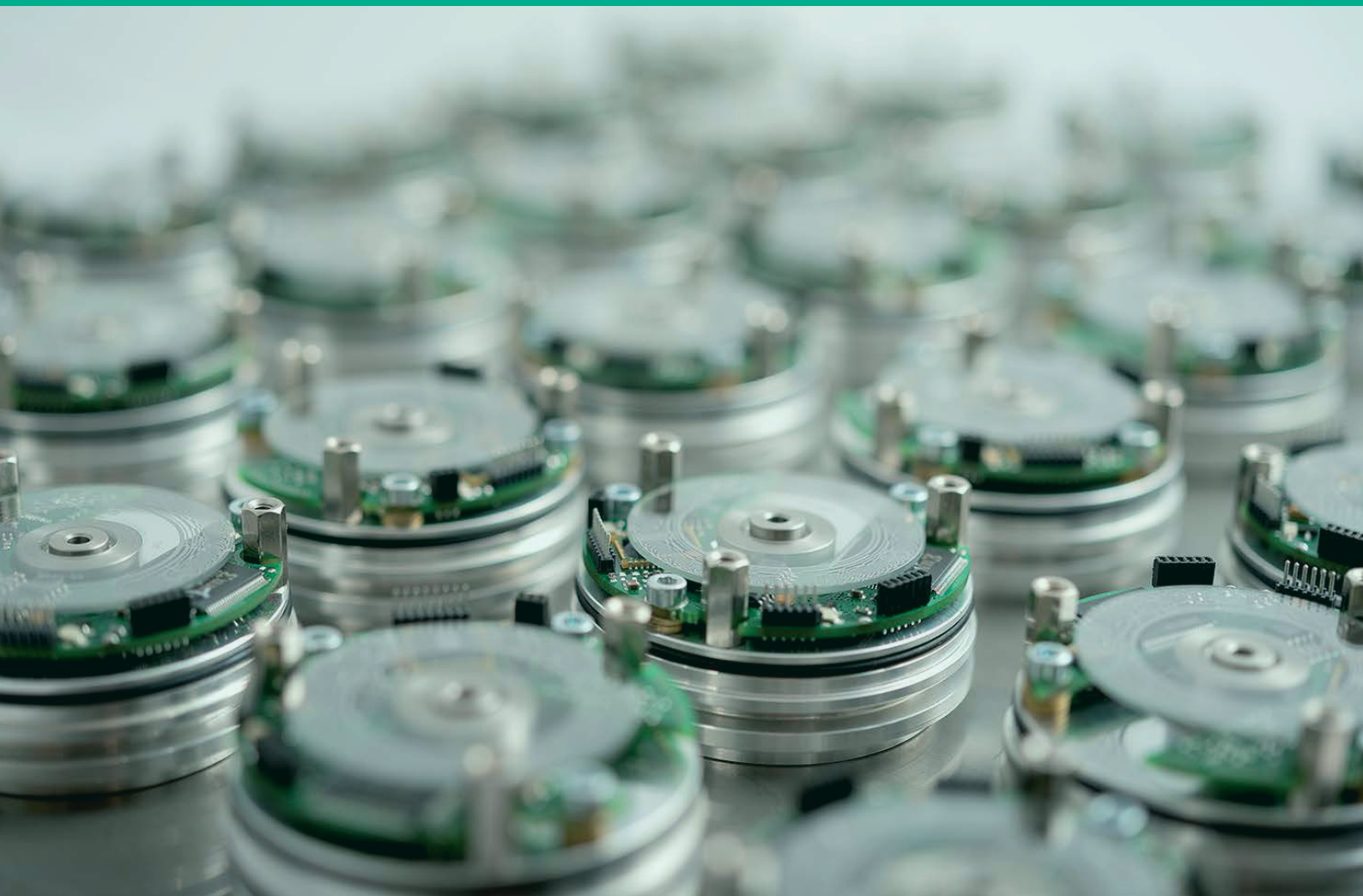
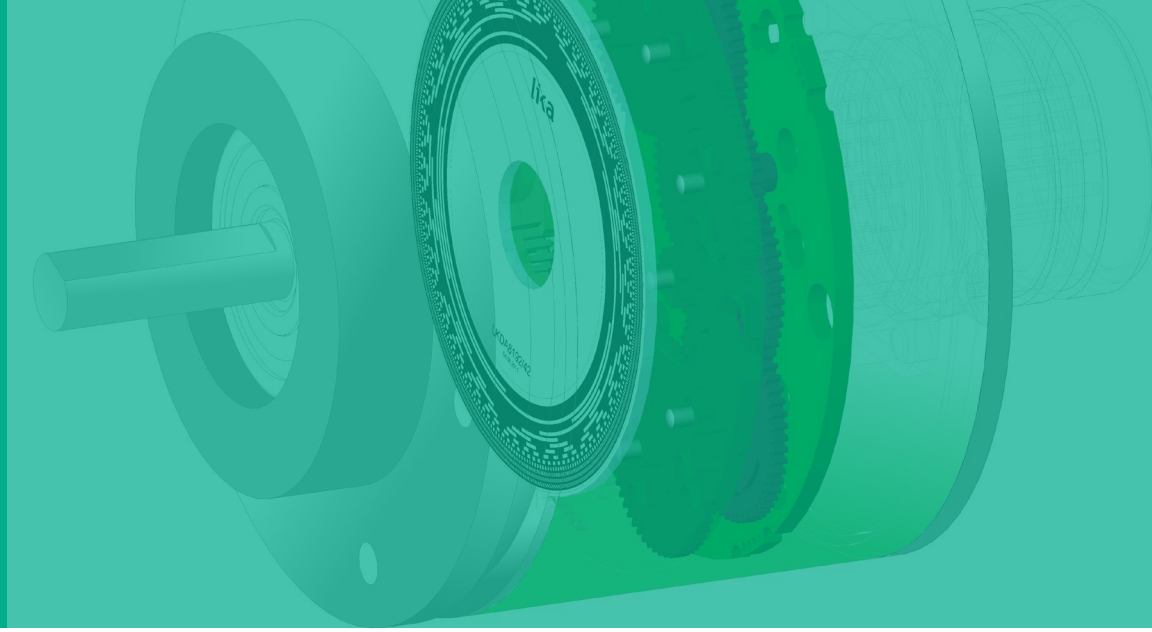
Smart encoders & actuators

Optical kit encoders and modular magnetic encoders: benefits and applications



WHITE PAPER



Rotary encoders are changing their shape.
The current trends in the most advanced industry and the modern automation are pushing the measuring systems to evolve towards new categories. More often encoder manufacturers also have to develop individual solutions for non-standard applications and specific sectors.
The primary purpose of this white paper is to describe the two main types of rotary encoders that are recently gaining ground and spreading impressively into the automation industry and the most expanding sectors such as robotics, motors and medical-surgical equipment: **optical kit encoders and modular magnetic encoders.**
It is also intended to show how they differ from and what are their advantages over each other and over the conventional shaft encoders.
Finally it will suggest some application areas they are most suitable for. Bearingless and frameless encoders are a cost-effective alternative to traditional rotary shaft encoders and enable manufacturers to produce smaller and lighter equipment, while reducing their cost and components.

What is an “encoder”?

For the purposes of this paper, an **“encoder”** is defined as a measuring system that generates signals in response to a motion.
In particular a **rotary encoder** is an electro-mechanical device (a transducer) that is specifically designed to translate the motion of a rotary axle, i.e. a rotary mechanical movement such as the one of a motor or a shaft, into either analog/digital electrical signals or a digital code in order to determine the change in position.
By the way a **linear encoder**, as its name implies, generates signals in response to a motion in a line.

Lika Electronic Srl
T +39 0445806600 • F +39 0445806699
info@lika • www.lika.it

Types of encoders

A rotary encoder is generally categorized according to its output.

AN INCREMENTAL ENCODER

produces square wave signals or sinusoidal signals in response to the motion and can provide travel, position and displacement information. Positional information is cyclical, i.e. relative and ambiguous. This means that it is possible to know whether the axis is moving and the direction of the movement; yet you cannot get information about its absolute information.

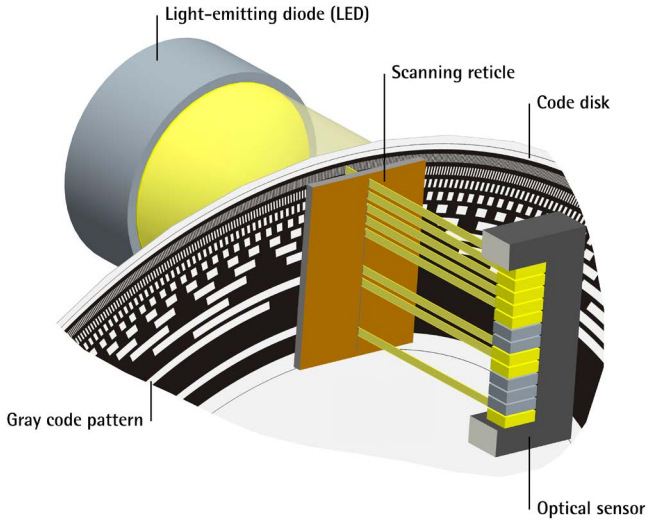
AN ABSOLUTE ENCODER

is designed to output the absolute position information. It relies on a unique code pattern encoded on the disc / magnetic ring, so it can provide a unique and unambiguous position without requiring knowledge of any previous position (actual position).

In addition a rotary encoder can be either optical or magnetic depending on the sensing technology it uses.
The working principle behind an **optical encoder** lies in a **code disc** (it can be made of glass, metal or synthetic material) mounted on the rotating shaft, with a radial grating of transparent/opaque slots around the perimeter.

As the disc rotates, a light beam generated by a LED shines through the slots and is sensed by an optical sensor which produces the encoder's output. Depending on the scanning method optical encoders can be transmissive or reflective.

Magnetic encoders can use either a magnetic code ring with MR sensing element or an IC sensor. In the first method the ring is coded with a sequence of North and South poles and mounted on the encoder or the axle shaft. The MR sensor detects the shift in the magnetic field and converts it into sinusoidal signals or an absolute serial signal. When a IC sensor is used, a 2-pole magnet integral with the shaft rotates over the center of an interpolator so providing complete information at output.



Basics of optical kit encoders and magnetic modular encoders

Optical kit encoders and magnetic modular encoders are actually a specific type of rotary encoder.
As conventional rotary encoders they respond to rotational motion, can be incremental or absolute and use either optical or magnetic sensing technology.
The basic difference between them is that kit and modular encoders have a compoundable design. The coded disc/magnetic ring and the scanning unit are two separate elements and need to be assembled and integrated directly into the application (the coded disc / magnetic ring -i.e. the rotor- mounts on the host shaft, e.g. at the end of a motor); the scanning unit -i.e. the stator- bolts to the main frame). This means that they rely on the equipment they are coupled to to get the proper operational configuration. Furthermore they are **shaftless, bearingless as well as frameless** in some cases.
Rotor and stator have no moving parts and are therefore **wear-free** and work together without making contact. The absence of contact limits the risk of failures due to vibration, shocks or mechanical stresses; while the lack of wear eliminates machine downtimes and maintenance.

Overall footprint and weight

Their design gives an immediate advantage. The elimination of a large part of the mechanical components that are installed in a traditional rotary encoder (bearings, frame, shaft, etc.) allows to reduce the overall footprint as well as the costs of the devices. So kit encoders and modular encoders have **small and compact size, very low profile, minimum thickness** and minimum weight and can be easily installed also in constricted spaces such as direct drive torque motors.

For this reason they are becoming the **first choice of robot and motor manufacturers** and for applications where a **direct integration** with the mechanical transmission device is required.
The use of miniaturized circuits and the mechanical simplicity enable magnetic modular encoders to have further smaller space requirements than optical kit encoders.

Lika Electronic Srl
T +39 0445806600 • F +39 0445806699
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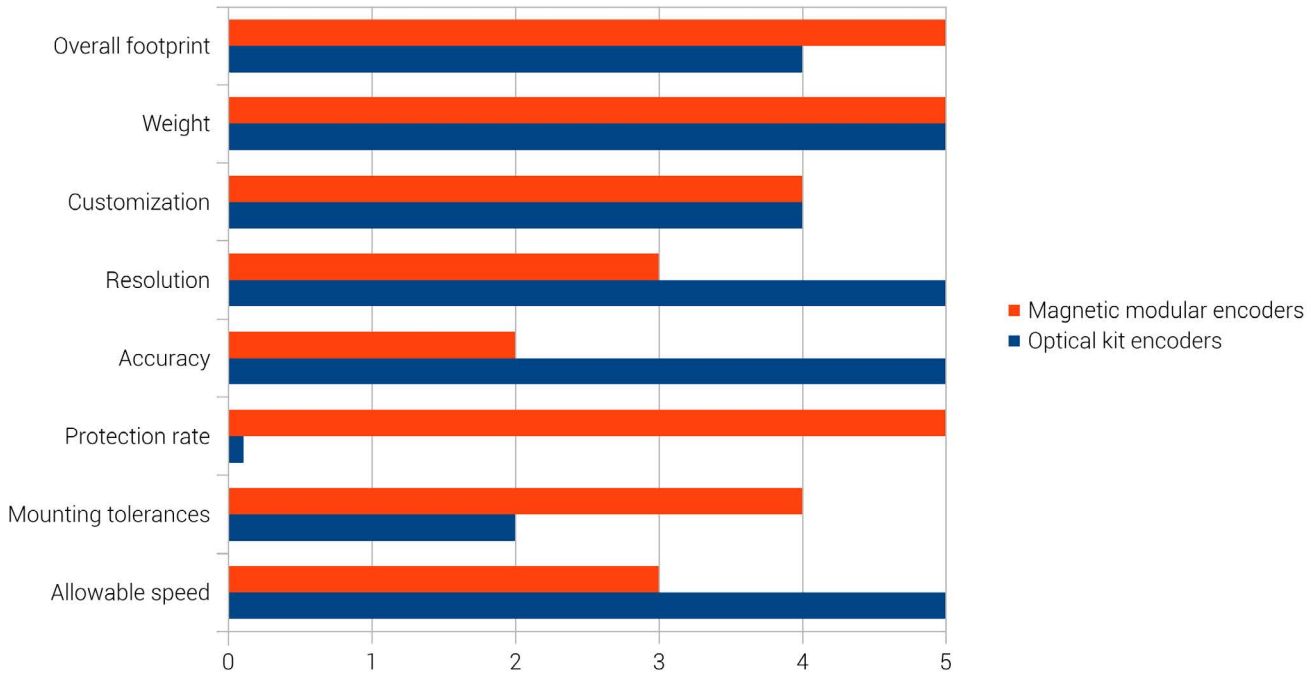
There are several other advantages over the traditional rotary encoders, yet they need specific considerations depending on whether it is about an optical kit encoder or a magnetic modular encoder.

The horizontal bar graph below shows a comparison between the main benefits provided by optical kit encoders (represented by blue bars) and magnetic modular encoders (represented by red bars). The highest is the bar value (0 … 5), the better is the performance (minimum size, minimum weight, maximum customization, maximum resolution, etc.).



Customization

Kit and modular encoders can be easily customized in nearly any shape and in a range of sizes.

Their mechanical and electrical features (support type and material, through hollow shaft and ring diameter, PCB shape and size, mounting configuration, resolution, type of interface and electrical connection, diagnostic information, etc.) can be tailored to meet individual needs and the varied market requirements.

Magnetic modular encoders enable even more **flexibility and freedom of design** and the market offers a variety of encoder's configurations: *small to very large diameter rings, segmented rings for large shaft machinery, flat rings for axial mounting of the sensor* (instead of radial mounting as usual), encoders specifically engineered for installation on the inner side of arcs, C-face motor encoders, etc.
Furthermore they are the most suitable solution for installation in very large shafts.

Resolution and accuracy

The **resolution** is the smallest change in measurement that can be measured; otherwise it is the spacing between two consecutive discrete points, i.e. the sequence of information.
For **incremental encoders**, resolution is defined as pulses per revolution (PPR, for instance 2,048 PPR).
For **absolute singleturn encoders**, it is counts per revolution (cpr; for instance 4,096 cpr).
Multiturn encoders (those that track over multiple 360° turns) are specified in counts per revolution (cpr), and the number of turns, usually defined in terms of bits (for instance 4,096 cpr x 16,384 turns is 26 bits).

The **accuracy** is the deviation between actual and theoretical position and refers to the maximum error of a position reading.

Typically, optical encoders can reach much higher resolution and accuracy values than magnetic encoders, thus they are ideally suited for dynamic and demanding motion control applications where high-level requirements for accurate position and speed feedback are needed, such as robot joints and mechanical transmission devices.

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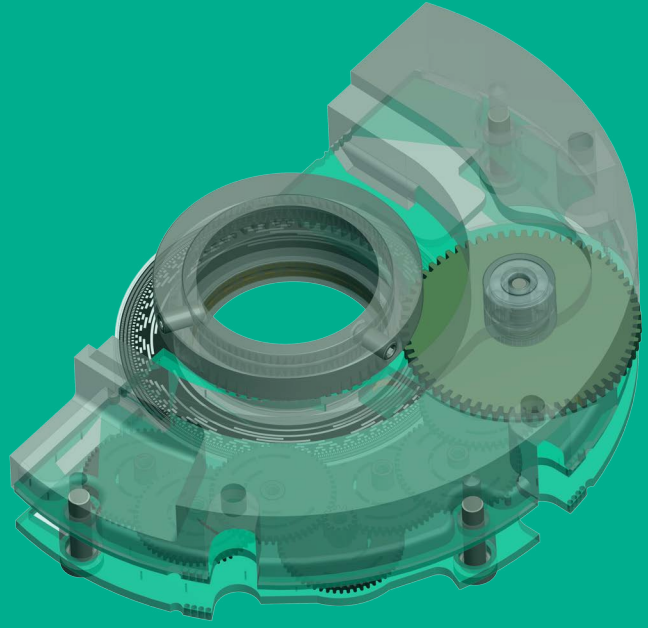
T +39 0445806600 • F +39 0445806699
info@lika • www.lika.it



Kit and modular encoders are not subject to resolution limitations and can reach the same values as the conventional encoders.

There is an important remark about the accuracy, in particular referred to optical kit encoders.
The improper mount of the kit / modular encoders as well as the level of rigidity and stability of the mechanical assembly can affect the accuracy.
Traditional optical encoders can be properly assembled and calibrated at factory so avoiding any misalignment between the disc and the sensor.

Kit and modular encoders need to be assembled “in the field” and any axial and radial run out can reduce the system accuracy.
For this reason they are expressly designed to ease the proper installation and eliminate the mounting inconveniences; in some cases they may require installation tools and calibration softwares.

Protection rate

Modular magnetic encoders withstand dirt, dust, water, and temperature changes far better than optical encoders.
They are **insensitive to external interferences** and most contaminants such as light, moisture, humidity, oil, grease, chemical agents and are able to guarantee higher shock and vibration resistance values. Furthermore they enable to easily adopt PCB protection methods such as encapsulating, tropicalization, conformal coating, varnishing. So **they can achieve the highest protection rates (IP67 to IP69K)** and are suitable to reliably operate in the harshest industrial environments.

Optical kit encoders are frameless and supplied without enclosure.
They are designed to all intents and purposes for direct integration into the host. So they necessarily need to be protected properly and the IP rate they achieve is the IP rate of the application’s housing. Consequently it is the application designer’s task to take the appropriate measures for the encoder’s protection and to ensure safe and reliable operational conditions through proper installation.

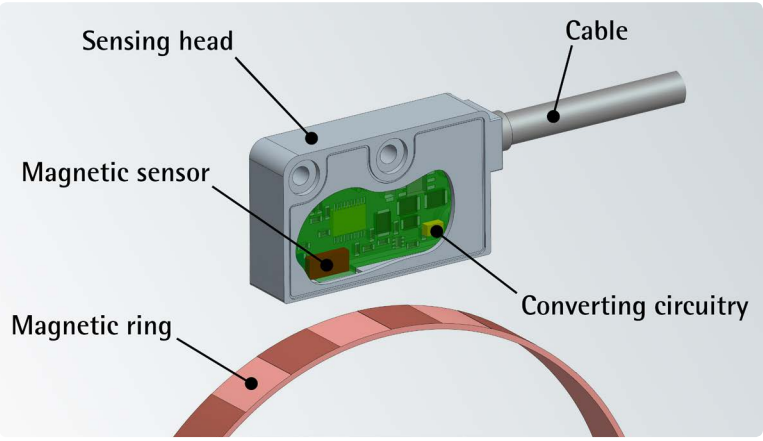
Mounting tolerances

As previously stated, kit and modular encoders need to be assembled “in the field” and mounting requirements must be fully met in order to achieve proper operation, performance specifications (such as accuracy, see above) and longer service life of the encoder.

Since kit and modular encoders have no integral bearings, they must rely only on the accuracy of the host application.
Engineers must always take into great consideration the encoder’s requirements when designing their system and limit critical factors such as axial end play or radial run out of the shaft. If the shaft of the application has a significant amount of axial or radial run out, it is preferable to install conventional shaft encoders.
Tradition encoders in fact can be further equipped with additional mounting accessories such as flexible couplings and fixing plates that minimize these factors.

Magnetic modular encoders are characterized by **simple mounting processes and uncomplicated adjustments.**
They allow mounting tolerances that are more generous than the ones required by optical kit encoders.

Their electronic and mechanical simplicity makes the mounting process far easier.
Typically the gap between the magnetic ring and the sensor as well as the lateral deviation are in the range of millimeters. Also roll, tilt, and yaw are measured in a few degrees.
Often **diagnostic LEDs** help users to find the tolerance limits and properly install the measuring system.
It is more crucial to mount the optical kit encoders according to the specified mounting tolerances in order to ensure proper operation and achievement of specifications.



So in specific models they are supplied with installation tools and calibration softwares hat allows the installer to easily meet the mounting tolerances and the correct alignment.

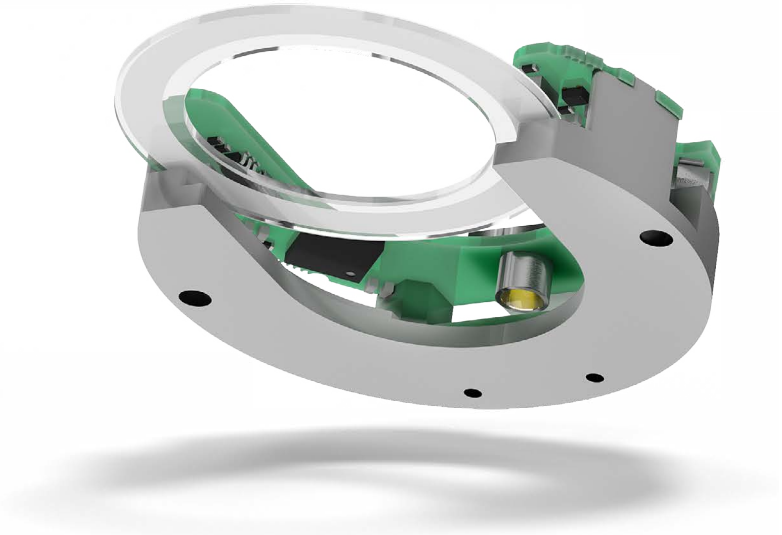
Lika Electronic Srl
T +39 0445806600 • F +39 0445806699
info@lika • www.lika.it

Allowable speed

The operational speed of the traditional encoders equipped with bearings is often limited to 6,000-12,000 rpm.
If higher speeds are required, kit and modular encoders may be the better choice.
Typically optical encoders are able to reach higher speed values, so they are more suitable for demanding applications where high resolution, high accuracy and high speed are a primary concern.

Shaft encoders with bearings suffer shocks, vibrations, mechanical loads and increase in temperature more than bearingless encoders. Mechanical stresses typically shorten bearing operational life.

Rotary encoders without integral bearings limit such fault conditions.



Applications

The design of high-performance, compact, and lightweight devices has always been an important topic across several industries.
Nowadays it is becoming the focus.
The most prominent and advanced sectors such as aerospace and robotics lend evidence to this current trend gaining momentum. Technology fusion and integrated devices are the prerequisite for smaller, more efficient, and more precise automation systems.

Optical kit encoders and magnetic modular encoders are first and foremost designed for direct integration into host applications.
Their compact, slim, and lightweight design allows the automation system designers the greatest flexibility, especially in applications where constricted or hardly accessible space and minimum weight are crucial. The elimination of parts that add size also gives designers the advantage of reducing cost.
For these reasons they are becoming the first choice of robot and motor manufacturers.
Kit and modular encoders can also take the form of small and inexpensive devices, so they are recommended for high-volume applications.
Optical kit encoders are best suited for high-dynamics applications with very little space where bearingless operation, high resolution, high accuracy, high speed, double track option for position and speed feedback (absolute and incremental tracks) are required.
They are ideal for installation in a wide range of applications in standard industrial environments including the following: **through hollow shaft motors and servomotors** (such as direct drive torque motors and brushless motor kits), **industrial robots and robot joints in particular, semiconductor industry, optical tracking systems, AGV systems for material handling and warehouse operations, slip ring assemblies, electromedical and surgical equipment and instruments, and high-performance mechanical transmission devices.**

Customization, bearingless design, minimum size, easy mounting, the highest IP rate are the prominent characteristics of magnetic modular encoders. As they are rugged, insensitive to dust, moisture and oil, and highly resistant to shocks and vibrations, they are ideal for reliable operation in harsh and even extreme industrial environments. They perform well over a wide range of assembly tolerances.
Their typical applications are **industrial robots and robotic arm joints, through hollow shaft and large shaft motors, servomotors, torque motors, radars and antennas, video surveillance systems**, **electromedical and surgical equipment, optical tracking systems, OEM applications**, and a variety of motion control and outdoor applications.

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T +39 0445806600 • F +39 0445806699
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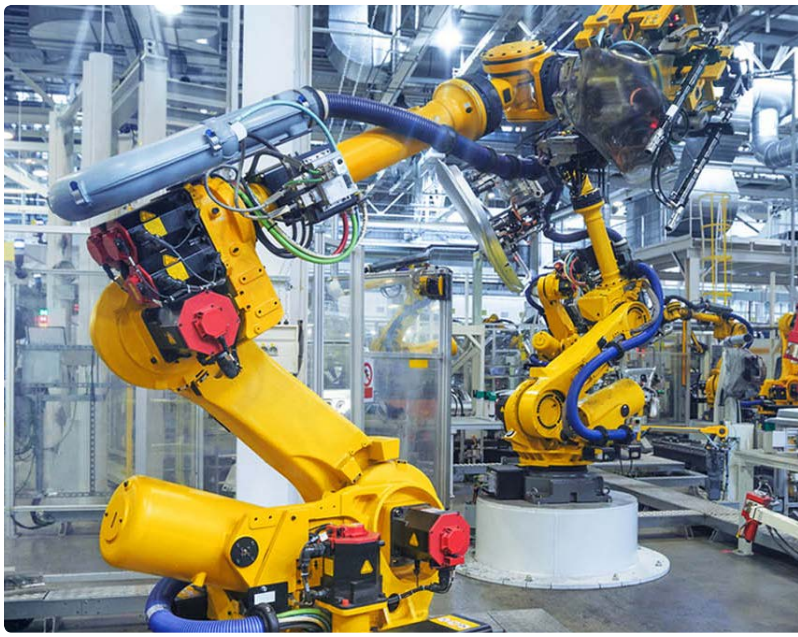

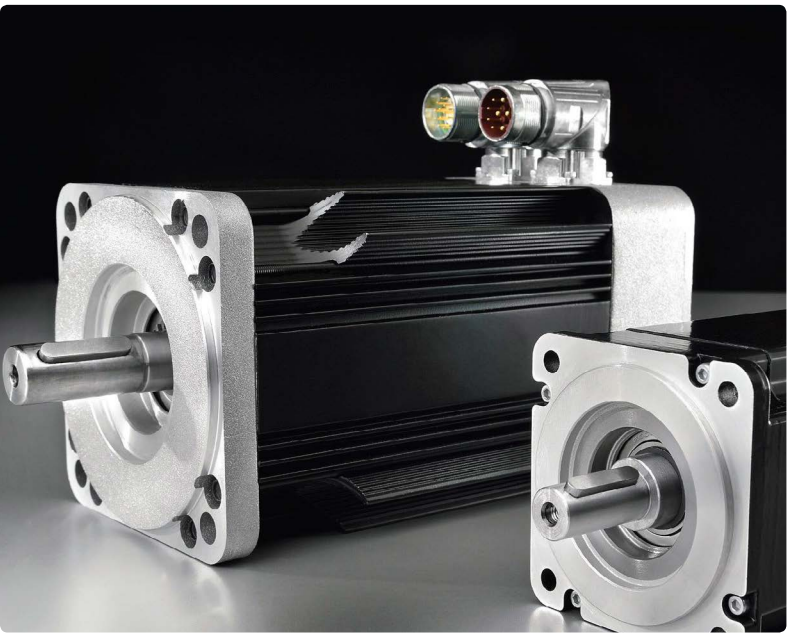

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Lika Electronic Srl
Via S. Lorenzo, 25
36010 Carré (VI) • Italy
Tel. +39 0445 806600
Fax +39 0445 806699
info@lika.it • www.lika.biz

Asia branch

Lika South East Asia Co. Ltd
Banwah Ind. Estate • Bang Pa-in Ayutthaya
13160 Thailand
Tel. +66 (0) 3535 0737
Fax +66 (0) 3535 0789
info@lika.co.th • www.lika.co.th