Choosing the Right Automotive Position Sensor Technology: A Comparative Guide

Power Flow Systems

Abstract:

In the automotive industry, the selection of position sensor technology is crucial for ensuring the performance, reliability, and safety of various battery powered vehicle systems (BEVs). Position sensors play a critical role in traction control, steering systems, and braking systems. The choice of sensor technology can significantly influence the overall vehicle performance and durability. This white paper compares three prominent position sensor technologies—Inductive Position Sensors, Variable Reluctance (VR) Resolvers, and Anisotropic Magnetoresistive (AMR) Sensors—to aid automotive engineers in making informed decisions.

Overview of Position Sensor Technologies

1. *Variable Reluctance (VR) Resolvers:*

VR resolvers operate on the principle of variable reluctance, where the inductance between a stationary coil and a rotating ferromagnetic target changes with the target's position. Traditionally used in aerospace and military applications, VR resolvers are now gaining popularity in the automotive sector due to their robustness, reliability, and ability to provide continuous analog feedback.

- Components: The VR Resolver consists of 3 Parts:
    1. Transmitter: Excitation windings
    2. Receivers: Sin and Cosine windings
    3. VR Rotor: Variable reluctance rotor

- Working Principle:
  1. The resolver excitation is generated using a high-frequency signal. This can be considered as a carrier signal used to communicate the rotor position information to the receiver windings through amplitude modulation (AM). Thus, it must comply with the principles of AM carrier signal i.e. the excitation frequency should be chosen such that it can achieve the following asks:
     a) Can be easily removed during Demodulation and filtering (Thus, subjective to demodulation method used).
     b) Can reduce the impact of speed/winding harmonics on position information. (A rule of thumb: when excitation frequency is 10 times larger than maximum fundamental frequency, it results in maximum harmonic error of 10%).

  2. The receiver windings are sinusoidally distributed wound. The sine winding is wound such that it makes electrically 90 degree with the cosine winding. Here, the mechanical/physical angle between the Peak number of turns (Ns) of Sin and Cos windings would be:

     $\varphi_p = \frac{90}{P}$, where P is number of Pole pairs (1)

     The sinusoidal distribution of windings along with VR rotor causes the generation of sinusoidal amplitude modulated receiver signal.

3. The VR Rotor produces a sinusoidal reluctance (inductance) variation causing the receiver signals to be sinusoidally modulated. The structure of VR rotor can be seen on Fig.1.

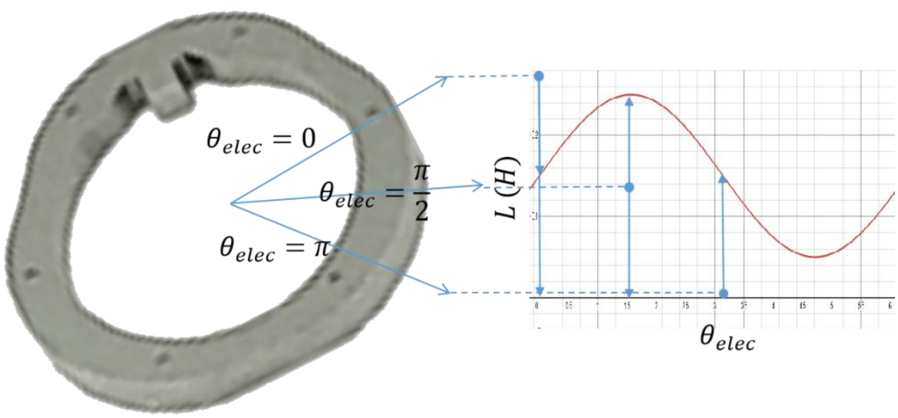

Fig.1: 3-pole pair VR rotor

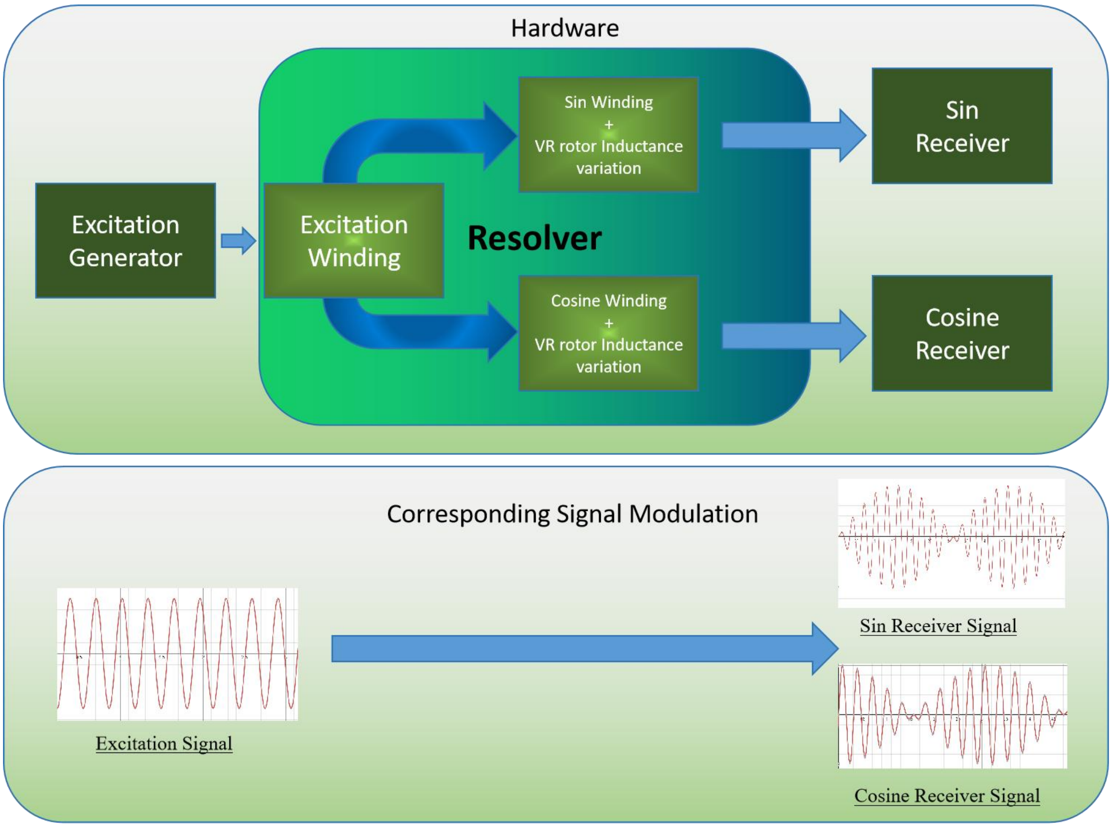

Fig.2: Working Principle of VR Resolver

2. Inductive Position Sensors

Inductive position sensors function based on electromagnetic induction. They measure the position of a metallic target by detecting changes in inductance as the target moves within the sensor's magnetic field. These sensors are known for their non-contact operation, high precision, and durability, making them ideal for various automotive applications.

- Components: The Inductive position sensor consists of 3 Parts (Fig. 3):
  1. Transmitter: L-R oscillator that generates a excitation signal
  2. Receivers: Sin and Cosine coil on PCB
  3. IC: An IC chip to generate excitation and sample receiver signals

- Working Principle:The working principle of Inductive position is the same as VR Resolver

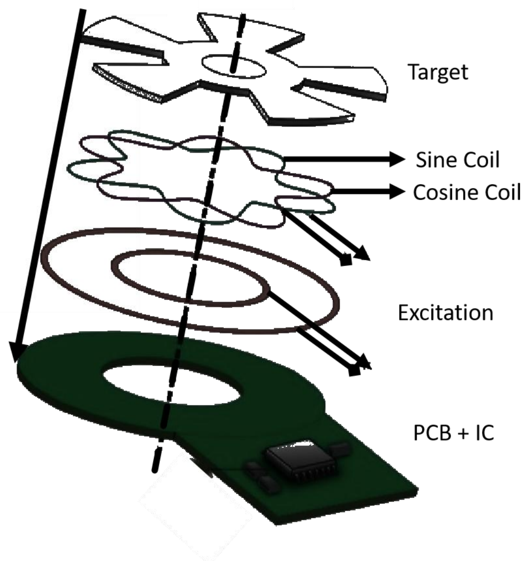

Fig.3: Inductive Position Sensor [1]

3. *Anisotropic Magnetoresistive (AMR) Sensors:*

AMR sensors leverage the magnetoresistive effect, where the electrical resistance of a material changes in response to a magnetic field. These sensors offer high sensitivity and versatility, capable of measuring both linear and angular positions with significant accuracy. However, their performance can be heavily influenced by temperature fluctuations.

Why AMR sensors are generally not preferred for automotive applications?

While AMR sensors offer high precision and versatility, their susceptibility to temperature variations and cost make them less suitable for automotive applications. Temperature changes can cause significant drift in the sensor's readings, associated with the change in residual magnetic flux density (Br) of magnets and resistance of the magnetoresistive material in the receivers, leading to potential inaccuracies in environments where temperature stability is critical. Automotive grade sensors are required to operate at temperatures between –40 DegC to ~200 DegC. The higher temperatures can cause significant reduction in the Br of the magnet causing change in the gain of the receiving system.

Furthermore, the cost associated with high grade magnets that can operate at such high temperatures is high. In Addition, magnetoresistive materials used for receivers in AMR sensors are expensive to manufacture, which contributes to cost of AMR sensors.

Given these limitations, further analysis will focus on comparing VR resolvers and inductive position sensors, which provide more robust performance across varying temperatures and lower cost making them suitable for automotive applications.

VR Resolvers vs. Inductive Position Sensors: A Comparative Analysis

The comparison will focus on the remaining two technologies: VR Resolvers and Inductive Position Sensors.

Here is a table with three columns based on the provided data:

Criteria	VR Resolver	Inductive Position Sensor
I. Accuracy and Precision	• High accuracy, particularly in angular position measurements. • Ideal for real-time data systems like EPS and transmission, drives control.	• Excellent accuracy in linear and moderate angular measurements.
II. Environmental Robustness	• Excels in harsh environments, withstanding extreme temperatures, shock, and vibration. • Ideal for critical applications in hybrid and EV systems.	• Less robust in extreme/harsh environments compared to VR resolvers.
III. Size and Packaging	• Bulkier and heavier, which can be a limitation in compact or lightweight vehicle designs.	• More compact and lighter, offering greater flexibility in design.

IV. Signal Output and Interface	• Produces continuous analog output, directly proportional to the rotor's position. Beneficial for real–time, continuous data systems.	• Generally provides digital output after signal conditioning, simplifying integration with modern vehicle control systems. • Since it contains an IC, prone to EMI coupling from nearby source.
V. Cost and Complexity	• More expensive and complex due to construction and materials. Installation and calibration are more involved.	• More cost–effective and easier to manufacture and install. Economical for applications where ultra–high precision is not critical.
VI. Ideal Applications	• EPS, hybrid and EV drive systems, transmission control systems.	• Throttle position sensing, camshaft/crankshaft position sensing, gear position detection, high–speed motor traction systems.

Conclusion: Tailoring Sensor Choice to Application Needs

Selecting the appropriate position sensor technology in automotive applications depends on a careful balance of factors including accuracy, environmental robustness, size, cost, and the specific demands of the application.

VR Resolvers are the go–to choice for applications where **high precision, robustness, and continuous analog feedback are paramount**, especially in critical systems **like automotive transmission, and drives controls.**

Inductive Position Sensors offer a **more compact, cost-effective solution with adequate precision, making them ideal for less extreme conditions and applications where space is limited.**

To decrease the cost, if traction drives for Automotive applications use Inductive Position sensors, it has to be ensured that,

1. **the components leading to the IC and the PCB layout is able to handle EMI issues,**
2. **able to withstand high temperatures upto 200 DegC or adequate cooling mechanism must be implemented to allow such operations,**
3. **The PCB is able to withstand mechanical vibration without causing component damage.**

References

[1] https://www.melexis.com/en/product/MLX90510/High-speed-Inductive-Resolver-Analog-on-chip