One heavy-duty encoder technology delivers reliability in tough environments.

Tougher than nails

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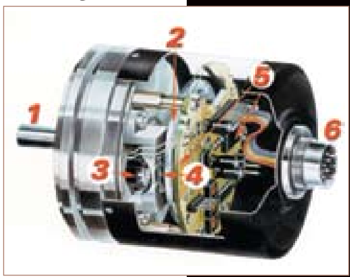
Traditional industrial encoders, whether incremental or absolute, satisfy many general industrial motion control applications. However, the heavy-duty encoders pictured here withstand more severe conditions.

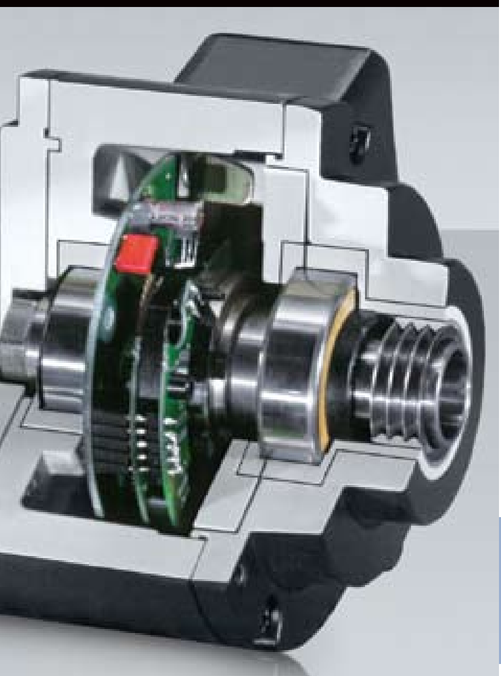
Rotary encoders are used in a range of industrial applications, from speed monitoring on conveyor systems to position control on automated handling machines. Industrial-rated encoders function effectively in rotational monitoring applications including motors, drives, automated process machines, robots, and elevators. However, these devices are more likely to fail when placed in operating environments that subject them to aggressive contaminants, impact, high shock and vibration, long-term submersion in liquids, intensive cleaning procedures, or EMI noise. Many industrial manufacturers use these off-the-shelf encoders without realizing the total impact of the operating environment on the machine. When standard encoders fail, downtime costs related to encoder failure can quickly grow to several times the cost of the encoder itself. In contrast, one heavy-duty encoder technology ensures long-term survival, even under challenging conditions.



There are six main components in every optical encoder: 1) Shaft and bearing assembly 2) Pulse disc 3) Light source 4) Grid diaphragm 5) Photodiode/decoding circuitry, and 6) Connector.

Hanging tough: To withstand liquid and solid particulate contamination, heavy-duty encoders feature die-cast housings and robust designs that permit reliable operation in open-air applications where normal encoders would fail.

With the potential to flow through the earthed encoder housing to the ground, shaft currents are very dangerous as spark erosion can cause lasting damage to the balls and the bearing surfaces. Ceramic ball bearings with special isolation resistance between the housing and shaft of the encoder can prevent the buildup of shaft currents.



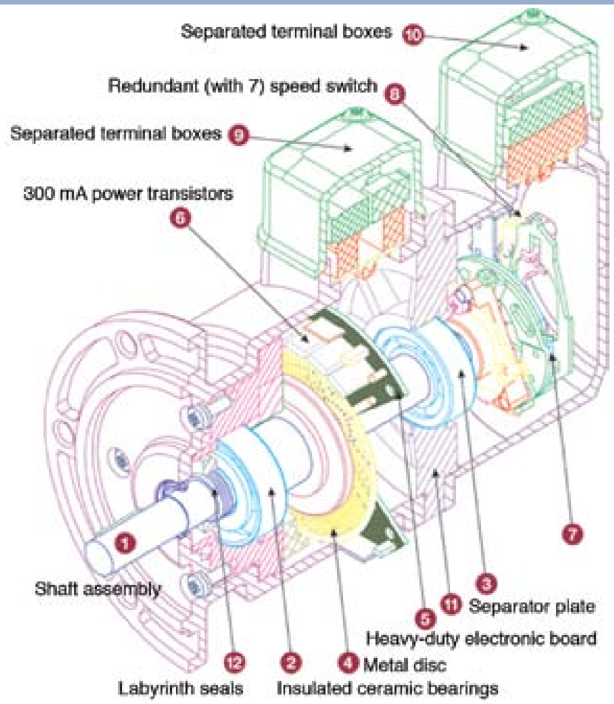
Harsh-environment challenges

Encoders are commonly used in harsh end-use applications, including food and beverage processing, heavy equipment, cranes, specialty vehicles, energy generation equipment, chemical and petroleum processing, medical devices, wastewater treatment, shipbuilding and marine vehicles, printing equipment, and other indoor and outdoor uses. In such harsh environments, there are three common causes of encoder failure: Solid particulate or liquid contamination, mechanical bearing overload, and signal-output failure. As a result of these problems, the encoder ceases to operate or the system operates erratically.

Ambient temperature variations can accelerate encoder failure rates. During encoder cool down, pressure differences between the outside environment and inside of the housing can cause the encoder to breathe, drawing air inward. As the temperature of an encoder's housing drops, any contained humidity condenses inside of the housing, resulting in the collection of dew on printed circuit boards, wiring, and code disc. This liquid ingress can quickly lead to encoder failure.

There are many applications where liquid ingress naturally occurs when encoders come into direct external contact with water, coolants, lubricants, and cleaning

Resilient models



Running at speeds up to 30,000 rpm with nearly zero wear, heavy-duty encoders monitor speed and position in harsh applications — for wind energy, steel processing, heavy industrial equipment, heavy duty vehicles, oil and gas processing, printing equipment, metal stamping and die casting, and motor and drive control.

Heavy-duty encoders pass tests that verify how much tougher they are than standard encoders. Resonant frequencies are checked (during development) on a measurement rig with continuously tunable frequency and amplitude, and a sine-wave sweep from 10 to 2,000 Hz. Assembled printed circuits are tested and optimized for component resonant frequencies so that components do not vibrate excessively, damage the output circuit, or break loose.

agents. Often, these applications are found outdoors or in environments subject to high-pressure washdown such as food and beverage processing facilities. For example, when yogurt is placed into containers during production, an encoder is often used to monitor the rotation of the rotary table that controls container filling. At the end of a day's production run, the packaging machine is washed down for sanitation purposes. This process involves cleaning the equipment by spraying hot, high-pressure liquid onto the machinery.

Liquids are not the only contaminants that encoders must endure. In harsh environments, encoders are often exposed to particulates such as sand, salt, wood chips, and dust particles. These particulates enter the encoder, block optical processes, and cause device failure. Paper plants and wood processing are prime examples of environments in which such failure is almost guaranteed with standard-rated encoders.

In paper processing, encoders monitor the speed or position of the rotary processes that control the flow of pulp into the machine and the feed of paper onto spools. Paper production is a

Traditional encoder operation

All optical encoders operate in the same basic way. A light source directs rays through a plane convex lens that focuses the light into a parallel beam. The light beam passes through a grid diaphragm, which splits it to produce a second beam of light 90° out of phase. Light passes from the original A and second B channel through a tempered glass, polycarbonate, or metal pulse disc onto a photovoltaic or photodiode array. The pulse disc turns, creating a light/dark pattern through the clear and opaque segments of the disc.

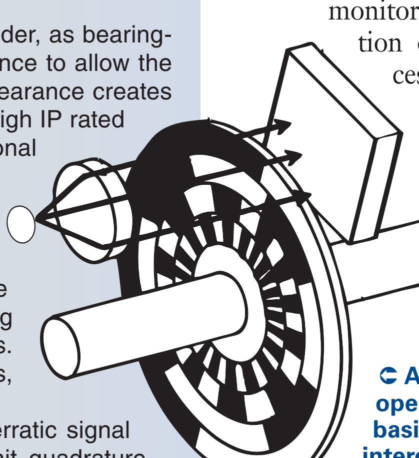
The light/dark pattern is read and processed by the photodiode array and decoding circuitry. Light beams A and B are each received by a separate diode and converted into two square-wave signals, 90° out of phase, commonly known as quadrature output. This output is then fed to a controlling device that processes the signal to determine number of pulses, direction, speed, and other information.

To operate flawlessly, optical encoders require a clean path from their emitter diodes to their receiver array through the pulse disc, which is located directly between the two. The encoder shaft (and therefore the connected pulse disc) rotates, forming a critical interface between the encoder electronics shaft and bearing assembly and the outside environment.

It is impossible to manufacture a perfectly sealed optical encoder, as bearing-to-shaft assembly is never perfectly tight. There must be clearance to allow the bearing to slide over the shaft during encoder assembly. This clearance creates openings or paths through which contaminants can wick. Even high IP rated bearings with rubber or plastic lip seals cannot cover all rotational speeds, encoder designs, and mounting positions. All seals are subject to wear, aging, and the effects of UV radiation.

Bearings allow the shaft to turn while permitting the housing to remain still. As they are not designed to support high loads under normal circumstances, mechanical bearings can become overloaded in harsh environments. Common causes of bearing failure are shock, vibration, and excessive radial and axial loads. These loads can cause excessive strain on encoder bearings, forcing them to become noisy and to fail.

On a factory floor, standard industrial encoders can deliver erratic signal output resulting from damage to the sensitive ICs that transmit quadrature output to the controlling device. Such damage can result from EMI or radiated noise from factory equipment surrounding the encoder. In large factories, long distances between the encoder and controlling electronics can also impair the quadrature output, resulting in intermittent failures.



All optical encoders operate in the same basic way: A disc intercepts light beams to create a pattern interpreted by decoding circuitry. Housing, sealing, mounting, and support structures make some more resilient.

Encoder electromagnetic compatibility (EMC) is tested for burst-voltage capability in a pulse-voltage test setup.

notoriously dirty process, and the environment is filled with small liquid drops containing pulp. In its liquid form, pulp collects on nearly everything in the plant, resulting in the formation of a fur on all components, including encoders. Even standard industrial encoders with high IP ratings do not withstand such contamination for long; failure quickly occurs as particulates enter encoder housings and block internal optical equipment.

Heavy-duty encoders

Heavy-duty encoders withstand applications and environments that normally cause standard encoders to fail. The robust design is inherently different: As their first line of defense, heavy-duty encoders incorporate labyrinth seals with reverse-lead spiral grooves that prevent the ingress of liquids and particulates into the housing. These seals allow heavy-duty encoders to be exposed to moisture, temperature extremes, chemicals, and vibration beyond traditional encoder limits.

In addition, larger ball bearings are fitted on opposite sides of a solid die-cast housing surrounding sensor electronics. Although these encoders typically take up more space, they feature a durable shaft preload condition that can withstand much greater forces in both radial and axial directions — so harsh-duty

Fire protection without water ingression

One of the toughest real-world applications for heavy-duty encoders: latest-generation fire extinguisher boats. Here, heavy-duty encoders manage the positioning of remote-controlled jet pipes that throw tons of seawater per minute over a distance of more than 100 meters onto fire. To effectively control the jet pipes, the encoders are positioned with the shaft side facing upward. Normally, this positioning would allow seawater to rapidly enter a standard industrial encoder. In contrast, heavy-duty encoders are hermetically sealed — so seawater cannot enter the encoder housing or damage internal electronics.

In fact, heavy-duty encoders can be submerged in liquids for extended periods or cleaned with pressure washers without failing — making these devices suitablefor marine applications. The encoders pass water-jet tests with strong jet streams at a pressure of 12 bars and a flow rate of 100 liters/min. During tests, the encoders are also immersed in water to a depth of 1 meter to ensure that sealing complies with IP67 standards. For marine and specialized food-grade and wash-down environments, heavy-duty encoders with full stainless steel housings utilize a specialized *Simmerring* seal for deep immersion, and hermetic encapsulation protects the encoder electronics from the outside world. The hermetic encapsulation allows the encoder to work unimpaired by environmental forces, as the magnetic field of the encoder permanent magnet is the only thing that can pass through the encapsulation. Some units reach the highest protection classes of IP 68 and IP 69K.

encoders survive shocks up to 500 *g* and operate reliably in temperatures from -40 to +100° C.

Ceramic ball bearings (with special isolation resistance between the housing and encoder shaft) prevent the buildup of shaft currents from large ac motors and generators. With the potential to flow through the earthed encoder housing to the ground, these shaft currents are dangerous as spark erosion can cause lasting damage to the balls and bearing surfaces.

In all rotary encoders, the sensor electronics and code disc are located inside the housing between the bearings. However, in heavy-duty encoders, code discs are made of metal instead of glass or plastic. Glass discs are susceptible to scratching and fracture under shock. Plastic discs are quite shock resistant, but are more likely to warp and lose their shape at higher temperatures. Plastic discs are also more likely to break down in chemically aggressive environmental conditions. Metal discs better withstand shock, heat, and chemicals, and do not break down.

The die-cast housing on heavy-duty encoders allows the shaft length to be extended between bearings to allow a second encoder device or a mechanical centrifugal switch to be mounted. The second device triggers an action when a specific speed limit is exceeded and is electronically independent of the first system, providing the redundancy needed in applications where extreme safety is required. For example, if the blades on a wind turbine are turning too fast in a windstorm, the secondary device slows the blades to protect the turbine from damage.

To prevent signal output failure, specially coated large terminal boxes can provide resistance to electromagnetic compatibility (EMC) fields. Encoders designed with large terminal boxes can be rotated through 180° to position the cable opening to the left or the right of the encoder. This facilitates the encoder's installation into any system. Besides other tests, heavy-duty encoders pass vibration, continuous shock, dust protection, and water jet testing.

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