



**Comparative Analysis of
Encoder Designs for Electric
Vehicle Applications**

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1 Introduction

Encoders play a crucial role in the operation of electric vehicles (EVs) as they contribute to the precision and efficiency of these vehicles. They are also an integral part to the control systems of EVs and help measure parameters like speed, position, and direction. This study aims to dive into the design of encoders used in EVs, with a focus on optical and magnetic encoders, as well as, exploring the working principles, advantages, disadvantages and how they contribute to the overall performance of EVs.

2 Background

Encoders are important components in many electromechanical systems which provide precise measurements of motion and position. They convert motion into an electrical signal which can be read by a control device in a motion control system. The encoder then sends a feedback signal that can be used to determine the position, count, speed, or direction of an object. There are several known types of encoders, but the two main types are optical and magnetic encoders.

2.1 Optical Encoders

Optical encoders digitise angular or linear motion. They're used in many mechanical system position control applications. An optical encoder has a light source (usually an LED), a photodetector (usually a photodiode or phototransistor), and a code disc or strip. The code disc is a circular plate with opaque and transparent portions. The rotating shaft or moving part's disc is attached. The code disc or strip follows the system. The photodetector is opposite the light source, which illuminates the disc. As the disc spins or moves, the photodetector receives light from alternating opaque and transparent areas. Photodetectors generate electrical signals from light received. The photodetector generates a strong signal when light passes through the clear disc. Low signals result from opaque parts blocking light. The system's location is output digitally. The digital signal can locate a microcontroller or other digital system. Rotary encoders may be rotated. Possibly a linear encoder site. An optical encoder's resolution depends on the code disc or strip's opaque and transparent areas. More sections increase the resolution and results in increased position accuracy [1] [2].

Advantages:

- High resolution
- High accuracy
- Low noise interference

Disadvantages:

- Sensitive to dust and dirt
- High temperatures – can interfere with the light source and reduce accuracy [1]

2.2 Magnetic Encoders

A magnetic encoder basically comprises of a magnetised wheel or ring, a magnetic sensor, and a signal processing circuit. A set of magnetic poles run around the perimeter of the wheel or ring. The magnetic sensor is activated as the wheel or ring rotates (due to the motion of the system being monitored). The alternating magnetic poles on the wheel or ring generate changes in the magnetic field, which are measured by the sensor. The magnetic sensor provides a response dependent on the intensity of the magnetic field. This answer is then supplied into a signal conditioning circuit, which analyses the signal and outputs it as a digital signal. The digital signal may be read by a microcontroller or other digital device to identify the system's location. The number of magnetised pole pairs on the wheel or ring, the number of sensors, and the kind of electrical circuit all contribute to the magnetic encoder's resolution [3].

Advantages:

- Less sensitive to dust, dirt and temperature – more robust in harsh environments [2]

Disadvantages:

- Offer lower resolution compared to optical encoders [2]

2.3 Applicability in EV Systems

Optical encoders, with their high resolution and accuracy can be used in precision applications. For instance, they can be used in the steering system where they provide feedback about the position and angle of the steering wheel. This data can then be used to control the steering motor and ensure accurate and responsive steering. Optical encoders can also be used in the motor control system to provide precise control of the electric motor's speed, direction, and position, which is important for the overall performance of the vehicle. On the other hand, magnetic encoders are more durable and less temperature- and dust-sensitive. This qualifies them for usage in the drivetrain and other more demanding EV components. The drivetrain can deliver dependable performance even under challenging circumstances. Also, feedback on the position and motion of various parts may be obtained from them, and this information can be used to regulate the gearbox system and ensure effective and seamless gear changes. Magnetic encoders in regenerative braking systems can also give information on the direction and speed of the wheels. With the help of this knowledge, the braking system can be managed to maximise energy recovery [3].

3 Comparison of Encoder Designs

Optical encoders provide excellent resolution, precision, and accuracy. Because of the very advanced optical discs, resolutions of up to 0.005° (16 bit) and precision of up to 0.01° are possible. Magnetic encoders have similar resolution and precision as optical encoders, although not as high. They have a resolution of up to 0.005° (16 bit) and a precision of up to 0.088° . Optical encoders can detect and measure position at very high rotation rates. Magnetic encoders also function well at high speeds, albeit perhaps not as well as optical encoders. Optical encoders are susceptible to dust, moisture, and severe temperatures, which can degrade their function. Magnetic encoders are more durable and can function consistently in difficult situations such as dust, moisture, severe temperatures, and strong shock and vibration. Optical encoders are frequently employed in applications requiring great precision and accuracy, such as electric vehicle (EV) control systems. Their sensitivity to external conditions, on the other hand, may limit their utility in some EV applications. Because of the durability of magnetic encoders, in hostile settings, they are excellent for use in EVs. They may give dependable position feedback in applications like motor control, which can increase the EV's efficiency and performance [3] [6] [7].

4 Error Analysis

4.1 Optical Encoder

Passing light beams across a disc generates pulses in optical encoders. Dust or particles on the disc may block the laser beam and cause mistakes. Vibration and stress can displace the disc or destroy optical encoders. Temperature variations can cause the encoder's components to expand or shrink, causing misalignment and faults. The light source, disc, and photodetector must be aligned for accurate readings. EVs use optical encoders for motor control and position sensing. Errors in encoders can cause motor control issues. The motor will be wrongly operated if the encoder readings are wrong, affecting the EV's performance and efficiency. EVs use encoders to locate parts. If the encoder readings are erroneous, the EV's operation may be affected. Cleaning the optical disc regularly prevents dust and grime from blocking the light path and causing errors. Vibration dampening materials and methods help reduce encoder damage from shock and vibration. Temperature adjustment prevents errors in some optical encoders. Many error compensation methods can be used to compensate for encoder reading errors. One option is to utilise a look-up table and fitting procedures to the Lissajous figure of the deteriorating measurement signals to improve sensor accuracy [8].

4.2 Magnetic Encoder

Magnetic encoders are affected by stray magnetic fields. By keeping magnetic stray fields and magnetism-transferring objects away from the magnetic encoder, angular inaccuracy and distortion of the magnetic field input to the Hall element are reduced. By increasing the magnetic field input to the Hall element, electrical noise is reduced, resulting in angular inaccuracy. Misalignment of the hall element during installation can result in angular inaccuracy. Because the permanent magnet and Hall element centres are shifted, the magnetic field input to the Hall element is distorted. The Hall element, AD converter, and arithmetic circuit required for the magnetic encoder are all included in the rotating angle sensor IC.

Temperature-related errors are reduced by its low sensitivity variation and offset. Magnetic encoders are used in EV motor control and position detection. Motor control problems can be caused by encoder defects. Encoder readings have an impact on EV performance and efficiency. Encoders are used in EVs to locate components. Errors in encoder readings can have an impact on EV functioning by delivering incorrect location information. Magnetic fields can shield encoders. Calibration on a regular basis assures precision. Temperature correction prevents inaccuracies in some magnetic encoders. Encoder readings can be corrected using error compensation methods. To improve sensor accuracy, one way employs fitting techniques to the Lissajous figure of decreasing measurement signals using a look-up database [9].

5 Conclusion

The report analyses how optical and magnetic encoders operate electric vehicles (EVs). EV encoders measure speed, position, and direction, improving precision and efficiency.

Steering systems and motor control employ optical encoders for their high resolution and accuracy. Their performance is affected by dust, grime, and extreme temperatures. Magnetic encoders, which employ magnetic fields to detect motion, are more durable for severe situations. They work in drivetrains and other demanding EV components like regenerative braking systems. They are lower resolution than optical encoders. EV performance and efficiency are affected by encoder errors in motor control and position sensing. Cleaning, protection from magnetic fields, calibration, and error correction reduce these inaccuracies. Encoder design affects EV monitoring and control. The application's accuracy, durability, and environmental resistance determine the decision between optical and magnetic encoders. Thus, high-resolution, accurate, robust, and environmental-resistant encoders might improve EV performance, accuracy, and dependability. Encoder improvements might boost EV performance. Hybrid encoders that combine optical and magnetic encoders might offer excellent resolution, accuracy, robustness, and environmental resistance. Advanced error correction might boost encoder accuracy. Advanced materials and manufacturing methods might potentially produce more durable, dependable, and cost-effective encoders. Encoder technology will certainly improve as EV demand rises.

6 References

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