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ANALYSIS OF RESOLVER TO DIGITAL CONVERTER FOR ANGULAR POSITION AND ROTATION OF STEPPER MOTOR

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Abstract

Electronic Monitoring, industrial motors, robots and vehicular power trains are necessary for higher efficiency, reliability, and safety, this technology provides the best angular position in terms of ruggedness, reliability, and resolution. Resolvers are developed mainly for military and aerospace applications. For high angular and velocity rotation of transformer, electronic control systems are necessary, which causes the noisy and rugged environment to avoid these, resolver to digital converter and op-amps are used. The resolver which is known as a rotary transformer converts the angular position of the shaft into Cartesian coordinates of components. The output of the transducer consists of two signals which are proportional to the sine and cosine of the angle which is represented in the form of a digital counterpart. Resolver to Digital Converter(RDC) driver is placed between microcontroller/ microprocessor and resolver, and to determine the angular position and rotation speed of the motor shaft, sine and cosine signals are used.

Keywords: Resolver, Resolver to Digital Converter, Angular Position, Rotation Speed, and Sine and Cosine signals.

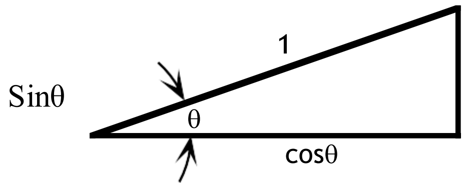

Fig 1: Resolving an angle into its Components

1. Introduction

The Resolver changes mechanical `motion into an analog electrical signal and it is a rotary transformer with AC voltage output that measures the angular position of the motor. The Resolver can be categorized into classical and variable reluctance resolvers, Classical resolver includes primary windings on the rotor and two secondary windings on the stator, and in Variable reluctance resolver have no windings on the rotor, but all primary and secondary windings are on the stator as shown in figure 2.

Similar to all transformers, a resolver requires an AC carrier or reference signal which is applied to primary windings, and the amplitude of the reference signal is modulated by the sine and cosine angle of the rotor which produces the output signals in two secondary windings, usually, for

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reference signal, the sine wave is considered, Transformer ratio is the value of output voltage produced from secondary windings which are fed into primary winding.

For resolvers, the transformation ratio (TR)is specified at the maximum coupling occurring between primary and secondary windings. As shown in figure 2, when a primary winding R1-R2 is excited with a sine signal is expressed in equation 1 and this signal is induced in the secondary windings. The relation between resolver output and input voltages is given in equations 2 and 3.

R1-R2 $= E_O \text{Sin } \omega t$ ———— 1

S3 - S1 = T × $E_O \text{Sin } \omega t \times \text{Sin}\theta$ ——— 2

S2 – S4 = T × E_O $\text{Sin}\omega t \times \text{Cos}\theta$ ——— 3

Where θ denotes shaft angle, ω denotes excitation signal frequency, E_O denotes excitation signal amplitude and T denotes transform ratio of resolver

In RDC, the sinewave reference signal and two differential output signals are excited from primary winding and from secondary windings, sine and cosine signals are electromagnetically induced. To determine the angular position and rotation speed of the motor shaft, RDC uses sine and cosine signals between the resolver and system microprocessor, and RDC circuit is used in avionics, automotive and critical industrial applications which measures the angular position and velocity accurately which requires reliability over a wide temperature range.

Fig 2: Classical Resolver and Variable Reluctance Resolver

In figure 3 shows a graphical representation of two output signals: sine and cosine signals and excitation signal. The maximum amplitude of the sine signal happens at 90^0 and 270^0 and for cosine signal happens at 0^0 and 180^0.

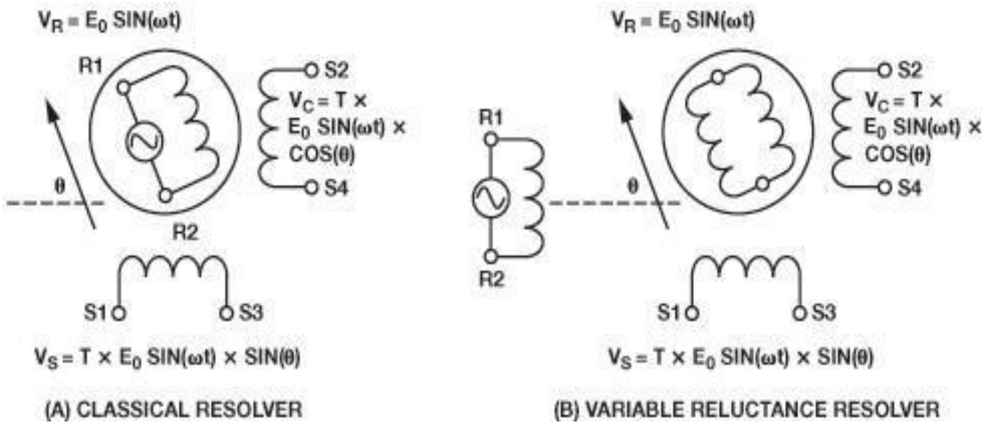

Fig 2: Classical Resolver and Variable Reluctance Resolver

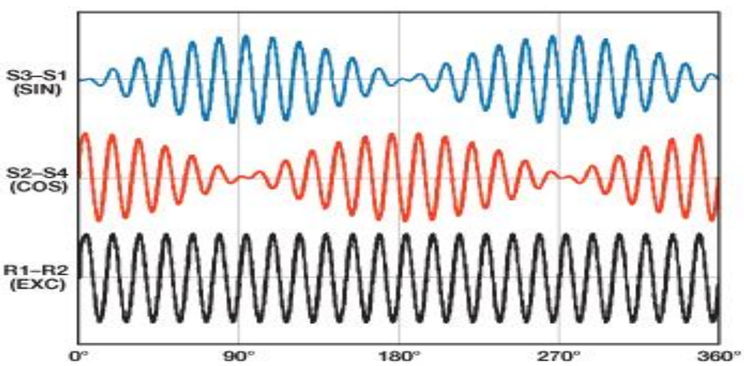

Fig 3: Electrical Signal Representation of Resolver

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2. Resolver Signal Representation

When primary winding is excited with sinusoidal reference signal as shown in figure 4, the same frequency at secondary windings is also sinusoidal in phase with the reference signal. The amplitude of the reference signal, transformation ratio, and sine and cosine signals of the rotor is proportional to the amplitude of secondary windings.

When the rotor of the resolver completes one revolution in the excitation frequency of 10 cycles the secondary signal envelope can be seen, which is shown in figure 4 with respect to the position of the rotor.

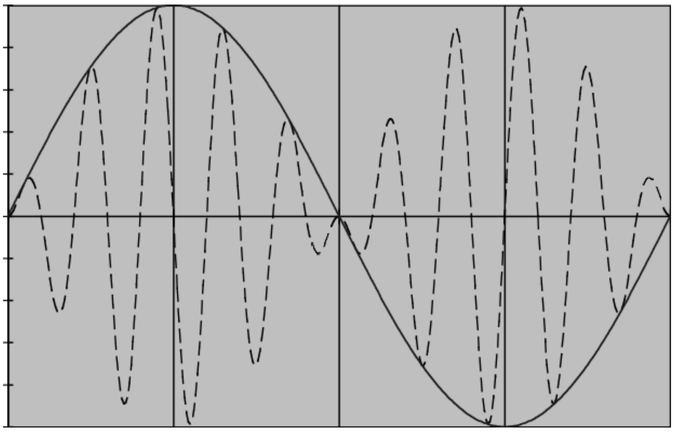

Fig 4: Modulation Envelope of Sine Secondary Signal

Removal of the carrier signal or envelope of the above signal is called demodulation which is performed by RDC.The sine and cosine demodulated resolver signals are shown in figure 5.

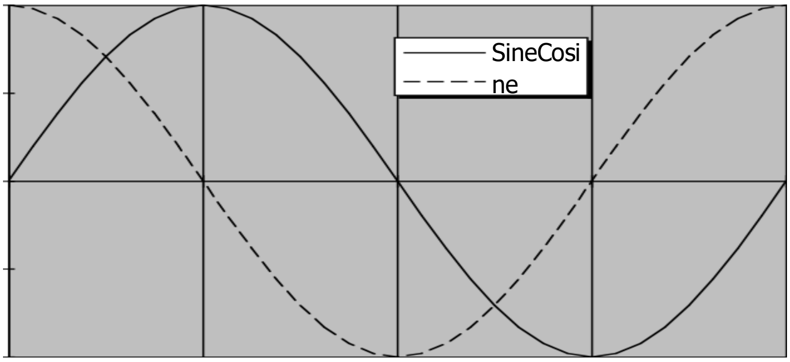

Fig 5: Demodulated Resolver Secondary Signals

3. Working of Resolver to Digital Conversion

The Resolver to Digital Converter includes two functions: removal of carrier signals through demodulation of resolver and rotor angle digital representation is provided from angle determination. For performing the above function method used is Ratiometric Tracking Conversion. Sine and cosine of rotor angle are representedby resolver secondary signals, and the tangent of rotor angle is represented by the ratio of signal amplitudes. Hence rotor angle,$\theta$is the arctangent of sine signal divided by cosine signal.

$$\theta = \arctan \frac{\mathrm{Sin}\theta}{\mathrm{Cos}\theta} = \arctan \frac{Vs}{Vc}$$

To track the resolver position, the counter is forced by the resolver, signal ratio of arc tangent calculation is performed by the ratiometric tracking counter. Calculation of arctangent is represented

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by trigonometric identity:
$\text{Sin}(\theta - \delta) = \text{Sin}\,\theta\,\text{Cos}\,\delta - \text{Cos}\,\theta\,\text{Sin}\,\delta$ -------- 4
The equation 4 describes that the difference between two angles of sine can be calculated by using two angles (sine and cosine) by cross multiplying and further results are subtracted. Therefore, two angles difference is relatively small
$(\delta = \theta \pm 30^0)$. $\text{Sin}(\theta - \delta) \cong \theta - \delta$
The equation 4 can also be used after simplifying the equation. Hence if two angles are less than 30^0 each other, differences in angles are calculated by applying cross-multiplication as shown above.
The equation 4 is implemented in the R/D converter using the D/A multiplier by multiplying resolver signals with cosine and sine of digital angles, □, which indicates converter output as shown in figure 6below.
The results which are obtained get subtracted and a reference signal is multiplied, when it is demodulated and the DC signal is obtained when it is filtered, which is proportional to the difference or error between digital angle □ and resolver angle θ, which is placed in the counter, further it is increased or decreased by using voltage-controlled oscillator till error becomes zero, at point □ = 0. This by increasing or decreasing of digital angle □, tracks the resolver angle θ, that is how this type of converter is the name so.

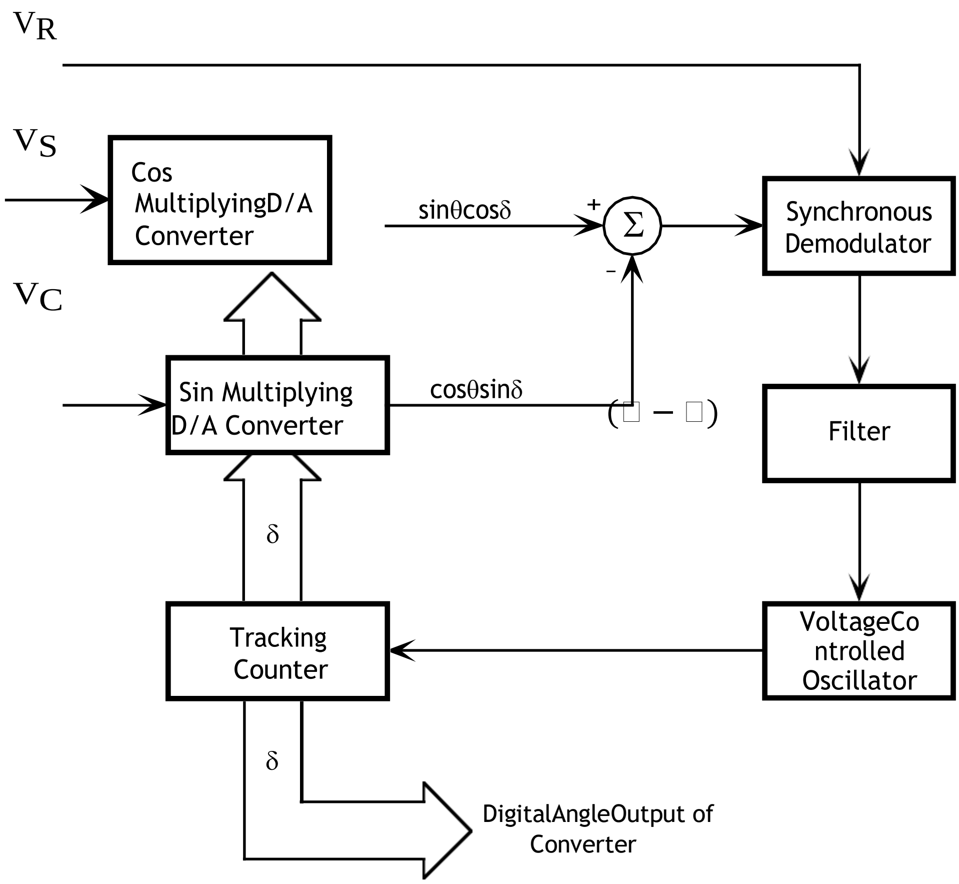

Fig 6: Typical Resolver to Digital Converter

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4. 10- Bit to 16- Bit Resolver – To – Digital Converter

In figure 7, the design of the signal chain not only considers amplitude and frequency but also consider phase shift and stability. Secondly, the inductive and resistive components are included in the winding impedance of the rotor resolver. The maximum number of resolvers are defined at an excitation frequency of almost around 10kHz. Non-identical phase shifts with various resolvers can be taken in signal chain design.

The resolver rotor winding is applied from the excitation signal, which comprises a resistive and non-ideal inductor ranging from 50Ω to 200Ω and reactive component ranges from 0Ω to 200Ω.

For resolver driver maximal current and maximal power consumption excitation signal can be equivalent to 20□□−□(7.1 □□□□). In the circuit shown in fig 7, AD8397 is considered due to the high supply range (24V), larger output current (310mA peak into 32 Ω on ± 12V supply), and minimum thermal resistance package. The AD2S1210 generates an excitation signal which is produced from internal DAC which causes distortion and quantization noise, due to this in the circuit shown in fig 7, AD8692 op-amp is designed which behaves as a third-order active Butterworth filter to minimize the driver signals noise.

The highest tracking rate of Resolver – To – Digital Converter is 3125rps in 10- bit mode (i.e., the resolution is 21arcmin) and for 16- Bit mode is 156.25rps (i.e., the resolution is 19.8 arcsec).

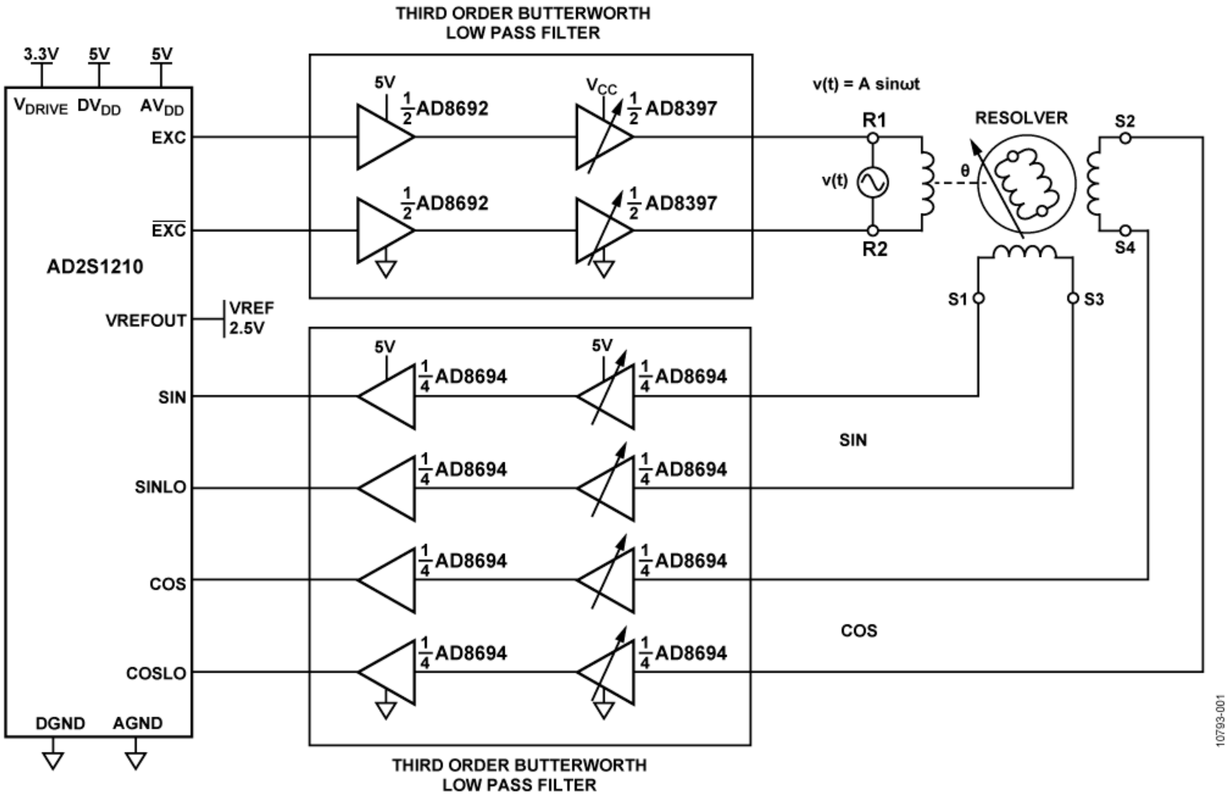

Fig 7: Complete Maximum Performance of Resolver to Digital Converter (RDC) Circuit

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5. Conclusion

Possible inimical environmental motor applications are controlled by a mixture of resolvers and an RDC like AD2S120 analog devices produce position and velocity of control systems with maximum reliability.

For good performance, the mixture of AD8397 and AD8694 produces buffer circuits that enhance excitation signals and generates necessary driver for resolvers such as feedback of secondary signals and filtering.

RDC with AD2S1210's fluctuating resolver, on-chip diagnostics, and source generation provides the perfect outcome for applications of the resolver.

References

[1]Bonnie Baker 'How to Precisely Determine Motor Angular Position and Velocity With a Resolver', Digi-Key's North American Editor-2019.

[2] JackubSzymczak, Shane O Meara, Johnny Gealon, and Christopher, Nelson De La Rama, "Precision Resolver to Digital Converter Measures Angular Position and Velocity" – 2014.

[3]MohieddineBenammar, MohammdedBager, Mohammed AI K aisi 'Proceedings of the Eurosensors XXIII Conference' "Digitally –Tuned Resolver Converter'-2009.

[4] Circuit Note CN-0276, High Performance, 10-Bit to 16-Bit Resolver –to- Digital Converter.

[5] Variable Resolution, 10 Bit to 16 Bit R/D Converter with Reference Oscillator, AD2S1210 - ANALOG DEVICES.

[6] 24 bit Analog to Digital converter, ADS1210, ADS1211- TEXAS INSTRUMENTS.

[7] Christopher J. Courtney, Janesville, 'HamioltonSunstrand Corporation', "Resolver-to-Digital Converter" – 2015.

[8]Understanding Resolvers and Resolver-to-Digital Conversion – Rotaysn – 2018 .

[9] S. Chandra Mohan Reddy, Dr. Konduru Nagabhushan Raju "Resolver to Digital Converter based on Angle Tracking Observers Method" – 2012.

[10] Choong Hyuk Yim, In-Joong Ha, Myoung-Sam-Ko "Resolver-To-Digital Conversion Method for fast tracking" – IEEE, 2010.

[11] T.Venu Gopal Reddy, Chandra Reddy Sivappagri "Design of Resolver-to-Digital Converter for Motor Control Applications"- International Journal of Computer Sciences and Communication Engineering, 2018.

[12]John Gasking "Resolver-to-Digital Conversion – A Simple and Cost Effective Alternative to Optical Shaft Encoders" – Analog Devices.

[13]Shuo Wang, Jinsong Kang, Michele Degano, Giampaolo Buticchi, "A Resolver- to – Digital Conversion Method Based on Third- Order Rational Fraction Polynomial Approximation For PMSM Control" – IEEE Transactions on Industrial Electronics, 2018.

[14]Yaoling Li and Zhong Wu, "High Accuracy Resolver- To- Digital Conversion Via Phase Locked Loop based on PID Controller" – ICMES 2017.

[15]G.Dorababu, S. Chandra Mohan Reddy, K Nagabhushan Raju, "Software Based RDC Using Pulse Excitation" – International Journal of Computer Sciences and Communication Engineering, 2013.