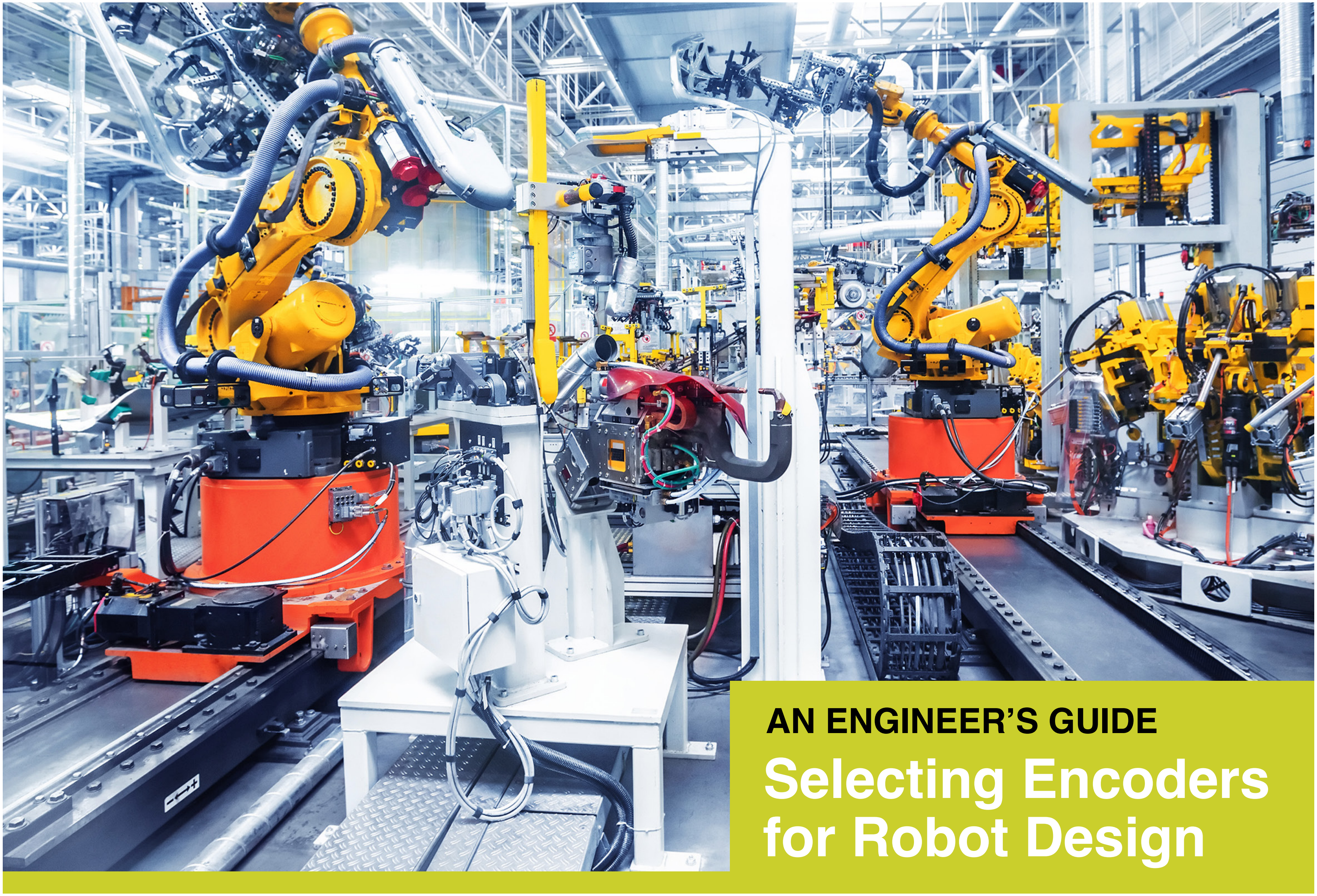


AN ENGINEER'S GUIDE

Selecting Encoders for Robot Design

HEIDENHAIN

Introduction

The 21st-century end-user expects robots with higher and higher dynamic performance, heavier load capacity, greater accuracy, smaller footprints and superior cost efficiency. Without those, it's difficult to optimize their processes or realize new applications.

Luckily, designers are skilled at juggling the practical limitations of robotic motion in the face of these intensifying demands. They understand that, because of the complexity of robotic systems, the right subcomponents play a big role in enabling elegant, functional designs that meet performance, cost and safety requirements.

The development phase requires important design decisions about how to achieve the desired robot characteristics and meet project requirements. From a design perspective, achieving this without exceeding the cost limit for robot production requires well-designed solutions and carefully selected components.

This guide will explain the different ways a critical subcomponent—the rotary encoder—is evolving to meet rising demands, and how to choose the best one.

Topics covered include:

- **Method of encoder operation**
- **Environment**
- **Functional safety**
- **Maintenance posture**
- **Installation space**
- **Assembly**
- **Flexibility**
- **Tolerances**
- **Quality assurance**
- **Cost**
- **Recommended products and solutions**

Method of Operation/Environment

Key Consideration:

Are there ambient conditions (oil mists, brake dust, humidity, etc.) that require a particular scanning principle?

It is crucial to consider how the design will behave under real-world conditions, where small factors can quickly add up to big problems. This is particularly true wherever temperature fluctuations, aging, contamination and vibrations in the drivetrain are involved. One solution is to install higher-quality components–encoders built for the specific environment, for example.

Common scanning methods

Magnetic

Somewhat accurate and reliable where vibration over 30-40 Gs and/or contamination are a risk. Magnetic is less accurate than inductive.

Optical

Extremely accurate and capable of facilitating high dynamic motion, these are best reserved for cleaner environments.

Inductive

The Goldilocks solution: accurate enough for most applications, while also able to withstand various environments and situations. Their above-average accuracy paired with above-average resilience makes them the ideal choice for a number of robotics applications.

Functional Safety

Key Consideration:
Does my application require Functional Safety? To what level?

In safety-related applications such as cobots, liability risks must be kept to a minimum. Safety Integrity Levels (SIL) and Performance Levels (PL) are measures of the reduction in risk provided by a safety function of a control system based in part on the probability of failure of the integrated components and subsystems. An encoder that has been certified in accordance with these measures, simplifies the implementation of a safety-related complete system.

The use of functional safety-certified dual encoders saves designers detail work and simplifies safety documentation, speeding up design time and reducing the number of error-related setbacks.

Maintenance Posture

Key Consideration:
What information can be gathered to anticipate maintenance intervals and prevent failure?

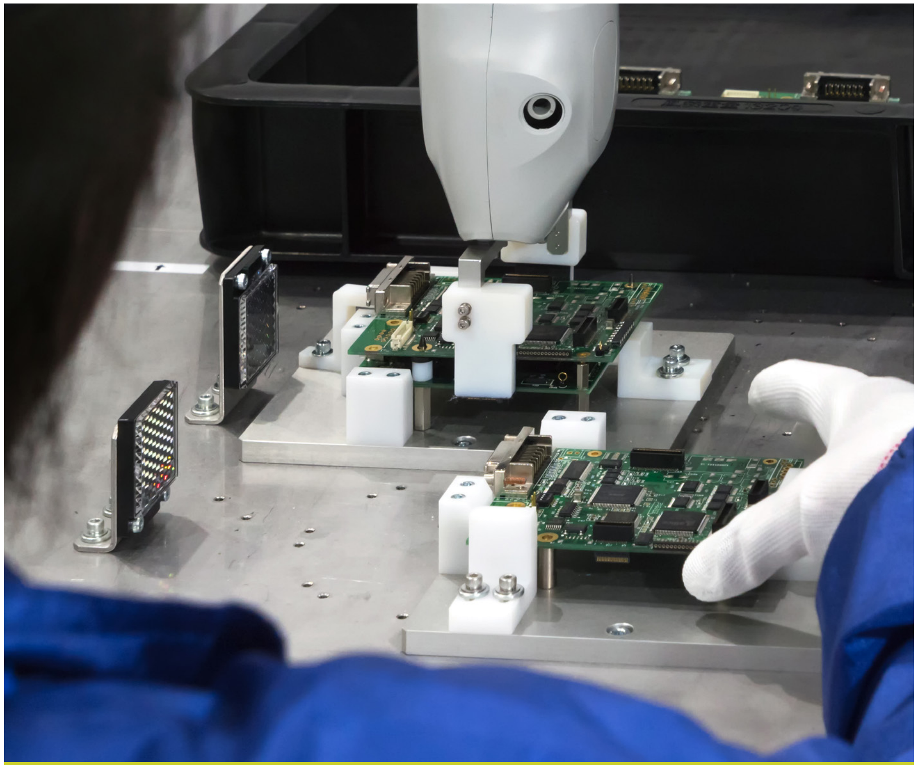
As Industry 4.0 advances, manufacturing machines are increasingly expected to deliver growing amounts of real-time data through trustworthy interfaces. The goal is to achieve flawless, uninterrupted operations supported by predictive maintenance. Rotary encoders can contribute to this flow of data by providing information about their current condition.

With the help of an intelligent interface and electronics, encoders can serve as diagnostic, information-sharing devices. They can deliver extensive condition data such as error messages, warnings and online diagnostics based on valuation numbers. This enables the implementation of detailed diagnostics for the complete system. When combined with state-of-the-art analyses, this facilitates rapid troubleshooting and predictive maintenance. Regularly triggered tests can also check the encoder's health.

Footprint

Key Consideration:
What can be done to decrease overall machine size?

Installation space is always limited in robots, particularly in compact cobots. Rotary encoders should have the smallest footprint possible, especially as it is now common to install two rotary encoders, one tracking motor speed and one for the positioning after the gearbox, at each joint for greater accuracy. In addition to low profiles, encoders that don't use bearings and/or require excessive cabling save space and lower weight.



Flexibility

Key Consideration:
Is the rotary encoder available in multiple variants regarding size, resolution, etc., so that the design can be readily varied and rescaled?

Geometric constraints arise through the choice of components such as the motor, bearings, gearbox and shaft. Rotary encoders should be geometrically versatile enough to fit these components or be available in matchable variants. The overall design is then easier to vary and rescale. Consider having encoders on hand, both with and without an integral bearing in order to accommodate the anticipated mechanical load and intended application.

Wide Tolerances

Key Consideration:
To what extent can the rotary encoder compensate hysteresis and other fluctuations?

Assembly

Key Consideration:
Can the individual parts be mounted free of error and without extensive training?

Path accuracy can be hindered by the zero point error of the robotic joint, reversal error of the gearbox or the elasticity of materials under load; these three factors are collectively known as hysteresis. Fluctuations are also noticeable during temperature swings and aging. To create robots that weld on-target or accurately insert screws for instance, designers must understand how to manage these effects

Some encoders can compensate, in part, for the effects of measurement deviations. Inductive encoders, for example, can compensate for shaft eccentricity due to loading and other factors. Inductive scanning also accommodates wide axial mounting tolerances, thus compensating for imperfect mounting or thermal expansion.

An estimated 70 percent of production costs arise from decisions made during the design phase. Subsequent changes to the design or manufacturing process become even more costly. Designers must, therefore, ensure that assembly will be simple, cost-efficient and as automatable as possible. Things like the number of installed parts, required work steps, and the necessary level of training affect how long the process takes and ultimately how much it will cost.

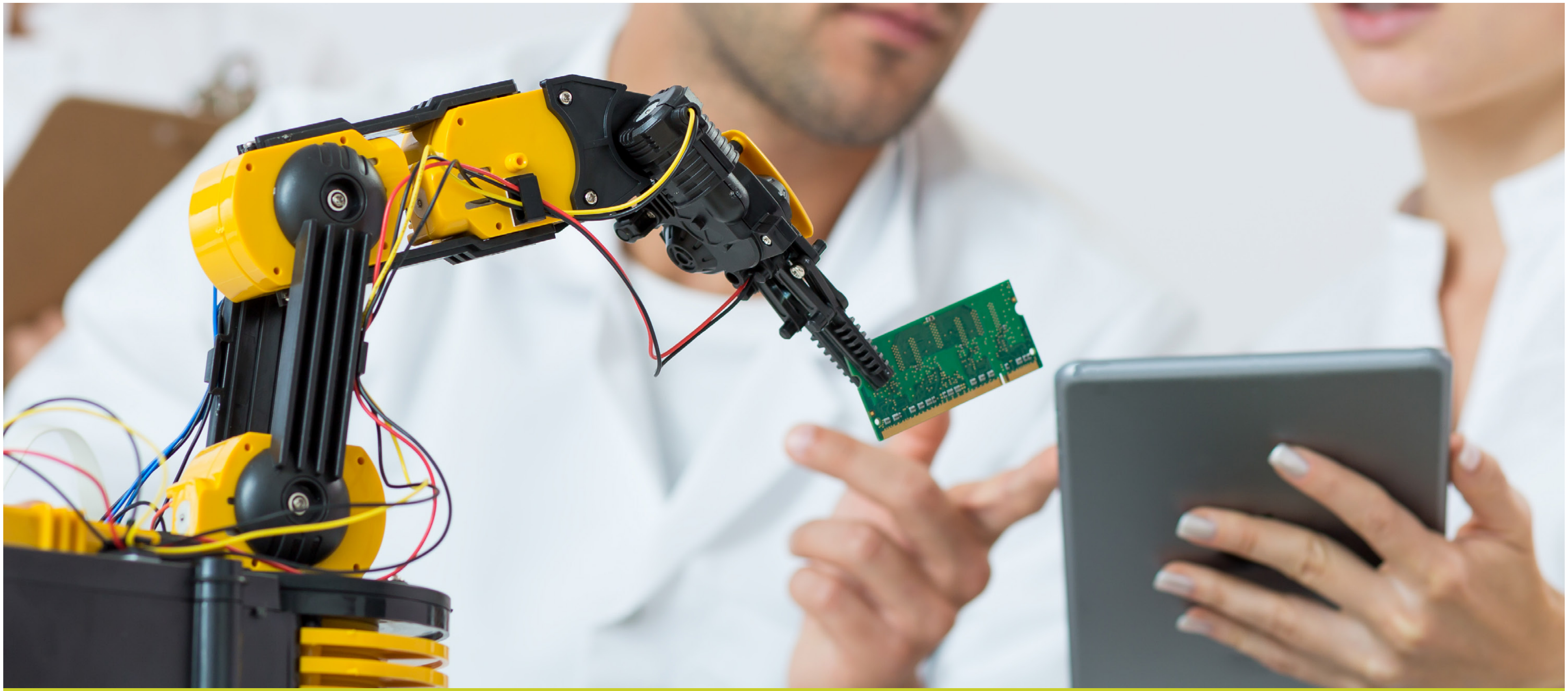
Quality Assurance

Key Consideration:

Does the rotary encoder provide information for verifying correct mounting and functionality?

Detailed quality inspections, particularly 100-percent inspections, can add significant time. The right rotary encoders can help. Some require no calibration run, making them immediately operable after mounting, for mount-and-play functionality. Bearingless encoders are even available with electronic mounting diagnostics that immediately determine whether the system is correctly installed and operational..

Some models also feature an electronic ID label that can be accessed through the interface, providing access to ID numbers and serial numbers. In a rewritable, non-volatile memory area, the installer can also store his own data, including operating parameters, test results (fault-proof mounting), a robot serial number and the date of production, thus enabling automated setup.



Cost

Key Consideration:
Which other aspects of your design and assembly process could benefit from the encoder choice?

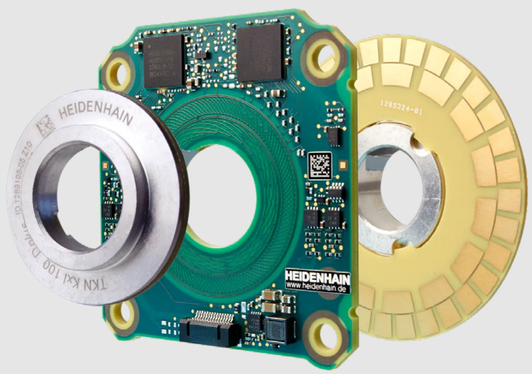
Careful design and cost both involve tradeoffs. If designers can show that an encoder doesn't ultimately raise system costs and may even lower them, then there's a solid argument. For example, if an encoder has wide tolerances inherent in the design, and a stable, contamination- and/or vibration-resistant scanning method, lower-cost components (bearings, shafts and gearboxes) can be used elsewhere. In other words, even if an encoder has a higher unit price, today's powerfully precise, resilient and compact devices can lower costs elsewhere in the design.

Integrated components and an intelligent interface can also reduce design time and controller programming effort. Even if an encoder was to exceed production cost limits, the overall design could still benefit from improved functional safety, function reserves, positioning accuracy and total cost of ownership, thus securing a market advantage.

Some Recommended Products and Solutions

HEIDENHAIN strives to support these kinds of solutions with its products, prides itself on being a reliable supplier, and offers extensive support to designers and programmers at the ready. Below are a few of our recommended rotary encoder solutions for robotics design.

We look forward to helping you solve your technical challenges.



KCI 120 D*plus* dual encoder

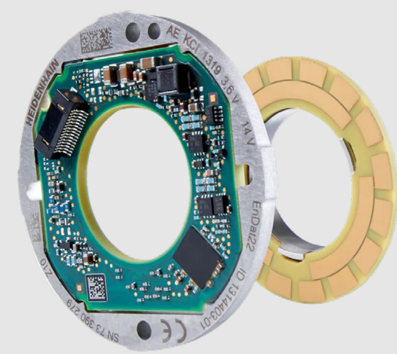
Motor feedback and position measurement all in one

This two-in-one encoder provides motor feedback and position measurement in a single device. Installed downstream from the gear system, it allows robot OEM's to reduce components and save space in their design while enabling the compensation of design-related inaccuracies in dynamic robots, such as joint elasticity, zero-position error, reversal error and machining effects. The encoder's purely serial EnDat 2.2 interface with functional safety permits deployment in applications such as human-robot collaboration.

HEIDENHAIN ECA 4000 and AMO WMRA

Secondary encoders for enhanced accuracy

The absolute position accuracy of your robots can also be improved by adding a high-accuracy angle encoder to each axis. Mounted downstream from the gear system, secondary encoders measure the actual position of each robot joint. We offer modular encoder solutions for this purpose, such as the HEIDENHAIN ECA 4000 with optical scanning, the AMO WMRA angle encoder system and angle encoders from RSF. These encoders are well suited to large shaft diameters and challenging installation requirements, making them ideal as secondary encoders.



KCI 1300 and KBI 1300 rotary encoders

Low-weight, low-profile encoders for robot motors

The KCI 1300 and KBI 1300 rotary encoders deliver inductive scanning capability in a low-weight, low-profile design, making them ideal for compact servomotors in robots. The unique circumferential scanning allows for larger mounting tolerances and easy installation with no calibration required. Their reliable inductive scanning method makes them insensitive to contamination and magnetic fields. The diagnostic data they provide enable condition monitoring, including motor monitoring via an external temperature sensor. Consisting of just a scanning unit and a screw-fastened circular scale or a disk/hub assembly press-fit to the motor shaft, the KCI 1300 and KBI 1300 are compact and lightweight solutions perfect for any robotic joint design.

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