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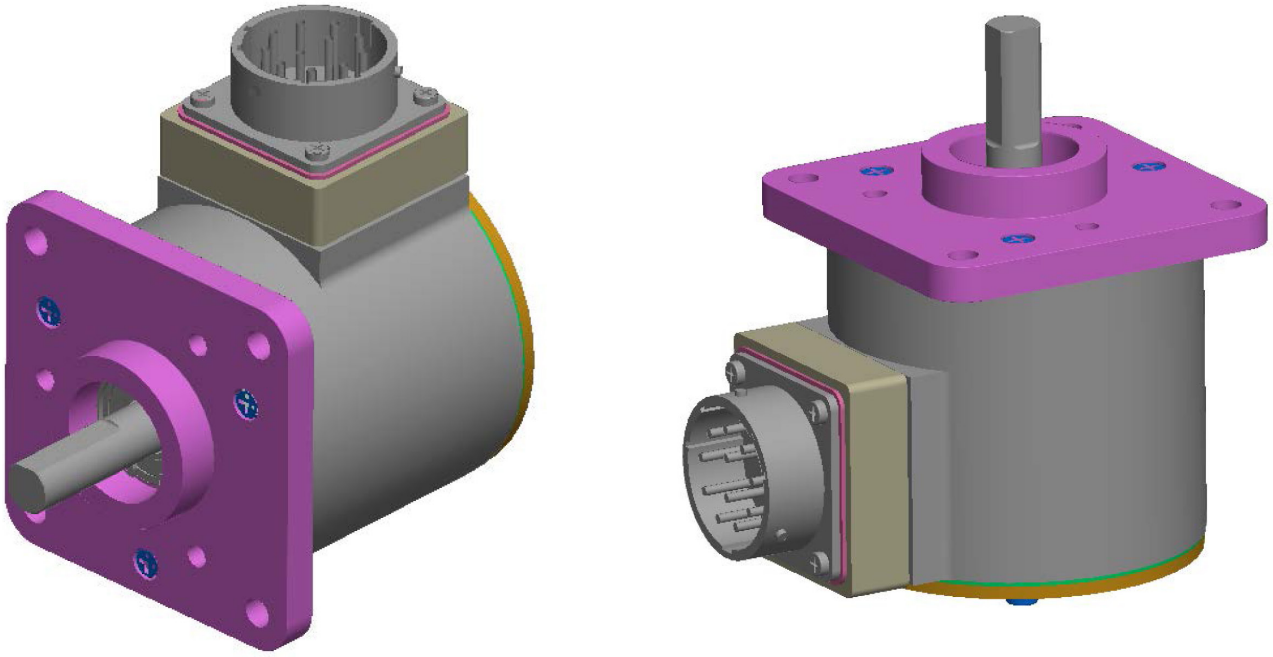
Specify the Best Resolver for Your Application

To ensure best performance, know your application demands, your system parameters, and your budget before you order.



RF25 CAD Drawing

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INDUSTRY WHITE PAPERS

written/edited by Michael Prentice, Harowe Resolver Product Manager, Dynapar Corp.

Specify the best resolver for your design

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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 (see figure 1). Based on a simple transformer design that does not require onboard electronics, resolvers perform even when exposed to harsh conditions like extreme temperatures, high shock and vibration, and contamination. Of course, designing a successful product requires matching the resolver to the application. In this white paper, we'll review the key electrical and mechanical characteristics you need to understand to properly specify your resolver and get the best performance and lifetime from your system.

A resolver consists of rotating windings and two fixed core windings that generate an analog (sine and cosine) feedback output (see Resolvers 101: Understanding the Basics). The ratio of these two signals is processed to determine absolute position. Because a single-speed resolver is an analog device and the electrical outputs are continuous through one complete mechanical revolution, resolvers deliver position feedback with infinite theoretical resolution.

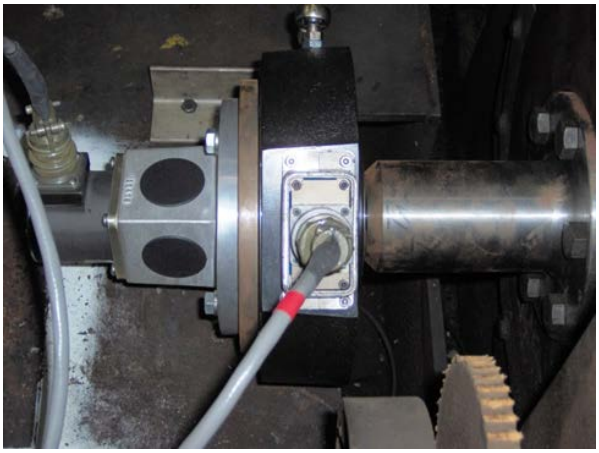

Figure 1: Designed to operate without vulnerable electronics, resolvers like this R25 housed resolver (left) provide high-resolution, robust feedback solutions in demanding environments like steel mills.

When it comes to choosing a resolver to fit your system, you need to consider electrical characteristics and mechanical characteristics. Some of the specifications of the resolver are driven by the needs of the application, while others are defined by the other components of the system. Let's take a closer look.

ELECTRICAL SPECIFICATIONS

Seven main functional electrical operating parameters define resolver operation.

1. Accuracy or electrical error is defined as the difference between the mechanical angular position indicated by the electrical output signals and the true or actual mechanical angular position of the rotor with respect to the stator, usually given in arc minutes. This information can be used to plot an error curve that displays the error (arcmin) versus angular position (degrees) over a full rotation of 360°. There are two ways to specify error: error spread (peak-to-peak error) or maximum deviation from actual value (+/-). Peak-to-peak error is defined as the difference between the highest positive error and the lowest negative error recorded in 360° while the maximum deviation represents the absolute value of the maximum error (see figure 2).

The sources of electrical error include various mechanical design and manufacturing issues such as the limitations in the distribution of the stator and rotor windings, inconsistencies in the winding placement in the lamination slots, number of slots in the rotor and

stator laminations, mechanical imperfections that affect the radial uniformity, and material variations in the magnetic characteristics of the material. In summary, the resolver error curve represents the sum of all the above issues. The application determines the magnitude of error that is acceptable.

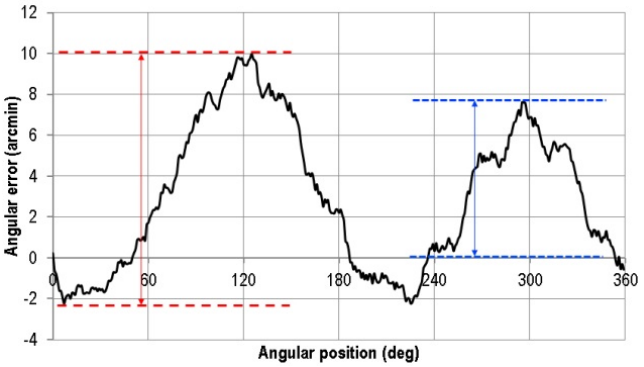

Figure 2: Plot of error as a function of angular position over a full rotation shows peak-to-peak error (red) of 12 arcmin and +/- error (blue) of 8 arcmin.

Ripple or velocity error is the time-based derivative of the accuracy or electrical error curve. It is calculated from the measured peak-to-peak error. In other words, the peak-to-peak error is a specified quantity for the resolver, whereas the ripple is a derived quantity. Ripple may be of concern if the resolver is being used in a closed-loop feedback system for velocity control.

2. Input excitation voltage and frequency refer to the input AC voltage (Vrms) and frequency supplied to the leads of the primary winding by the system. Typical voltages will range from 1 to 26 VAC and frequencies will vary between 400 and 10,000 Hz. It is not always necessary to develop special windings for each individual application, because a particular winding design can generally be operated at voltages and frequencies other than those specified. Nominal variations in the input voltage excitation will not normally produce any noticeable change in the other operating parameters. Be aware that large changes in voltage or frequency can affect a resolver's magnetic structure, resulting in increased error and null voltage as well as changes to other operating parameters. Higher frequencies can increase magnetic flux leakage, which will also raise error and null voltage.

3. Input current maximum is the maximum current in amps that flows through the primary winding at the system's input voltage and frequency. Per Ohm's law, the ratio of the input voltage to the winding resistance gives the current through the winding, which typically ranges from 10 to 100 mA. Each resolver is rated for a maximum current.

What to know before you call

1. *What kind of accuracy do you need?*
2. *What are your operating conditions (temperature, contamination, vibration, etc.)?*
3. *What input voltage and frequency does your system present to the resolver?*
4. *What is your desired transformation ratio?*
5. *What is your system requirement for phase shift?*
6. *What is your maximum allowable input current?*
7. *How long are your cable runs?*
8. *What is the shaft diameter?*
9. *Should the resolver be housed or frameless?*

4. Transformation ratio (TR) is the ratio of the output voltage to the input voltage when the output is at the maximum magnetic coupling. Remember, a resolver is essentially a special type of transformer. During operation, it takes a set input voltage and steps it down. The TR is determined by the winding design and is approximately proportional to the ratio of the number of effective turns in the secondary winding to the number of effective turns in the primary winding. The transformation ratio is driven by user requirements for input and output voltage. Within reasonable limits, a manufacturer can design the windings to deliver the desired TR; it does not affect resolver performance.

5. Impedances are the comprehensive expression of any and all forms of opposition to electron flow, including both resistance (friction) and reactance (inertia). A resolver exhibits four impedances:

Z_{ro}, the impedance of the primary winding (rotor) with the secondary winding (stator) open circuit
Z_{rs}, the impedance of the primary winding with the secondary winding short circuited
Z_{so}, the impedance of the secondary winding with the primary winding open circuit
Z_{ss}, the impedance of the secondary winding with the primary winding short circuited

Impedances can be expressed in vector form as:

$$Z = \sqrt{A^2 + (jB)^2} \qquad [1]$$

or in rectangular form as:

$$Z = A + jB \qquad [2]$$

where A is the active component, sometimes called the real component, and B is the reactive component, sometimes called the imaginary component. We can further break down A as:

$$A = R_{DC} + R_{AC} \qquad [3]$$

where R_{DC} represents the DC resistive components (wire gauge and number of turns) and R_{AC} represents the AC resistive components (magnetic core eddy currents and hysteresis).

Using equation 1, we can express Z_{ro} as:

$$Z_{RO} = 90+j160$$
$$= \sqrt{90 + j160}$$
$$= 183\ \Omega$$

Resolvers are like most other active AC components in which the ratio of the output impedance to the load must be kept low to improve performance. In order to achieve the maximum distance between the resolver and the controls, keep the output impedance as low as possible. Properly designed, a system can operate over distances of as much as 1,000 ft. If the distances are very large between the resolver and the controls, use shielded, twisted pair, low-capacitance cable. Typical impedance values range from 50 to 1000 Ω.

6. Phase shift in degrees is the difference between the time phase of the primary voltage and the time phase of the secondary voltage when the resolver is operating with maximum magnetic coupling. For a given primary winding DC resistance R_{DC} and primary reactive component *B*, we can approximate the phase shift Δϕ by:

$$\Delta\phi = \tan^{-1}\left[\frac{R_{DC}}{B}\right]$$

The phase shift must be within the allowable range for the resolver-to-digital conversion chip used in the system. Commercial off-the-shelf resolver-to-digital conversion chips can accommodate a phase shift of ±10° but high-performance versions can handle phase shifts as high as ±45° the typical phase shift is in the range of ±20°.

7. Null voltage is the residual voltage at the minimum magnetic coupling between the primary and secondary windings. Null voltage is essentially a measure of the quality of the resolver. It is measured when the in-phase secondary voltage is zero. Theoretically, this zero point occurs when the axis of the primary winding is at right angles to one of the secondary (sine or cosine) windings, which occurs at 0°, 90°, 180°, and 270°—at these cardinal points, when the sine voltage is at maximum, the cosine voltage is at minimum, and vice versa. In reality, due to the mechanical imperfections and winding errors, there is always a small amount of residual voltage. The typical null voltage ranges from 10 to 40 mV.

MECHANICAL SPECIFICATIONS

Resolvers can be packaged as either frameless or housed designs (see figure 3). Frameless resolvers provide absolute position feedback for brushless motors, robots, and direct-drive motors in precision rotary platforms and similar servo applications. Frameless resolvers like the 15BRCX-510-L36P are ruggedized against vibration and shock, able to operate at temperatures as high as 200°C, resistant to noise, and impervious to most industrial contaminants. Housed units can generally be found either flange mounted with a shafted input to be coupled to the customer's shaft, or shaft-mounted with a hollow/hub shaft input that is mounted directly on the customer's shaft.

Figure 3: Resolver mounting options include frameless (upper left), housed flange-mounted (upper right), and housed hub-mounted (lower left). Tethers are added to maintain stability, as in this tethered housed hub-mounted resolver (lower right).

With the frameless resolver, the cost is minimized but the customer must assume the responsibility to correctly mount both the stator assembly and the rotor assembly. The cost is greater for a housed resolver package because the resolver now has its own shaft, bearings, and housing but the installation process for the customer is both faster and easier.

Resolvers deliver high-performance feedback in a rugged package for high-reliability applications in a wide range of harsh-environments. Because the results simply depend on the ratio of output voltages, the devices require no additional processing electronics that might make them vulnerable to temperature extremes. They don't include detectors, so contamination and age will not degrade their performance. Simple, robust, and effective, resolvers play an essential role in systems ranging from missile-fin adjusters to centrifuges. Whether you're working with temperatures as high as 200°C, high radiation environments, or high shock and vibration loads, a resolver can deliver the resolution and long-lasting performance you need.

*Dynapar offers the world's broadest range of encoders, resolvers and accessories for motion feedback control. For 50 years, the four brands of Dynapar have been providing innovative, customized system solutions for virtually any heavy-duty, industrial, servo, or light-duty application. Innovative products, designed your way, delivered when you need them—that's the Dynapar difference. Click **here** for more information.*

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