TECHNICAL Talk

ROTASYN

The following is based on a technical paper presented by David T. Robinson, VP Engineering, Admotec Inc., at the Intelligent Motion Systems '95 conference in Long Beach CA, Sept. 1995.

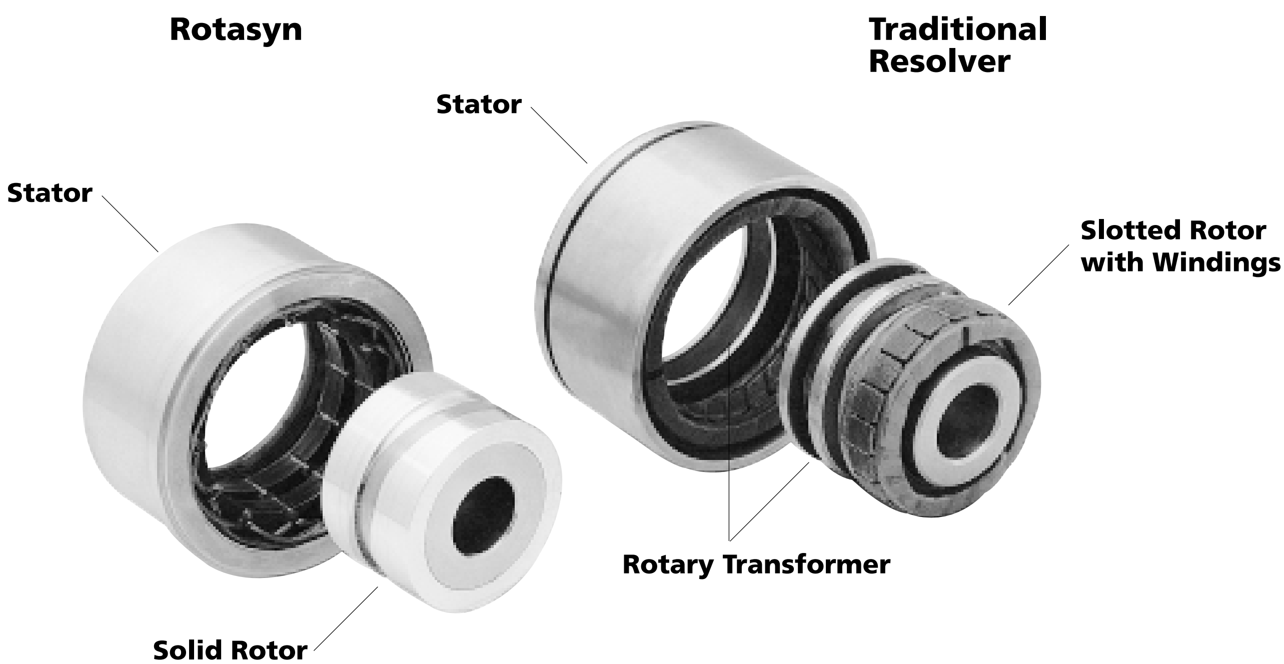
# A New Absolute Inductive Transducer for Brushless Servomotors

## Introduction

Today, frameless brushless (pancake) resolvers are commonly used on AC and brushless DC servomotors to provide commutation, position, and velocity information to the servo controller. These angular position transducers give a constant signal representing the absolute position of the motor shaft within one revolution, making them well suited for this purpose. However, traditional resolvers are complex and expensive to manufacture, limiting their use in industrial servomotors. A new type of absolute inductive position transducer—one that is mechanically and electrically compatible with traditional resolvers—is now available. This device utilizes a solid rotor without windings and overcomes the disadvantages of traditional resolvers. As such, it offers higher speed operation, better reliability, and lower cost.

## An Overview of Angular Transducers

Flexible motion control is unthinkable without precise information about the position of each axis. For this purpose, different types of shaft angle sensors are used, often built into the driving motors. On the basis of their physical design, these angular transducers can be classified into two main groups:




***The design advantages of the Rotasyn resolver***

**Optical** where a phototransistor or other light-sensitive electronic device counts lines on a transparent disk mounted to the rotating shaft. The most common of these devices are incremental and absolute encoders.

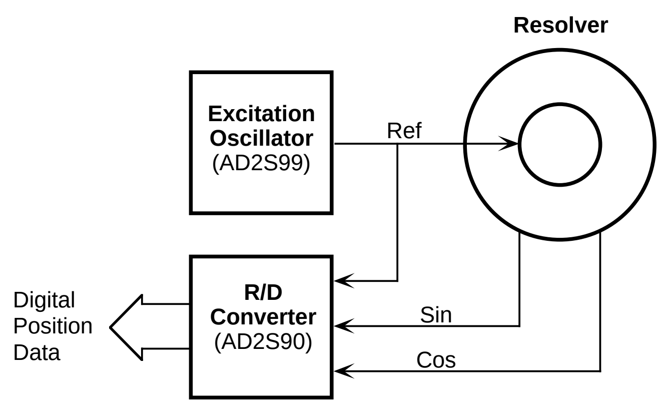
**Inductive** built like small electrical motors, where inductive coupling between a rotating part (the rotor) and a stationary part (the stator) generates signals indicating shaft position. Resolvers and synchros are the most common devices.

Optical transducers, especially incremental encoders, have found wide application because their digital outputs can be easily processed by both discrete logic and microprocessors. Nevertheless, optical transducers have a number of characteristics that make them less than optimal for many applications. The built-in semiconductors used to amplify and format the digital output signals are sensitive to temperature and the LED light sources commonly employed are susceptible to aging. Furthermore, applications that require an absolute output signal require absolute encoders, which are much more complicated and therefore expensive.

From a purely practical standpoint, the precise concentricity between the encoder disk and the sensors required to maintain accuracy as well as the mere presence of optical devices in an industrial environment dictate that a fully enclosed device with bearings and shaft be used in all but the crudest applications. Since encoders are typically connected to a shaft having its own bearings, the user must pay for the second set of high-quality bearings in the transducer as well as a flexible coupling to connect the two shafts. In many applications, especially brushless servomotor commutation or flux vector control of AC induction motors, the additional length of the optical encoder's shaft, bearings, and coupling is too great and the optical encoder cannot be used.

On the other hand, inductive transducers such as resolvers are intrinsically absolute and require no semiconductors on the transducer itself—the raw output signal can be transmitted over distances of more than 100 meters. In addition, since they consist primarily of copper and steel, resolvers are virtually insensitive to temperature over a wide range. Because no sensitive electronics or optics are employed, resolvers are often supplied in an unhoused (also called frameless or pancake) configuration and can be mounted directly to the shaft whose position is to be measured. Cost and length savings are realized by the user since no shaft-to-shaft coupling or extra bearings are required.

While resolvers were originally developed for military and aerospace applications, in recent years industrial automation has shown more interest in these rugged and precise absolute position transducers. Nevertheless, the expansion of the use of resolvers was often limited by the fact that the signal conversion required cumbersome circuitry and automated resolver production was difficult. Now, however, inexpensive and easy-to-implement monolithic ICs that perform complete resolver-to-digital conversion are available. These R/D converters give an absolute or incremental output with a resolution of up to 65,536 counts per revolution. A typical two-chip solution is shown below.




***Simple R/D conversion using two monolythic ICs***

The resolver signals are low bandwidth amplitude-modulated sine waves. Since these sine wave signals contain only a single frequency component rather than the virtually infinite frequency spectrum of an optical encoder's square wave signals, they are inherently much more immune to the high-frequency noise generated by PWM motor drives and other industrial machinery.

Finally, since the resolver itself was handicapped by a high level of manual labor, some manufacturers have opted to transfer production to low labor-cost countries.

While lowering unit costs, this reduces their ability to respond to the market needs and does not allow them to quickly meet customer demands.

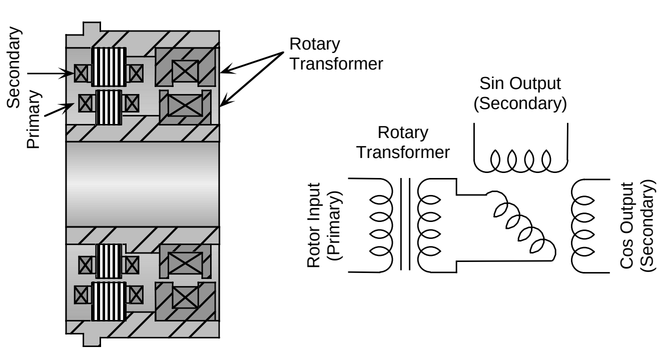
## Feedback Requirements for AC Servomotors

Commutation of AC and brushless DC servomotors can be done with Hall-effect sensors to switch current into the proper phase at the proper time. However, a tachometer and encoder are then required to close the velocity and position loops in the drive.

Using a resolver reduces the number of transducers on the motor from three to only one. Indeed, from a single transducer it is possible to generate all three of the required signals: high resolution digital position information is available directly from the R/D converter; this position data allows generation of sine wave signals for commutation from a lookup table; and a velocity signal is available from the R/D converter chip to replace the tach in analog drives. In completely digital drives, the basic absolute shaft position information can be used to derive velocity and commutation signals within the microprocessor. In fact, a fast DSP can perform the R/D conversion itself by synchronously sampling the resolver signals.

## Traditional Brushless Resolvers

The traditional brushless resolver consists of a wound rotor and stator as shown below. The windings on the rotor generate an AC magnetic field with a sinusoidal distribution. This field induces voltages in the two stator windings whose amplitudes are dependent on the rotational angle of the rotor. To provide sine and cosine signals, the two secondaries are wound in space quadrature (90 physical degrees apart) in the stator.




***Traditional brushless resolver with wound rotor and rotary transformer***

Electrical energy has to be supplied to the rotor to generate its AC magnetic field. However, as the rotor must be able to rotate freely it is not possible to use wires. The use of slip rings is also not recommended because they are subject to wear, generate signal noise, and compromise the mechanical ruggedness of the resolver.

Traditional brushless resolvers therefore use a rotary coupling transformer to transfer energy from the stator to the rotor. The primary of this rotary transformer is built into the stator. The secondary is mounted on the rotor and connected directly to the resolver primary. Because of the energy lost in energizing this two-stage transformer (basically two transformers in series), many turns of wire are required to generate usable output signal amplitudes. The large number of turns means that a traditional resolver is a relatively high-impedance device, limiting its use at high excitation frequencies or rotational speeds.

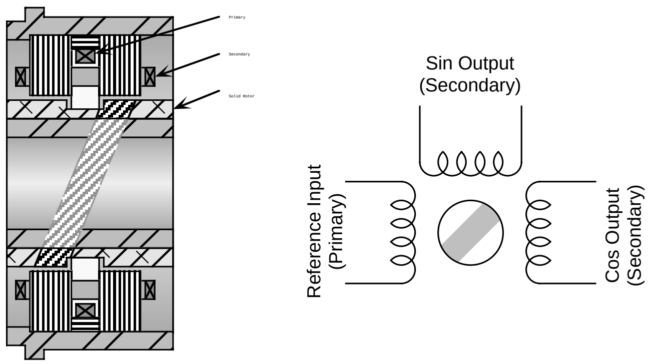
Because a traditional resolver has a wound rotor, its maximum speed is limited since the windings tend to fly out of the rotor due to centrifugal force. Typical maximum speeds are 10,000 RPM or less.

## The Rotasyn™

Unlike the traditional brushless resolver, the Rotasyn has both primary and secondary windings in the stator and thus no rotary transformer is required—the Rotasyn is intrinsically brushless! The transferred energy remains magnetic from the primary coil through the air gap to the sinusoidally shaped poles of the solid rotor.

The Rotasyn is similar to a rotary variable differential transformer (RVDT) in which the rotor acts as a magnetic valve completing the flux path. The total flux through the gap is constant—the rotor determines the angular position within the stator bore where the coupling occurs, and thus the relative amplitudes of the output signals.

The primary coil is wound circumferentially between the two stators. The two secondary windings are wound in the stator slots in space quadrature (shifted by 90 physical degrees) similar to a traditional resolver. Hence the induced voltage amplitudes correspond to the sine and cosine of the rotor angle as in a traditional resolver.




***Rotasyn resolver with solid rotor***

This new design (EC patent; US patent pending) gives the Rotasyn some unique advantages over both traditional brushless resolvers and optical encoders:

**More Reliable** The rotor coils of traditional resolvers are subject to very high accelerations and forces in today's high speed, high hit-rate applications. These forces can break a wire or wear the insulation. Since its solid rotor has no coils, the Rotasyn has virtually no speed or acceleration limitations. And since the Rotasyn has only half the windings of a traditional resolver, its MTBF (mean time between failure) is double that of a traditional resolver.

**High Speed** Since the solid rotor has no windings, there are no problems at very high speeds. While the standard Rotasyn is rated to 30,000 RPM, higher speeds are simply a matter of mechanical balance. The top speed is primarily limited by the excitation frequency.

**Low Impedance** The Rotasyn's efficient single-stage magnetic design brings the advantage of high electrical efficiency, so that powerful output signals are produced using relatively few turns of wire. Fewer turns translates to lower source impedance which means less susceptibility to noise pickup and less sensitivity to long cable runs. The Rotasyn can be excited at frequencies up to 40 kHz and beyond.

**Reduced Ripple** In traditional resolvers, rotor slots passing stator slots induce pulsations on the output signals that manifest themselves as velocity ripple. The poles on the Rotasyn rotor have no slots and therefore produce a smooth output with no slot ripple effects.

**Lower Cost** Since the Rotasyn is mechanically simpler than a traditional resolver, it can be manufactured more efficiently than traditional resolvers. The solid rotor is much less costly to manufacture than a wound rotor. In addition, the lack of slots on the rotor means that the stator slots can be wider, making winding easier without introducing slot ripple.

## Conclusions

The advantages of this new inductive transducer (Rotasyn) for absolute positioning make it ideally suited for sinusoidal commutation of AC and brushless DC servomotors as well as for flux vector control of AC induction motors. This type of low-cost angular transducer will find broad application, not only in industrial automation but also as a component in increasingly sophisticated automotive control systems.

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