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THE ROLE OF SENSORS IN ELECTRIC BICYCLES: A COMPREHENSIVE GUIDE

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INTRODUCTION

An electric bicycle, commonly known as an e-bike, is a bicycle equipped with an electric motor and battery to assist with pedaling. The rapid market growth of the e-bike is attributed to its clear advantages. Compared to a conventional bicycle, an e-bike offers enhanced comfort, integrated safety features, and improved health benefits, while remaining highly affordable. In the modern e-bike, multiple sensors are used to ensure safety, comfort, and high efficiency. Magnetic sensors are integral to the increasing popularity of the e-bike. Various magnetic sensors used in an e-bike are shown in Figure 1, and a typical system architecture of an e-bike is shown in Figure 2.

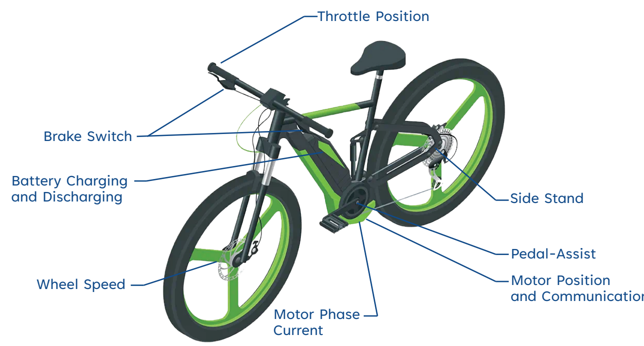

Figure 1: Magnetic Sensors Used in an E-Bike

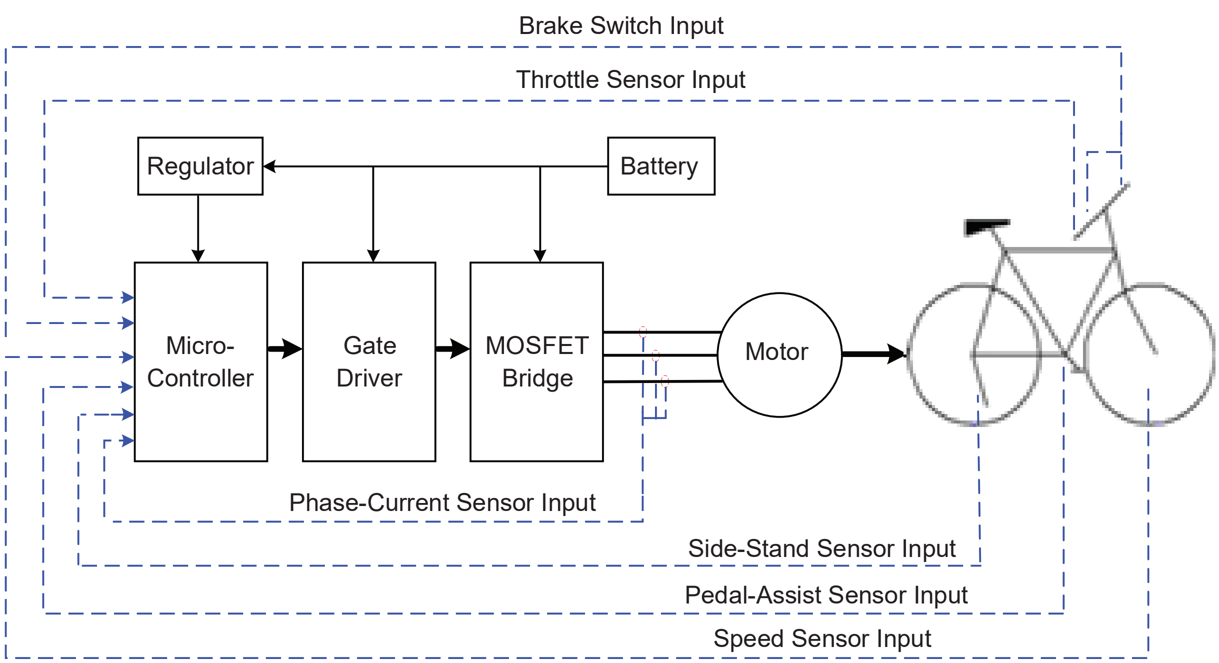

Figure 2: Architecture of an E-Bike

Throttle Position Sensor

In an e-bike, a throttle sensor, also known as an accelerator position sensor, is mounted on the handlebar to allow speed control without the need for the rider to pedal, similar to a motorbike or scooter. It provides power assistance via a signal to the controller, which controls the motor. The throttle sensor provides an analog or digital input to the controller, which allows the rider to set the speed of the e-bike.

The throttle position sensor can be implemented as a thumb-press lever or twist-grip arrangement mounted to the handlebar. In a thumb-press lever arrangement, a diametric cylindrical magnet is used, with an angle sensor placed on the same axis as the magnet; this is known as an on-axis setup. In a twist-grip arrangement, a diametric arc magnet is used, with the grip rotating 90 degrees and an angle sensor placed in front of the magnet; this is known as an off-axis setup. The Allegro A31315 3DMAG™ position sensor [1] measures on-axis and off-axis rotation. Based on the position of the thumb-press lever or the twist grip, the A31315 sensor provides an analog or digital output to the controller to assist the rider. The thumb-press lever with the diametric cylindrical magnet and the twist-grip throttle with the diametric arc magnet arrangement are shown in Figure 3.

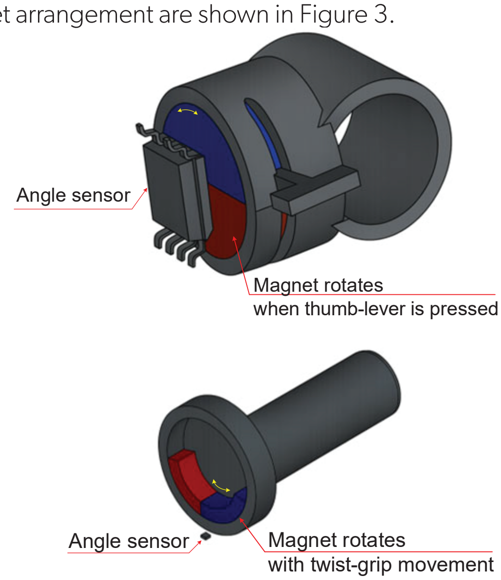

Figure 3: Throttle Setup—Thumb-Press Lever (top) and Twist-Grip (bottom) Arrangements

Pedal-Assist Sensor

A pedal-assist sensor or a cadence sensor contains discrete magnets that are symmetrically placed in a casing that spins with the pedal. The sensor detects the forward-rotation speed and direction of these magnets and generates the corresponding square-wave output pulses. As pedal speed increases, the frequency of the output signal increases and more power assistance is required. The pedal-assist sensor setup with six axial magnets and a Hall-effect latch mounted to the pedal shaft is shown in Figure 4.

The Allegro APS12625 [2] is a single-chip Hall-effect latch with speed and direction outputs. The device is available in a 5-pin, surface-mount SOT23 package. The speed and direction outputs of the APS12625 can be combined to create a unique interface for an e-bike pedal-assist sensor. For additional information about the pedal-assist sensor, refer to the Allegro technical article Magnetic Position Sensors Efficiently Drive E-Bike with Pedal Assist Systems. [3]

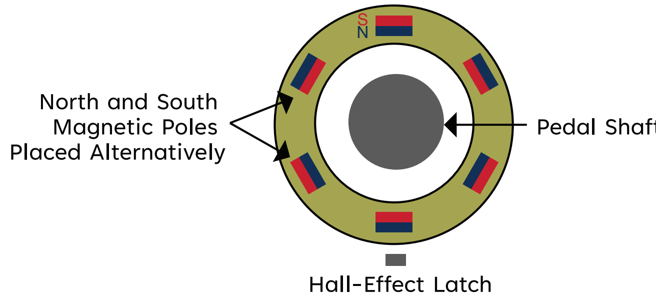

Figure 4: Pedal-Assist Sensor Setup

[1] https://www.allegromicro.com/en/products/sense/linear-and-angular-position/3d-magnetic/a31315
[2] https://www.allegromicro.com/en/products/sense/switches-and-latches/dual-hall-effect-latches/aps12625-6
[3] https://www.allegromicro.com/en/insights-and-innovations/technical-documents/magnetic-position-sensors-efficiently-drive-e-bike-with-pedal-assist-systems

Wheel Speed Sensor

To measure the wheel speed of the e-bike, a simple Hall-effect switch is used. The magnet is attached to the spoke of the wheel, and the sensor is placed on the stationary fork. As the wheel spins, when the magnet passes in front of the sensor, the sensor provides a pulse. The e-bike travel speed is calculated by use of pulse counts as the wheel revolves. This data can be used to determine the maximum travel speed, to maintain a consistent cruising speed, and to provide the rider with timely feedback to ensure user safety. The magnet and sensor arrangement mounted to an e-bike wheel for speed detection is shown in Figure 5.

Allegro offers the low-cost APS1120x [4] precision Hall-effect switch, which is suitable for wheel-speed sensor applications. When the magnet passes in front of the sensor within the desired air gap between the magnet and the sensor, the APS1120x produces a pulse output. This Hall-effect switch is available in either a three-pin SOT23 package or a three-pin single-inline package (SIP).

To improve the speed, safety, and accuracy of braking, some e-bikes now implement an anti-lock braking systems (ABS). The ABS sensor, which consists of a wheel-speed sensor and a ferrous target wheel, is shown in Figure 6. An ABS uses a wheel-speed sensor to deliver exact wheel speed and position measurements to the ABS controller, which is mounted to the front or rear wheel of the e-bike. In these e-bikes, when brake application would otherwise cause the wheel to lock, the ABS system applies and releases the brakes briefly, to prevent the locked-wheel condition. The A19200 [5] is a versatile and user-friendly solution for ABS wheel speed sensing, with two wire interfaces, integrated capacitors for improved electromagnetic compatibility (EMC) performance, and optimal Hall-element spacing for high-resolution measurements. Allegro also offers the ATS19580, [6] which is a precise speed and direction sensor for ferromagnetic gear-tooth targets. The ATS19580 includes giant-magnetoresistance (GMR) technology for extended air-gap performance.

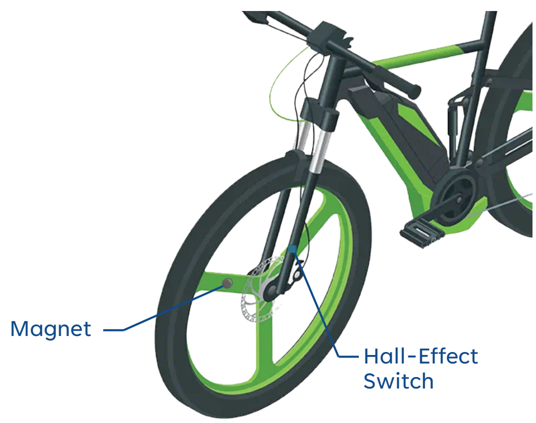

Figure 5: Wheel Speed Detection

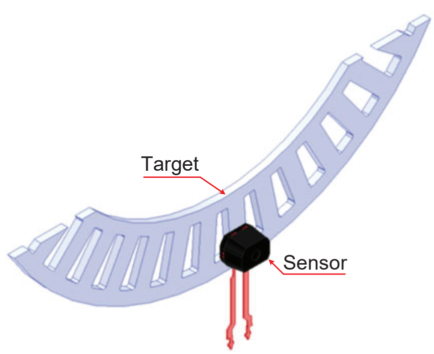

Figure 6: ABS Sensor with Target

[4] https://www.allegromicro.com/-/media/files/datasheets/aps11202-datasheet.pdf?sc_lang=en
[5] https://www.allegromicro.com/en/products/sense/magnetic-speed/wheel-speed-sensor-ics/a19200
[6] https://www.allegromicro.com/en/products/sense/magnetic-speed/transmission-sensor-ics/ats19580

Brake Switch

In an e-bike, when the brakes are applied, the controller must turn off the motor assistance. Provision of data about the use (or nonuse) of the brakes requires a sensor that can send an input signal to the controller to stop the motor assistance. Brake switches are mounted on the left and right sides of the handlebar to detect if the front and rear wheel brakes are engaged. For production simplicity, a low-cost omnipolar Hall-effect switch provides the control signal and pole-independent functionality (either south or north pole). A small cylindrical NdFeB magnet is mounted to the brake lever, with an air gap between it and the switch. When the magnet approaches the sensor when the brake is engaged, the magnetic field crosses the magnetic operating point (BOP), which causes the sensor to change the output level. After the controller receives the switch output signal, the controller turns off the motor assistance. When the switch output is turned off, motor assistance resumes. Additionally, the switch output signal is used by the controller to control the brake light. The Allegro A1126 [7] ultrasensitive Hall-effect switch with omnipolar operation is suitable for this application. The arrangement of magnet and sensor for the braking switch is shown in Figure 7.

Motor Position and Commutation

For better efficiency, modern e-bikes use brushless DC (BLDC) motors. In a BLDC motor, proper commutation requires the rotor position to be known. Motor-position sensing helps to determine the optimal timing and sequence for this switching, which ensures smooth and efficient operation. Traditionally, trapezoidal commutation uses three Hall-effect latches spaced 120 degrees apart on the stator. A permanent magnet mounted on the rotor shaft generates a revolving magnetic field that interacts with the stator electromagnetic field to produce the torque required for rotation.

In a high-performance e-bike, a permanent magnet synchronous motor (PMSM) is used to provide a smooth and efficient ride. The PMSM drives generate sinusoidal excitation and require greater resolution for the angle data, typically one degree. To provide angle data with better resolution, an angle sensor can be used. Allegro devices, such as the CT310 [8] tunneling magnetoresistance (TMR) angle sensor offers the capability for differential sine cosine outputs while supporting magnetic field inputs ranging from 200 gauss to 900 gauss. The A33230 [9] 3D Hall-effect sensor can provide the sine and cosine outputs and supports magnetic field inputs ranging from 300 gauss to 1200 gauss. The three possible sensor arrangements for rotor-position sensing are shown in Figure 8: three Hall-effect latches (left); angle sensor mounted on the axis (center); and c) angle sensor mounted off the axis (right).

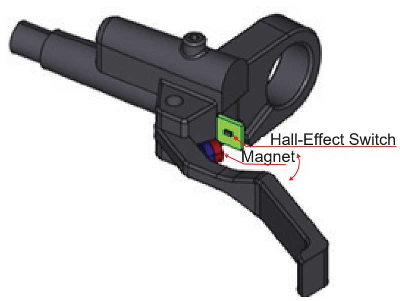

Figure 7: Brake Switch Arrangement

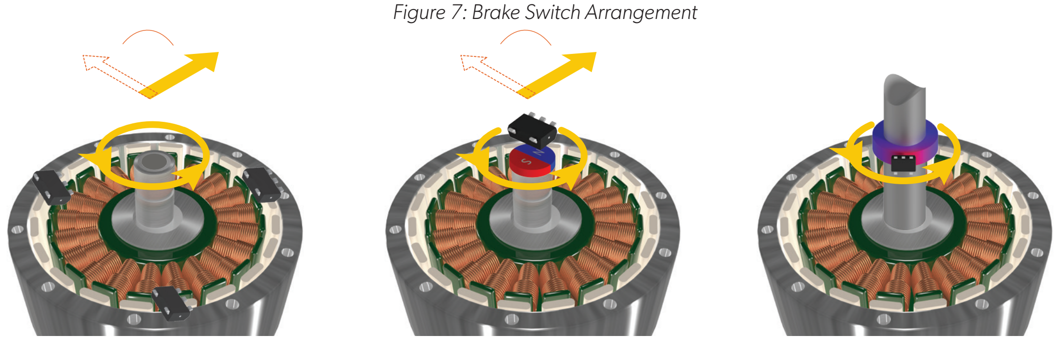

Figure 8: Rotor Position Sensor Mounting: Hall-Effect Latches (left), Angle Sensor in On-Axis (XY, center) and Off-Axis (YZ, right) Arrangements

[7] https://www.allegromicro.com/-/media/files/datasheets/a1126-datasheet.pdf
[8] https://www.allegromicro.com/en/products/sense/linear-and-angular-position/motor-position-sensors-2d/ct310
[9] https://www.allegromicro.com/en/products/sense/linear-and-angular-position/motor-position-sensors-2d/a33230

Motor-Phase-Current Sensing

Motor-phase-current sensing measures the current flowing across two or three phases of a three-phase motor. Many motor-control techniques, such as those that use direct torque control and field-oriented control, require real-time phase current sensing. A well-controlled electrical drive that allows the motor to function effectively requires a precise measurement of the current passing through the coils.

In a motor-driver circuit, current can be sensed at various locations. For example, motor current can be measured at the low side or high side of the driver or motor phase. Certain Allegro products, such as the integrated current sensor ACS71240 [10] and the contactless TMR current sensor CT455, [11] are suitable for measuring the motor-phase current. Current measurement with inline current sensors in a BLDC motor-driver circuit is shown in Figure 9.

Battery-Current Sensing

E-Bikes use battery current measurement to monitor bidirectional energy flow, encompassing both charging and discharging currents. This real-time current data is provided to the battery management system (BMS), enabling optimization of charge cycles and load balancing. Consequently, this data maximizes operational efficiency, extends battery service life, and enforces critical safety protocols. This current data helps in the accurate determination of the state of charge and state of health of the battery, thereby preventing catastrophic overcharging or deep discharge cycles and enabling intelligent, adaptive charging strategies.

Several Allegro current sensors—such as the ACS71240, [10] ACS37041, [12] and ACS724 [13]—can be used for the battery-current sensing application.

Side-Stand Sensor

Side-stand sensors, like those found on motorcycles and scooters, are employed in e-bikes to give additional rider protection. If the side stand is lowered, the rider can become endangered, so the motor assistance is not allowed; if the side stand is raised, motor assistance is allowed. When paired with a permanent magnet, a Hall-effect switch provides a very reliable contactless method to identify the position of the stand. To achieve optimal sensor performance, the magnetic flux lines must maintain the correct polarity and must be directed perpendicularly through the active area of the device. Depending on the internal architecture, this target zone is the sensitive edge in a vertical Hall sensor or the branded face in a planar Hall sensor.

Allegro offers a wide range of low-cost Hall-effect sensors, including the APS1120x [14] series, which supports a wide range of values for the magnetic operating point (B_{OP}) and the magnetic release point (B_{RP}) switch points.

CONCLUSION

Electric bicycles are becoming increasingly popular, and Hall-effect sensors play an important role in their design. These sensors send position, speed, and human input data to the controller, allowing more-efficient motor control and delivery of a safer, more-enjoyable riding experience.

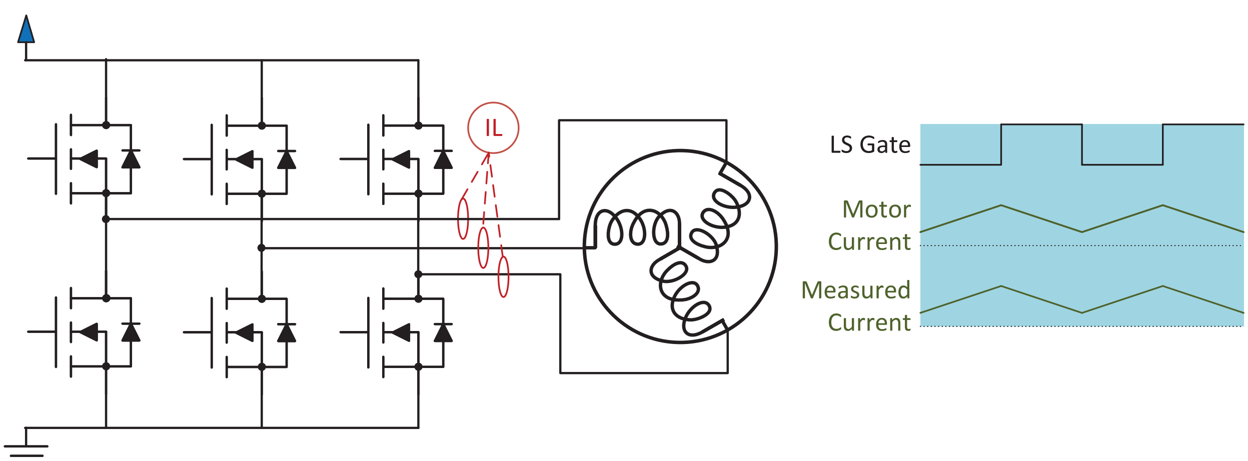

Figure 9: Current Measurement with Inline Current Sensors in a BLDC Motor Driver Circuit

[10] https://www.allegromicro.com/en/products/sense/current-sensor-ics/integrated-current-sensors/acs71240
[11] https://www.allegromicro.com/en/products/sense/current-sensor-ics/field-current-sensors/ct455
[12] https://www.allegromicro.com/en/products/sense/current-sensor-ics/integrated-current-sensors/acs37041
[13] https://www.allegromicro.com/en/products/sense/current-sensor-ics/integrated-current-sensors/acs724-5
[14] https://www.allegromicro.com/en/products/sense/switches-and-latches/switches/aps11203

Revision History

Number	Date	Description	Responsibility
–	February 13, 2026	Initial release	R. Farakate