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Technology Overview

If there's any one truism in engineering it is that there's no one perfect solution – there's only the best solution for the application at hand. When it comes to feedback devices, OEMs have a wide range of options. Should you use a resolver or an encoder? If you need an encoder, should you select an Incremental or an absolute encoder? Should you opt for an optical or a magnetic device? What is the most appropriate mounting configuration? Do you need ingress protection (IP), and if so, to what level? How about resolution? The sheer variety of choices can be overwhelming, but while you're well advised to work closely with your vendor to make a final decision, there are a few main things to consider when narrowing down the right feedback options for your system.

There are two main types of feedback devices: Encoders (both incremental and absolute) and Resolvers. Also, within encoders there are two main sensing technologies used today: Optical and Magnetic.

INCREMENTAL ENCODERS

Incremental encoders provide speed, direction and relative position feedback by generating a stream of pulses proportional to the rotation of a motor or driven shaft. Single channel incremental encoders can measure speed while dual channel or quadrature encoders (AB) can interpret direction based on the phase relationship between the 2 channels. Indexed quadrature encoders (ABZ) are also available for homing location at startup. Incremental encoders are typically used in cut-to-length, crane or hoist, web based or continuous stream processing (such as pulp, paper, steel) and heavy vehicle applications.

ABSOLUTE ENCODERS

Absolute rotary encoders measure actual position by generating a stream of unique digital codes (instead of pulses) that represent the encoder's actual position. Single turn absolute encoders output codes that are repeated every full revolution and do not output data to indicate how many revolutions have been made. Multi-turn absolute encoders output a unique code for each shaft position through every rotation, up to 4,096 revolutions. Unlike incremental encoders, absolute encoders will retain correct position even if power fails without homing at startup. Absolute encoders are typically used in CNC, medical and robot applications where high resolution is required and absolute feedback reduces power up sequences.

RESOLVERS

A resolver is a rugged, analog device that can provide position and velocity feedback for a wide range of demanding applications, from wood processing to semiconductor fabrication, from radiation treatment machines to steel mills. Because the resolver is an analog device and the electrical outputs are continuous through one complete mechanical revolution, the single speed (2-pole) devices offer infinite theoretical resolution. Resolvers can be frameless or housed and are used in applications that are environmentally demanding. This means extreme temperatures, shock and vibration. These applications can be aerospace, military, CNC, off highway vehicles and radioactive (for example nuclear reactors and medical)

OPTICAL SENSING

Optical encoders use light (optics) to identify unique positions for the encoder. Optical encoder engines can bring almost unparalleled resolution and accuracy for both incremental and absolute encoders. This makes an optical encoder a desirable choice where precision matters. With modern phased-array technology, an optical encoder is increasingly able to perform in much tougher environments which require a combination of durability and resolution

MAGNETIC SENSING

A magnetic encoder uses magnetic fields to identify position for the encoder. Magnetic encoder engines typically excel in areas where most other encoder technologies fail. They are more robust in nature and are designed to output reliable digital feedback in the most demanding and harshest of application environments with high shock and vibration, contaminated areas,

It is also important to note the distinction between resolution and accuracy. The illustration in **Figure 1** shows that although there is the same number of transitions in a rotation, they can clearly be in the incorrect real position if the feedback device has poor accuracy. The application engineer must pay very close attention to the accuracy of high resolution devices; it can be misleading.

RESOLUTION AND ACCURACY

Resolution is the number of measuring segments or units in one revolution of an encoder shaft or one inch or mm of a linear scale. Shaft encoders are available with resolutions up to 10,000 pulses per revolution (PPR) directly, and 40,000 PPR by edge-detection of the A and B channels, while linear encoders are available with resolutions measured in microns. The bottom line is, the selected encoder must have resolution equal to or better than that required by the application. But resolution is not the whole story.

Accuracy and resolution are different, and it is possible to have one without the other. **Figure 1** shows a distance X divided into 24 increments or “bits.” If X represents 360° of shaft rotation, then one revolution has been resolved into 24 parts. While there are 24 bits of resolution, the 24 parts are not uniform. This transducer could not be used to measure position, velocity or acceleration with any accuracy. On the other hand, in **Figure 1** the distance X is divided into 24 equal parts. Each increment represents exactly 1/24 of a revolution.

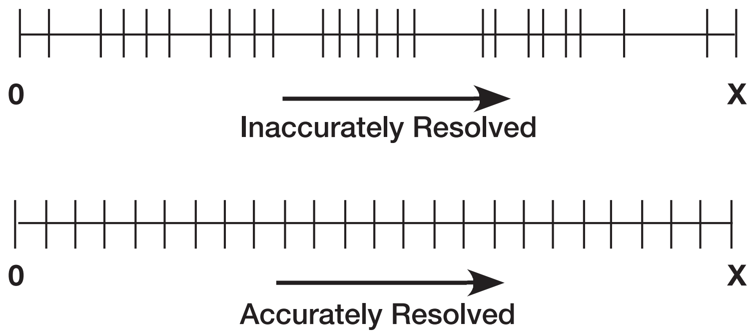

Figure 1: Resolution and Accuracy

This transducer operates with accuracy as well as resolution. Accuracy, however, can be independent of resolution. A transducer may have a resolution of only two parts per revolution, yet its accuracy could be ±6 arc seconds.

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FEEDBACK DEVICES

Encoders provide feedback for a wide range of motion tasks from positioning a patient in an MRI machine to bottling beverages at 300 units per minute. When it comes to specifying an encoder, users must make decisions about a number of key characteristics. Are they tracking linear or rotary motion? Should they use optical or magnetic technology? And, perhaps most essential to the success of the application, should they choose an incremental or an absolute encoder? Even when incremental and absolute encoders are based on the same sensing mechanism, the two deliver very different performance.

As the name suggests, an absolute encoder maintains a record of its position within some absolute coordinate system, whereas an incremental encoder outputs incremental changes from a predefined home position. As a result, an incremental encoder requires additional electronics (typically a PLC, counter, or drive) to count pulses and convert the data into speed or motion, while an absolute encoder produces digital words identifying absolute location. Not surprisingly, incremental encoders are typically better suited to simpler, lower performance applications, while absolute encoders are most often used in more complex, mission-critical applications with higher speed and position control requirements. The correct choice of output type depends on the application.

INCREMENTAL ENCODER OVERVIEW

An incremental encoder can be used in positioning and motor speed feedback applications. An incremental encoder provides excellent speed and distance feedback and, since there are few sensors involved, the systems are both simple and inexpensive. An incremental encoder is limited by only providing change information, so the encoder requires a reference device to calculate motion.

HOW AN INCREMENTAL ENCODER WORKS

When an incremental encoder moves, it generates a stream of pulses proportional to the rotation of the shaft (rotary encoder) or distance traveled (linear encoder). In the case of an optical design, a patterned disc or linear strip passing between an LED and a photo-sensor alternately passes or blocks the beam, producing an analog signal; additional circuitry, often in the form of an onboard ASIC, converts this signal to a square wave. Magnetic encoder designs can be based on any one of a variety of mechanisms but typically involve rotating a magnetic field to generate a voltage pulse or a change in resistance that can be converted into a pulse.

Single-channel incremental encoders feature a single stream of output pulses. As a result, they can only provide limited information. Based on the resolution of the encoder— i.e., the number of pulses per revolution in a rotary design or millimeters/inches of travel in a linear design—the external electronics can count pulses to calculate speed, or track offset relative to some reference coordinate (home), which can be used to determine position. Single-channel designs provide good solutions for applications like single-direction conveyor systems.

Although they are simple, robust, and economical, single-channel incremental encoders have an important limitation—they cannot be used to determine direction of motion. That task requires more input, typically from a dual-channel design that generates output over two distinct channels (“A” and “B”), which are 90° out of phase with each other. One channel will always lag the other. By determining whether “A” lags “B” or “B” lags “A”, you can determine the direction you are moving. These dual-channel designs are sometimes called quadrature encoders due to the four rise and fall points of their signal output. The direction of travel determines which channel goes high first, allowing the processor to easily monitor direction of motion **(see Figure 2)**. Resolution can be increased by as much as a factor of four by triggering on the leading and/or trailing edge of the pulses for one or both channels.

Quadrature encoders provide robust solutions for challenging applications. In a high-vibration environment, for example, a single-channel encoder might misinterpret the pulse stream generated by an axis wavering about a set point as a real displacement. A quadrature encoder would be able to recognize the changes in direction and ignore the pulse stream or filter it out as noise.

Incremental encoders can also include an additional channel known as the index, or Z channel. This track causes the encoder to generate a pulse once per revolution for a rotary encoder or at a specific position for a linear encoder **(see Figure 3)**. The Z channel can be used as a mark to identify the starting position of the encoder. Another term for this is the "Home Position". For high-speed applications, it can be an easy way to indicate a single revolution, which can then be calculated with time to yield RPMs.

COMMUTATION (U, V, W) CHANNELS

Commutation (U, V, W) channels **(see Figure 4)** can also be provided on some encoders. These signals are aligned to the commutation windings found on servo motors. They also ensure that the drive or amplifier for those motors apply current to each winding in the correct sequence and at the correct level.

INCREMENTAL ENCODER APPLICATIONS

Applications suitable for incremental encoders are generally simple, only requiring a direct connection between the encoder and the control device regardless of whether it is a counter, PLC, or drive.

In theory, incremental encoders are applied where velocity control is important to the process such as:

- Determining motor speed control for web processing both in the uptake and roller synchronization
- Precise acceleration on crane lifting applications when lifting, holding and lowering the load
- Classically used in the acceleration and deceleration for drive motor applications in electric hybrid or off highway vehicles
- Accurately controlling conveyor speed and position in Food and Beverage
- Camera synchronization for accurate positioning, identification and sorting in packaging applications
- Pump speed monitoring to identify movement in petrochemical industries

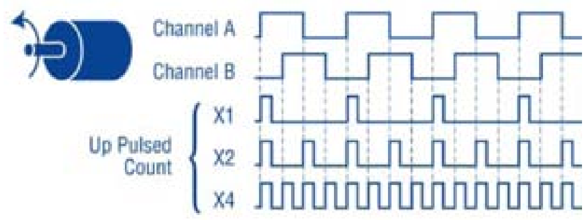

Figure 2: A quadrature encoder generates two pulse streams that are 90° out of phase with one another. As a result, the system can determine directionality by monitoring which channel leads in phase. Triggering off of the leading and or trailing edges of the pulses can increase resolution by up to four times.

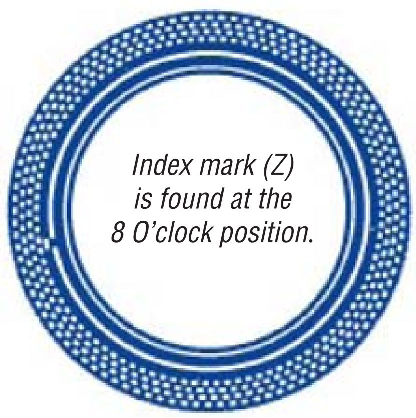

Figure 3: Code disc for an optical quadrature encoder shows the inner ring for the Z channel, which generates a single pulse per revolution. The outer bands correspond to the A channel and B channel; notice that they are offset by 90°.

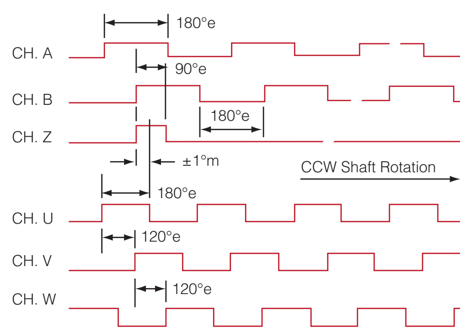

Figure 4: Commutation Channels

ABSOLUTE ENCODER OVERVIEW

Every absolute rotary encoder is used to determine the speed or position of something – the difference is in how that encoder determines that movement. The "how" defines what type of encoder works in your application. Absolute encoders work in situations where accuracy for both speed and position, fail tolerance, and interoperability matters more than system simplicity.

HOW AN ABSOLUTE ENCODER WORKS

Absolute encoders provide an effective alternative suitable for high-reliability applications. An absolute encoder generates output as digital words that identify its position as a static reference point within an absolute coordinate system. As a result, even in the event of power outage, an absolute encoder maintains record of its absolute position. Upon restart, the system can resume motion immediately, without rehoming. Because absolute encoders output data as a digital word, absolute encoders are compatible with a range of communications protocols and busses, including BiSS, synchronous serial interface (SSI), DeviceNet, Profibus, Interbus, CANopen, CanLayer2, Parallel and a number of Ethernet-based protocols.

Most often absolute encoders use either geared or wiegand wire technology. An absolute "geared" rotary encoder features a code disc attached to the shaft and a fixed mask that allows the system to essentially create a unique binary identifier for each point of travel (linear versions operate analogously, but for the sake of simplicity, we'll focus on rotary versions here). As the code disc rotates atop the fixed mask, the system periodically reads out the identifier, outputting it as a multi-bit digital word. The associated controller or drive polls the encoder to capture position data that it can use directly or process into velocity information.

In the case of an optical encoder, the fixed mask features alternating transparent and opaque regions. Similarly, the code disc is patterned with transparent and opaque regions to define a set of rings (tracks) and periodic radial zones on those tracks **(see Figure 5)**; each track is read out by a different LED/photosensor pair. The code disc sits atop the fixed mask, which typically sits atop a sensing ASIC that contains the detector array and associated electronics. As the code disc turns, its transparent regions periodically overlay the transparent regions on the fixed mask, allowing the optical signal to pass through to the detector to generate a pulse. Each track on the code disc corresponds to a specific bit in the output; the number of tracks n generates 2n radial positions. The common standard for absolute encoders is 12 bits, or 4096 positions per rotation, although some designs offer 22 bits (4.19M positions) or more. Magnetic encoders operate analogously, substituting magnetic coding for optical coding.

***Figure 5**:* Code disc for an optical absolute encoder features one track for each bit of resolution. The number of bits n (2n) corresponds to 2n radial positions.

Some applications involving long travel distances may require a multi-turn design, in which a secondary disc (or discs) geared to the primary code disc tracks the number of rotations of the primary. Each time the primary disk completes a revolution, the secondary disk indexes. This design thus assigns a unique coordinate for each shaft position corresponding to each revolution of the index disc, up to 65,536 revolutions.

The latest innovation in absolute encoders is the wiegand wire technology. The wiegand wire technology allows you to count the number of shaft turns so you can gather position information simply without the need for batteries or gears. Instead, wiegand wire technology incorporates magnets which are used to tighten the wire until it is so tense that it physically creates a release. This release or snap of the wire creates a voltage spike that in turn represents itself as a pulse to provide you the feedback you desire. With this new technology, the absolute encoder becomes simpler, more reliable and robust.

Applications that use absolute encoders are usually more complex, requiring both hardware and software implementation in order to interact with other electronics in the system (PLC, drive, etc.).

ABSOLUTE ENCODER APPLICATIONS

The absolute rotary encoder itself understands the positioning information – it doesn't need to rely on outside electronics to provide a baseline index for the encoder position. Absolute encoders enable applications which rely on non-linear positioning to work without additional external components.

In real life, absolute encoders are applied when the position is key to the process such as:

- Determining multi-axis orientation for CNC machines used in parts manufacturing
- Automatically determining the height of scissor beds used in hospitals
- Accurately positioning multiple stabilizers for large vehicles like cranes or aerial lifts
- Moving automatic doors or bays without a limiting switch
- Continuing robotic movement cleanly even after a power failure

Especially when compared to resolvers and incremental encoders, the obvious strength of absolute encoders is how their positioning accuracy affects the overall application performance.

ENCODER APPLICATIONS

An Encoder is designed to be versatile and customizable to fit a wide variety of applications. The five broad categories of applications based on environment are:

- Hazardous Duty: relates to areas where flammable liquids, vapors, gases or combustible dusts are likely to occur in quantities sufficient enough to cause a fire or explosion.
- Heavy Duty: demanding environment with a high probability of contaminants and moisture, higher temperature, shock, and vibration requirements as seen in pulp, paper, steel, wood mills, rail and off highway vehicles.
- Industrial Duty: general factory operating environment which requires standard IP ratings, moderate shock, vibration, and temperature specs as seen in food and beverage, textile, generally factory automation plants.
- Servo/ small motor Duty: controlled environment with high accuracy and temperature requirements such as robotics, electronics, and semiconductors.
- General Purpose/ Office: commercial environments with little temperature variations, are fairly clean, and not generally subjected to high shock loading or moisture such as office printers, copiers and laboratory equipment.

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RESOLVER OVERVIEW

Resolvers are electromechanical precursors to encoders, based on technology going back to World War II. An electrical current creates a magnetic field along a central winding. There are two windings that are perpendicular to each other. One winding is fixed in place, and the other one moves as the object moves. The changes in the strength and location of the two interacting magnetic fields allow the resolver to determine the motion of the object.

Because the resolver is an analog device and the electrical outputs are continuous through one complete mechanical revolution, the theoretical resolution of a single speed resolver is infinite. Because of its simple transformer design and lack of any on-board electronics, the resolver is a much more rugged device than most any other feedback device. It is the best choice for those applications where reliable performance is required in high temperature, high shock and vibration, radiation and contamination environments. In these conditions, the resolver is the sensible design alternative for shaft angle encoding.

HOW A RESOLVER WORKS

A resolver functions as an electromechanical position transducer which is essentially a variable coupling or rotary transformer. Like all transformers, the resolver requires an AC carrier or reference signal (input excitation) to be applied to the primary winding, contained in the rotor. The resulting changing magnetic field in the primary winding induces a voltage in the secondary stator windings.

The secondary of the resolver stator consists of two sets of windings that are at right angles to each other. The magnitude of the magnetic coupling between the primary and the secondary varies according to the position of the rotating element (rotor) which then varies the amplitude of the output voltage. The amplitude of the reference or input signal is modulated by the sine and the cosine of the rotor angle to produce the sine and cosine output signals on the two secondary windings as shown in **Figure 6**.

Typically, there is one sine and one cosine wave per mechanical revolution which provides absolute position. A multi-speed resolver creates multiple sine and cosine waves throughout a revolution, which increases accuracy but at the expense of absolute position.

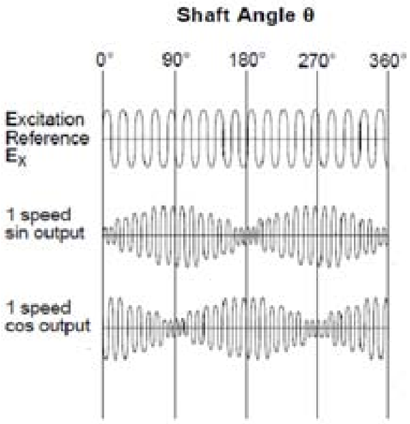

Figure 6: Resolver Waveforms

RESOLVER APPLICATIONS

The simplicity of the resolver design makes it reliable in many standard and extreme applications, extreme temperatures, high shock and vibration, radiation and contamination (dirt, oil, grease, etc.) are present. Resolvers are the ideal candidate for applications such as servo motors, factory automation, steel and paper production, oil and gas production, jet engine fuel systems, aircraft flight surface actuators, communication position systems, missile fin actuators and land based military vehicles just to name a few. (Aerospace, Military and CNC)

Notes

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ENCODER ENGINES

At the heart of every encoder lies the encoder engine that converts motion into a signal that can be translated by external electronics into speed or position. Most encoders operate based on either optical or magnetic sensing principles. Each of the two types of encoder engines has its own set of benefits and limitations. In general, optical encoders are good choices for applications requiring high resolution and/or low cost, while magnetic encoders are the best choice for harsh environments. That said, there are no hard and fast rules—some optical encoders carry a hazardous environment rating suitable for the oil and gas industry, while some magnetic encoders can be quite compact and affordable. Building a successful system requires knowing the options, understanding the pitfalls, and matching the attributes of the encoder engine to the needs of the application.

THE TECHNOLOGY OF OPTICAL ENCODER ENGINES

As the name implies, optical encoders use light (optics) to identify unique positions for the encoder. Traditional optical absolute and incremental encoders have four main components **(Figure 7)**:

- Light source (an LED light)
- Moveable disk
- Sensor
- Fixed mask

The disk will have as many tracks as signals (A, B, Z, etc.), and the mask will have windows for each track. The windows on the mask will also have a size proportionate to the window size on the disk. In manufacturing, the mask is fastened directly to the sensor. This allows for one sensor to be used with several resolution options.

The LED shines through one side of the optical shaft encoder. The disk has a series of tracks on it, similar to the concentric grooves in an LP. The mask has a corresponding track for every track on the disk of the optical encoder, and small perforations, called windows, are cut along the tracks in the mask. As the disk moves, different windows in the mask are covered or open, showing the movement and position of the optical encoder. Each arc in the rotation indicates a different position and has a different pattern of open/closed windows.

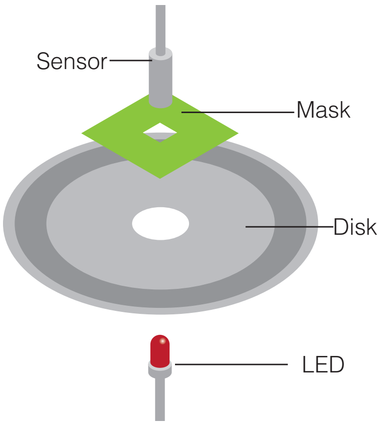

Figure 7: Traditional Optical Encoder Engine

The sensor behind the mask identifies the optical encoders' current pattern. Each sensor represents one single signal for the optical encoder. A track can contain two sensors, which are offset to give two slightly different signals produced at the same time. These offset signals can be used by the optical encoder engine to determine more detailed motion information, like speed. A second track can be used to give an index pulse once per revolution, providing a method to orient the signals. Then lastly, some modern optical engines use 4 or more window tracks for increased reliability and signal integrity. An even more reliable cousin to basic mask optical encoders is phased-array optical encoders.

THE TECHNOLOGY OF OPTICAL ENCODER ENGINES (Cont.)

Phased-array optical encoders use multiple signal outputs to average together to create a single signal that is delivered by the engine. These multiple signals that are used by an optical shaft encoder are called the array. By using averages instead of a single reading, phased array-optical encoders have much more stable signals so they can be used in unfriendly environments, such as mining or heavy manufacturing, where vibrations or shock could affect a traditional mask optical shaft encoder. In addition, they require less precision during manufacturing than traditional mask optical encoders. Manufacturers can easily install these modules without the need of precision fixtures and align disks without the use of microscopes. This allows simpler encoder designs for lower costs, yet higher reliability. **Figure 8** shows the cross sectional side view of the disk, and how the components are used to provide a proper signal.

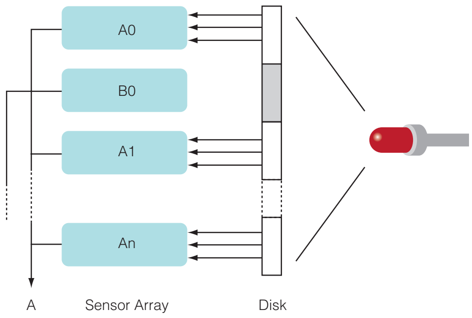

Figure 8: Phased Array Technology

OPTICAL ENCODER APPLICATIONS

The bulk of encoders in production today utilize optical sensing. Optical encoder engines also known as the "workhorse" of the sensing technology world can bring almost unparalleled accuracy and resolution to both incremental and absolute encoders. This makes an optical encoder a desirable choice where resolution matters, from medical equipment to office equipment like printers and copiers. With phased-array technology, an optical encoder is increasingly able to perform in much tougher environments which require a combination of durability and resolution, like crane operations and automated vehicle guidance.

Look at the demands of your application – whether it is the delicate movement of a medical device or the high speed, precision of robotic assembly line units – to determine whether an optical encoder can offer the required performance in your applications:

- High precision
- Good resistance to shock and vibration in industrial applications
- High operating RPMs on incremental encoders
- Multi-turn/multi-gear absolute encoders, which require a lifetime cumulative rotation count

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THE TECHNOLOGY OF MAGNETIC ENCODER ENGINES

An optical encoder uses light (optics) to identify unique positions for the encoder. A magnetic encoder uses the same principle to determine a position as an optical encoder, but it does it using magnetic fields rather than light.

With an incremental magnetic encoder, a magnetized wheel spins over a plate of magneto-resistive sensors. Just as the disk spins over the mask to let light through in predictable patterns, the wheel causes predictable responses in the sensor, based on the strength of the magnetic field. The magnetic response is fed through a signal conditioning electrical circuit.

The number of magnetized pole pairs on the wheel pole, the number of sensors, and the type of electrical circuit all work together to determine the resolution of the magnetic encoder.

The wheel is magnetized mainly with 480, 512, and 600 pole pairs. The amount of sensors and the signal conditioning circuit logic combine to multiply or divide the number of pole pairs to result in several different resolution options using only the three different wheels. The key to using magnetism as the element to produce a signal is that it is unaffected by very demanding environments – including dust, moisture, and extreme temperatures, and shock.

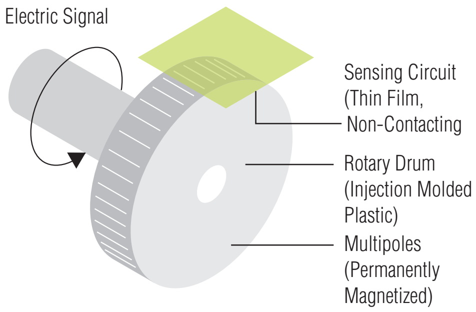

Figure 9: Incremental Magnetic Technology

In absolute magnetic technology, there is a single pole pair rotating above a sensing element. The resolution is dependent upon the ability of the sensing element or ASIC (application specific integrated circuit). In both absolute and incremental magnetic encoders, the engine allows for use in applications that are equal to or more demanding than the phased array engine capabilities.

The innovation of phased array technology has dramatically improved optical technology. Similarly, magnetic phased array systems have benefited in the same way increasing resolution, compactness and reliability of magnetic encoder systems. Their designs spread data capture across multiple detectors, averaging out errors and increasing sensitivity.

Magnetic phased arrays use hall sensor elements arranged in a pattern to match the magnetic wheel and those signals are then interpolated to the desired resolution. This magnetic phased array technology is now available in an IC Chip which integrates both the sensor and the processor in the same chip which considerably decreases the chip count and pc board complexity for a robust, compact, easily manufacturable component. Magnetic Hall Phased Array technology represents the leading edge technology in magnetic encoders today.

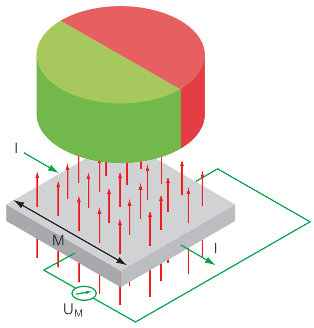

Figure 10: A Hall-array sensor averages the signal over multiple detectors to deliver robust, high-resolution performance that is insensitive to misalignment, shock, and vibration.

MAGNETIC ENCODER APPLICATIONS

Magnetic encoders can be extraordinarily robust. Because magnetic encoders are based on an inductive effect, they do not require bearings, which removes a point of failure from the system. Typically, the electronics are encapsulated so that they are not exposed to the elements. As a result, the devices can operate covered in dust in a sawmill or splashed daily in a washdown environment without any special protection.

A magnetic encoder is designed to output reliable digital feedback in the most demanding and harshest of application environments. Applications for this technology usually require broad temperature specifications, high shock and vibration resistance, robust sealing, and contaminant protection all while focusing on output signal reliability, easy installation, and downtime reduction. Popular applications for magnetic encoders include position and velocity feedback in Steel, Pulp, Paper, Web Production Lines & Lumber mills.

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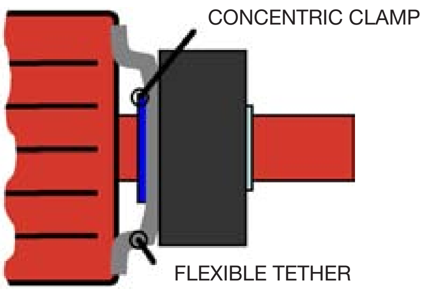
Encoder Mounting Styles

Encoders are a physically small component of a complex closed-loop feedback system that allow manufacturers to make quality parts or move objects from point A to point B in a swift smooth motion. If you break down this system into its major physical components, it most often includes a motor, a drive or amplifier, a brake, and an encoder. When it comes to mounting, the encoder requires the most thought.

Encoders are the component in motion control systems that provide feedback to drives for accurate speed and position control. Selecting the appropriate encoder involves considering environmental, electrical and mechanical factors, and will largely depend on your application requirements. Encoders are available in numerous mounting styles, and these different styles dictate how encoders integrate or "mount" into motion control systems. Encoder mounting styles are typically classified as shafted, hollow-shaft, hub-shaft and bearingless. The appropriate mounting selection can optimize both the life and performance of the encoder.

HOLLOW-SHAFT

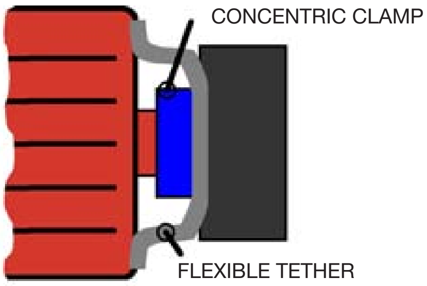
The motor or machine shaft extends through the hollow encoder shaft and is affixed by a concentric clamp. A flexible tether or torque arm attaches to the motor or machine surface to prevent the encoder body from rotating with the shaft.



NOTE: Eliminates the need for a coupling, and allows the encoder to be moved to the correct position for tethering without shaft modifications. Product Examples: HS35R (page 1.101), HS20 (page 1.95).

HUB-SHAFT

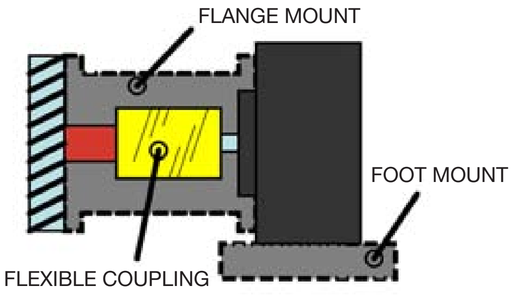
A hub shaft encoder is similar to the hollow-shaft configuration, except the shaft does not extend through the encoder.



NOTE: Eliminates the need for a coupling, but may require a more precise shaft length to properly locate the encoder for tethering. This type provides improved sealing, as there is no opening on the back of the encoder. Product Examples: AI25 (2.07 - 2.29), HSD25 (page 1.77), E14 (page 1.03).

SHAFTED WITH COUPLING

The original encoder configuration, a shafted encoder requires two special interfaces to properly mount the unit. The first is an encoder mount, which is typically either a mounting flange or a foot mount. The second is a flexible coupling, which compensates for shaft misalignment while providing little or no backlash.



NOTE: This solution is typically used when a hollow or hub-shafted solution cannot work. It requires care in aligning the encoder and driven shafts. Product Examples: E14IC (page 1.05), HR26 (page 1.53).

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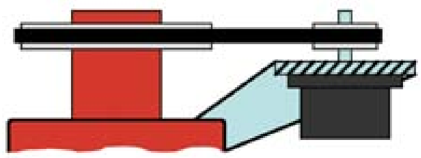
SHAFTED WITH BELT

A shafted encoder can be interfaced to a driven shaft by a belt. This is often done when the driven shaft is too large for coupling, or the application is space constrained and the encoder must be located to the side.

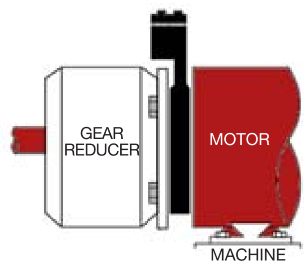
NOTE: The additional mechanical hardware adds cost and complexity to the system. Product Examples: H56 (page 1.63), RIM6200 (page 1.67).



C-FACE

NEMA motor come with standard interface dimensions on the face for mounting an aligning accessories. Common face mount dimensions are 4.5”, 8.5”, and 12.5”.
C-face encoders mount the housing to the motor face, and mount a wheel to the motor shaft separately. These are bearing-less.

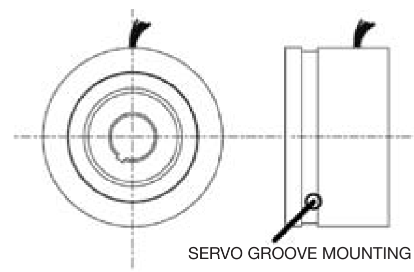
NOTE: Bearing-less solution eliminates a wear component. Product Examples: ST5 (page 1.163), ST8 (page 1.171).



FRAMELESS RESOLVER

Designed for standard resolver motor mounts, the resolver rotor mounts to the shaft, and the resolver housing mounts to the motor face. A clip secures the resolver housing via a groove, as shown.

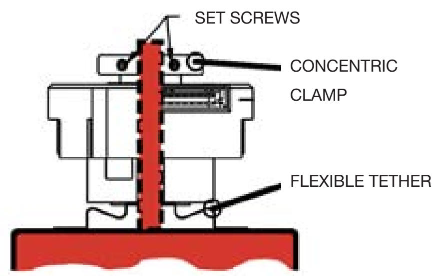
NOTE: A frameless resolver mount is a bearing-less solution that makes a rugged resolver technology even more rugged. Product Examples: HAROMAX 15 (page 3.05), HAROMAX 21 page 3.09).



SERVO FLEX-MOUNT

This style of encoder mount is designed as a drop-in replacement for frameless resolvers. The encoder quickly clips into place. Flex mount designs include the ability to make fine adjustments to align for motor commutation.

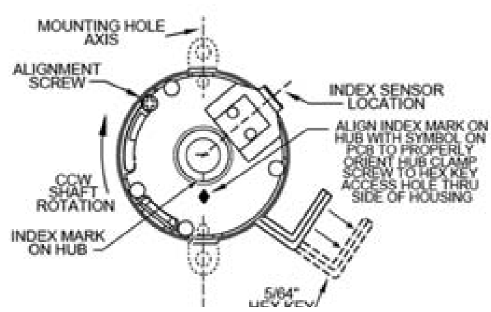
NOTE: The rigid encoder design incorporates bearings, which allows it to be used on motors that have higher shaft axial play and radial run-out. Product Examples: F14 (page 1.91), F18 (page 1.93).



SERVO KIT

The encoder is a modular assembly, eliminating the bearings, similar to the frameless resolver. The encoder housing affixes to the face of the motor, and the encoder disk is fastened to the motor shaft.

NOTE: Ideal for motors with tight tolerance on axial and radial shaft run-out. Bearing-less design eliminates a wear component. Product Examples: M53 (page 1.147), M15 (page 1.143), M602/832 Module (page 1.149).



DYNAPAR™

Encoder Duty Classifications

As a leading supplier in the motion feedback controls industry, Dynapar's comprehensive line of encoders and resolvers are integral to your daily operations. We can help you design the perfect solution for your specific application need and get your facility running efficiently. From traditional manufacturing to many of today's automation industries, market leaders around the world are using Dynapar motion feedback for their applications.

There are five major categories of motion feedback devices which are differentiated by the demands of the operating environment. These run from hazardous duty (the most demanding environment with potential for fire or explosion) to general purpose (the most controlled environment). When looking for an encoder which meets your application requirements, make sure to look for the appropriate duty class icons found throughout our Catalog, our Feedback Quick Reference Guide and our Technical Data Sheets.

HAZ HAZARDOUS DUTY ENCODERS

Hazardous Areas or Hazardous Locations relate to areas where flammable liquids, vapors, gases or combustible dusts are likely to occur in quantities ample to cause a fire or explosion. If your encoder is going into an environment where explosive gas or dust may be present, determine what level of protection is required and then look for an encoder that carries at the least the minimum requirement. Below are several protection methods and levels they achieve.

Intrinsically Safe Encoders: A common type of protection class for encoders is Intrinsic Safety (Ex ia). Encoders classified in this area can be approved for use in either IEC Zone 0 or NEC500 Class 1 Division 1. Intrinsically safe encoders are used in conjunction with an energy limiting electronic device commonly known as an IS Barrier. This device, in Zener, opto-isolated or galvanic, limits the energy allowed in the circuit such that any arcs or sparks in this equipment has insufficient energy (heat) to ignite a vapor.

Flame Proof Encoders: Flame proof (Ex D) equipment construction is such that it can withstand an internal explosion and provide relief of the external pressure via flamegap(s) such as the labyrinth created by threaded fittings or machined flanges. The escaping (hot) gases must sufficiently cool down along the escape path that by the time they reach the outside of the enclosure not to be a source of ignition of the outside, potentially ignitable surroundings. Both optical and magneto-resistive encoders are available in one piece designs. Encoders classified in this area can be approved for use in either IEC Zone 1 or NEC505 Class 1 Zone 1.

Encapsulated Encoders: Devices utilizing encapsulation have the electronics encased in a resin type material to isolate them from the surrounding atmosphere. Encoders classified in this area can be approved for use in either IEC Zone 1 or NEC505 Class 1 Zone 1.

Non Incendive Encoders: Equipment is non-incendive or non-sparking and approved for IEC Zone 2 and NEC500 Class 1 Division 2.

A multitude of options exist for applying encoders successfully in hazardous locations. Each has its own pros and cons, and ultimately the end user or design engineer must factor several things into account such as level requirement, electrical requirements, IP ratings and physical size and total cost of ownership.

Please see following charts for an outline of how to understand Area Classifications and IP Ratings.

AREA CLASSIFICATIONS

European and IEC Classification	Definition of Zone Division	North American Classification
Zone 0 (Gases / Vapors)	An area in which an explosive mixture is continuously present or present for long periods	Class I Division 1 (Gases)
Zone 1 (Gases / Vapors)	An area in which an explosive mixture is likely to occur in normal operation	Class I Division 1 (Gases)
Zone 2 (Gases / Vapors)	An area in which an explosive mixture is not likely to occur in normal operation and if it occurs will exist only for a short time	Class I Division 2 (Gases)
Zone 20 (Dusts)	An area in which an explosive mixture is continuously present or present for long periods	Class II Division 1 (Dusts)
Zone 21 (Dusts)	An area in which an explosive mixture is likely to occur in normal operation	Class II Division 1 (Dusts)
Zone 22 (Dusts)	An area in which an explosive mixture is not likely to occur in normal operation and if it occurs will exist only for a short time	Class II Division 2 (Dusts)

Nearly all industrial applications present some sort of challenging environmental conditions, making the choice of housing and IP rating an essential part of encoder specification. Producing an optimal product or system requires a clear understanding of the IP rating system and a thorough knowledge of the application (see table 3 for Dynapar Examples).

To buy an encoder that will last, you have to pay close attention to IEC 60529 details like duration and pressure of exposure to solid objects and liquids. How do you choose the correct IP rating for your application?

ENCODER DUTY CLASSIFICATIONS

DYNAPAR™

Encoder housings provide protection for devices by preventing the entry of solids and liquids that might damage the electronics. Although most countries and regions have their own enclosure standards, such as DIN 40050 from the German Institute for Standardization or NEMA 250 from the U. S. National Electrical Manufacturers Association, IEC 60529 is the primary international standard governing electrical enclosures. IEC 60529 defines enclosure performance based on a two-digit code of the form IPxy, where x refers to the enclosure's ability to keep out solid materials (see table 1) and y describes protection from liquids (see table 2). An IP54 rating, for example, means the device is protected against dust and against water splashed from all directions. In general, the higher the number, the greater the degree of protection provided.

Table 1. Protection against solid objects (meaning of first digit in code)

x	Protection Provided
0	No protection
1	Protected against solid objects > 50-mm (2-in.) diameter
2	Protected against solid objects > 12.5-mm (0.5-in.) diameter
3	Protected against solid objects > 2.5-mm (0.1-in.) diameter
4	Protected against solid objects > 1.0-mm (0.04-in.) diameter
5	Limited protection against dust (no harmful deposit)
6	Fully protected against dust (dust tight)

Table 2. Protection against liquids (meaning of second digit in code)

y	Protection Provided
0	No protection
1	Protected against vertically dripping water for 10 min.
2	Protected against vertically dripping water for 10 min. when tilted 15° from vertical
3	Protected against spraying water for 5 min. when tilted up to 60° from vertical
4	Protected against water splashed from any direction for 5 min.
5	Protected against low pressure water sprayed from all directions for 3 min.
6	Protected against high volume jets of water from all directions for 3 min.
7	Protected against 30 min. of immersion in water to a depth of 1 m (3.3 ft.)
8	Protected against immersion in water to manufacturer-specified pressure
9K*	Protected against high-pressure and high-temperature water jets

** Per German standard DIN 40050-9*

Table 3. Encoder enclosure rating examples

Application	Dynapar Encoder	Enclosure Rating	Protection
Light Duty	Series E14	IP54	Limited protection against dust and splashing water
Light Industrial Duty	Series H20 without shaft seals	IP54	Limited protection against dust and splashing water
Industrial Duty	Series H20 with shaft seals	IP66	Fully protected against dust and large volumes of water from all directions
Heavy Duty	Series HSD37	IP67	Fully protected against dust and 30 min. of immersion in water to a depth of 1 m (3.3 ft.)
Heavy Duty	Series AR62/AR63	IP69K	Fully protected against dust and high temperature, high-pressure jets of water from all directions

ENCODER DUTY CLASSIFICATIONS

DYNAPAR™

Hazardous Duty applications typically benefit from:

- Triple certified U.S./Canadian, ATEX, and IECEx
- High resolution unbreakable code discs
- Reliable signal transmission
- Seals and housings that provide at least IP67 rating
- PCB designs for high shock and vibration resistance
- Industrial grade components rated for -40 to 100+ C

Most Popular Heavy Duty Industries:

- Oil and Gas
- Paper and Steel
- Aerospace
- Food and Beverage
- Chemical
- Mining
- Power

Heavy Duty Applications:

- Top Drives
- Iron Roughnecks
- Wirelines
- Logging
- Coil Tubing
- Cementing and Fracing/Blenders
- Winch
- Propulsion Systems
- Completion and Production Equipment
- Drawworks Drum Applications
- Coal Dust Environments
- Petro Chemical Handling
- Bottling Machines
- Mixers
- Ethanol Plants
- Enameling
- Production Line
- Silo Works

ENCODER DUTY CLASSIFICATIONS

DYNAPAR™

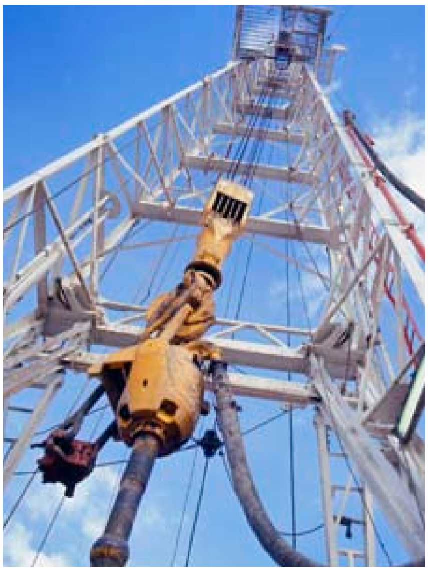
HD HEAVY DUTY ENCODERS & RESOLVERS

As the name implies, heavy duty encoders and resolvers can take the most abuse and they are designed to survive some of the toughest environments. Dynapar has been designing and manufacturing tough, reliable motion feedback devices for over 6 decades. Leading Dynapar's Heavy Duty products is the NorthStar™ brand of heavy duty Magnetic and Optical encoders.

The NorthStar™ line of MAGNETO-RESISTIVE (MR) encoders uses state-of-the-art "direct read" sensing technology to precisely track machine speed for optimum control. It is resistant to common mill contaminants such as water, oil, grease, dirt, and designed to operate in hostile environments where shock and vibration are the norm. This provides the customer with reliable digital output for the life of the encoder and is why it is the most requested Magneto-resistive encoder today.

NorthStar™ SLIM Tach and RIM Tach encoders have proven themselves in tough steel and paper mill applications and other hostile environments where downtime is not an option. These tough tachs are offered in C-face bearingless, hollow shaft with oversized bearings, and foot-mounted configurations.

The NorthStar line of OPTICAL encoders incorporates patented phased array opto-ASIC technology that is setting the standard for future tough and reliable optical designs. This technology, along with other innovations from NorthStar, drastically improves the reliability of optical encoders. It is the reason major oil & gas companies specify NorthStar HD.



ENCODER DUTY CLASSIFICATIONS

DYNAPAR™

Dynapar's Heavy Duty products typically benefit from:

- High resolution unbreakable code discs
- Phased array ASIC that eliminates potentiometers and manufacturing error
- Seals and housings that provide at least IP67 rating
- ATEX certification for Intrinsically Safe application requirements
- Oversized bearings for increased life
- PCB designs for high shock and vibration resistance
- Industrial grade components rated for -40 to +100°C

Most Popular Heavy Duty Industries:

- Pulp and Paper
- Steel
- Oil and Gas
- Aerospace
- Food and Beverage
- Chemicals
- Rail
- Mining
- Off Highway Vehicle

Heavy Duty Applications:

- Extruders
- Pickling Equipment
- Processing Equipment
- Paper Machines
- Test Stands
- Traction Motor Speed Feedback
- Mud Pumps
- Winches and Capstans
- Top Drives
- Drawworks Drums
- Iron Roughnecks
- Catwalks
- Pipe and handling cranes

ENCODER DUTY CLASSIFICATIONS

DYNAPAR™

IND INDUSTRIAL DUTY ENCODERS AND RESOLVERS

The most common class of motion feedback devices is the industrial encoder or resolver. Dynapar's industrial duty products are versatile and well-suited for today's factories and manufacturing environments.

Often considered the "workhorse" of the motion feedback world, industrial duty encoders achieve a good compromise between ruggedness and performance. An industrial encoder can take punishing operating environments almost as well as heavy duty encoders – rough factories with contamination from dust, particulates, and moisture, in addition to moderate shock and temperature. An industrial encoder offers excellent speed and positioning performance. This class of industrial encoders and resolvers are versatile. The hollow- shaft variety of industrial duty encoders is often the preferred choice of vector motor OEM's for speed feedback.

ENCODER DUTY CLASSIFICATIONS

DYNAPAR™

Dynapar's Industrial Duty products typically benefit from:

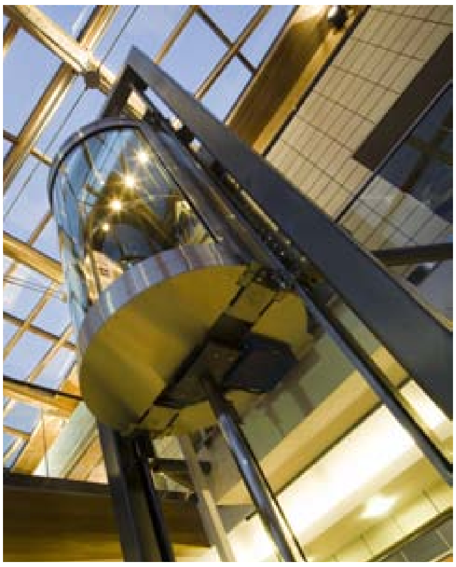
- Dual row ball bearings for long life
- Optional shaft seals for environmental protection
- Unbreakable code disks on select models
- High resolution capability up to 10,000 PPR on select models
- Variety of communication options on absolute encoders
- True batteryless mult-turn positioning on absolute models

Most Popular Industrial Duty Industries:

- Factory Automation
- Food and Beverage
- Pharmaceuticals
- Off Highway Vehicles
- Medical
- Pulp & Paper
- Steel
- Elevator

Industrial Duty Applications:

- Machine Tool Positioning
- Printing Equipment
- Medical Equipment
- Material Handling Machinery
- Cut-to-Length Applications
- Converting Machinery
- Packaging Equipment
- Pickling Equipment
- Processing Equipment
- CNC Machines
- Car Plants
- Pick n Place
- Wafer Production



ENCODER DUTY CLASSIFICATIONS

DYNAPAR™

SSM

SERVO/ SMALL MOTOR DUTY ENCODERS AND RESOLVERS

Servo/Small Motor Duty encoders and resolvers, unlike both heavy duty and industrial duty encoders and resolvers, actually reside inside a motor housing. Rotary encoders designed for servomotor duty face special challenges such as high temperatures, high peak speeds, and commutation. Ease of installation is equally important, so Dynapar offers “One Size Fits All” mounting — Our size 15 frameless resolvers, absolute encoders, and commutation encoders are physically interchangeable. This gives the brushless motor customer unlimited flexibility in feedback options, while using the same motor shaft and endbell.

Dynapar’s Servo Motor Duty encoders offer:

- High 120°C operating temperatures that won’t downgrade motor ratings
- Up to 10,000PPR and commutation tracks up to 32 pole at 12,000 rpm
- Drop-in replacement for all mounting configurations

To meet the lightning-quick communication response brushless servomotors require, Dynapar offers the Hengstler absolute encoder family designed especially for high-performance servo feedback. These encoders provide features such as:

- Fast response with either SSI or BiSS communication protocol
- High 22-bit resolution for the ultimate in low-speed smoothness
- Integrated diagnostics that monitor temperature and other safety parameters to monitor system performance

Dynapar also provides Harowe™ brand ultra-performance resolvers, long recognized as the benchmark in the brushless motor industry. Harowe resolvers provide reliable analog output in some of the harshest conditions where shock, vibration, temperature extremes, and even radiation are present.

The new HaroMax line of frameless resolvers combine traditional resolver reliability with

- Machine-wound stators for unparalleled accuracy
- Tough anodized aluminum housings with low mass for weight savings
- Ultra-high 155°C temperature rating for the toughest servo applications

For those OEM’s customers with special requirements, Dynapar has an engineering team ready to tackle custom modifications whether electrical, mechanical, or environmental in nature. With these custom products manufactured across the globe, Dynapar supports today’s servomotor manufacturers by combining high performance with fast delivery.

This class of encoders and resolvers is specifically suited to use on small-to mid-size stepper and servo motors. They typically have limited sealing due to their use inside motor housings, but are capable of very high speeds and high temperatures, a benefit due to being in such close proximity to motor windings. These encoders typically come from the factory ready to mount to common motor back shafts.

ENCODER DUTY CLASSIFICATIONS

DYNAPAR™

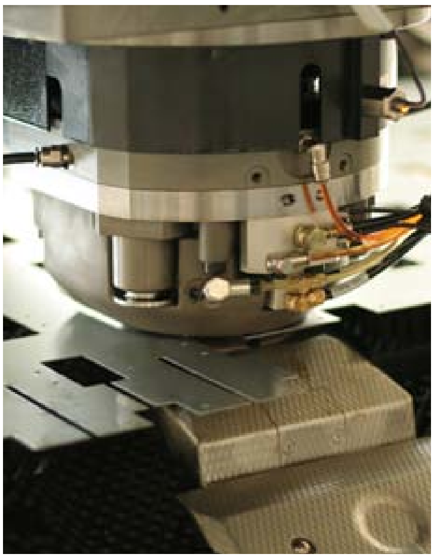
SSM SERVO/ SMALL MOTOR DUTY ENCODERS AND RESOLVERS (CONT.)

Servo/Small Motor Duty Industries:

- Pharmaceutical
- Elevators
- Medical

Servo/Small Motor Duty Applications:

- BLDC, Brushed DC and Stepper Motors
- Elevators, Automated Doors, Escalators
- Catscans
- Robotic Arms
- Surgical Robots
- Robotics
- Ultrasound Equipment
- CNC Factory Machines
- Lab Equipment
- Pharmaceuticals
- Wafer Production



ENCODER DUTY CLASSIFICATIONS

DYNAPAR™

GP

GENERAL PURPOSE/ OFFICE EQUIPMENT DUTY ENCODERS

General Purpose encoders are used in more consumer-facing applications with fairly clean environments, little temperature variation, low to moderate shock and vibration and no moisture or humidity. General Purpose or Light Duty encoders are commonly referred to as “commercial duty” due to their frequent use in commercial or office automation products. Although intended for use in commercial applications, these encoders are manufactured with industrial features.

Dynapar general purpose encoders are especially suited for applications using small motors and actuators in relatively clean environments such as office printers, copiers, and laboratory equipment. Their compact dimensions and advanced circuitry make them well-suited for many applications too small to accept “standard” encoders such as desk top and bench top testing equipment and precision actuators.

General Purpose or Light Duty products typically benefit from:

- Metal housings
- O-ring seals
- Precision bearings

General Purpose or Light Duty Industries:

- Factory Automation
- Medical
- Small Motor Feedback

General Purpose or Light Duty Applications:

- Industrial Equipment
- Assembly Machinery
- Phototypesetters and Printers
- Robotics
- Medical Diagnostic Equipment
- Motor-mounted Feedback
- Computer Peripherals
- Office Equipment (copiers, faxes and computer

ENCODER DUTY CLASSIFICATIONS

DYNAPAR™

Before choosing an encoder that is right for your application, please ask yourself the following questions:

1. What is the complexity level of your application?
2. What parameters (speed, position, direction) do you need to control?
3. Can your application afford to rehome if powered down?
4. What performance level (in pulses-per-revolution and accuracy) does your application require?
5. How will the encoder/resolver communicate with other electronics in the system?
6. Does your application require communication via one of several protocols?
7. How cost sensitive is your application?
8. Does your application involve dirt and dust or do you simply need to prevent the incursion of foreign bodies like screwdrivers, wires, or fingers?
9. Does it involve exposure to liquids? If so, what kind of liquids?
10. Will the encoder/resolver need to survive only occasional exposure or will it be ongoing? Will the exposure take place at high pressure and/or high volumes?
11. What is the operating temperature for the application?

Once you have the answers to these questions, you can then make an informed decision that best meets your application.

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