		X		X / √		X
Temperature Rating	–40°C to 115°C/125°C		–40°C to 115°C		–40°C to 115°C/125°C		–40°C to 115°C
Base/Max Frequency	200 kHz / 2 Mhz				200 kHz / 4 Mhz		250 kHz / 4 Mhz
Sine/Cosine Differential Output	Output: 1Vpp – Index (Analog) – Index (Ungated digital) Output: 0.5Vpp – Index (Analog) – Index (Ungated digital)			X			Output: 1Vpp – Index (Analog) – Index (Ungated digital) Output: 0.5Vpp – Index (Analog) – Index (Ungated digital)
Differential ABI Output	√						
Line Per Inch (LPI)	225	318		225	397		198.4
Base Cycle per Resolution (CPR)	256	625		256	512		256
Base Optical Radius (ROP)	4.5995	7.9452		4.5995	5.2135		5.215
Scalability (Base CPR up to Linear)	√						
Resolution	(Cycle Per Revolution [CPR] × interpolation × 4) / 360 = mech deg						
Resolution Linear (example)	LPI / Interpolation / 4	16x = 1.25 µm		28x = >1 µm with residue	16x = 1 µm; 160x = 0.1 µm		32x = 1 µm; 320x = 0.1 µm
Accuracy	Typical ±0.1 mdeg (Factory Setup with motor bearing and metal code wheel)						
Latency (typical)	5 µs			7 µs			
Spatial Tolerance (Base CPR)	±200 µm			±500 µm	≥512 CPR ±300 µm (Auto Cal) ≥1000 CPR ±500 µm (Auto Cal)		128 CPR ±200 µm (Auto Cal) ≥512 CPR ±200 µm (No Cal) ≥625 CPR ±350 µm (Auto Cal)
Calibration Required	X				√		
Max Digital Output (AB) Interpolation	1x~16x Selectable			1x~256x Selectable	1x ~ 512x Selectable		1x ~1000x Selectable
				1x ~ 512x Programmable	1x ~ 1024x Programmable		1x ~ 1024x Programmable
Status Pin	X				√		
Offscale Calibration	X					√	

a. Manufacturing/Quality Management System compliant to automotive IATF-16949. AEDR-98xxA, AEDR-99xxEA/ELA (production status) qualified to Grade 1 AEC-Q100 automotive reliability 125°C.

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