Technical Article

Designing a Position Sensing System With an AMR Angle Sensor

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As global initiatives push for reductions in greenhouse gases emitted from internal combustion engine (ICE) automobiles, original equipment manufacturers (OEMs) are redesigning mechanical systems into electrically controlled systems. High-level system connectivity and intelligence have enabled self-driving vehicles, which have increased the demand for electronics and software algorithms to address safety requirements such as International Organization for Standardization (ISO) 26262.

Sensors, especially angle sensors, are an integral part of systems that need to meet functional safety standards, as they help monitor and provide the torque and angle information needed to efficiently drive or operate various automotive systems.

Designing EPS systems

An electric power steering (EPS) system consists of a steering column, an electronically controlled steering motor, and an electronic sense-and-control mechanism. An electric motor, often a brushless-DC motor, assists in steering when the driver turns the steering wheel, replacing the traditional mechanical and hydraulic system.

The benefits of an EPS system include faster and smarter operation, fewer carbon dioxide emissions, higher fuel efficiency, and an enhanced user experience. The driver provides the system inputs at the steering wheel interface. The sensor detects the position of the motor shaft and rotation of the steering wheel and sends the data to an electric control unit (ECU). Figure 1 highlights basic elements of an EPS system.

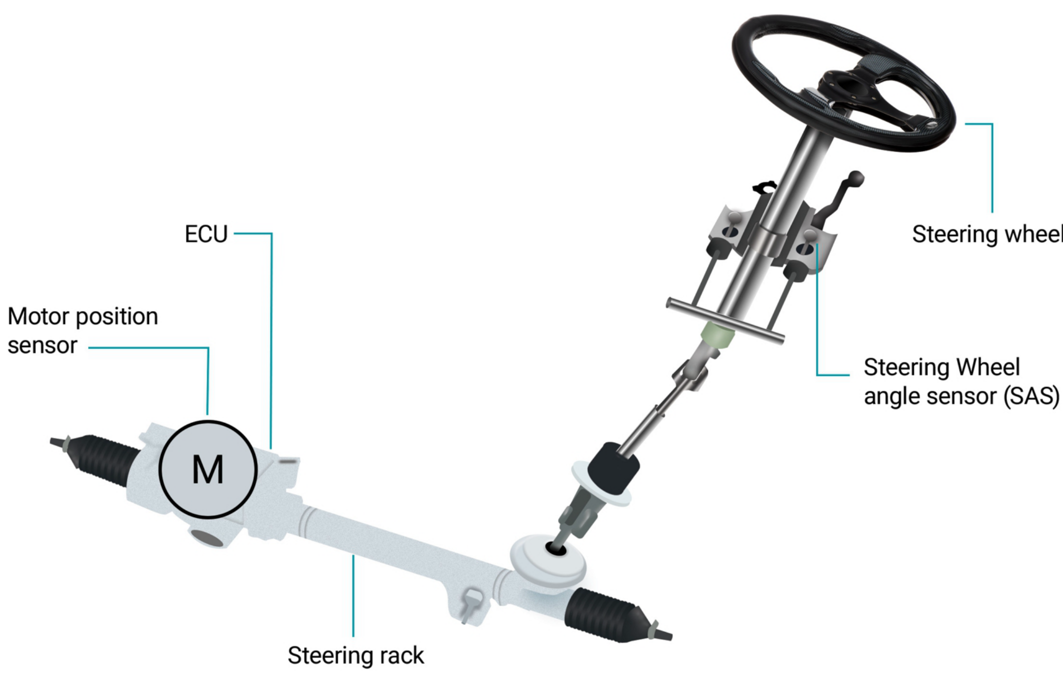

Figure 1. EPS System

The components used to design an EPS system include a microcontroller, sensors, power supply, motor driver and transistors. These are essential to the efficient communication and operation of the system. As Figure 2 illustrates, Controller Area Network is the bus standard used to interface with the ECUs in the vehicle.

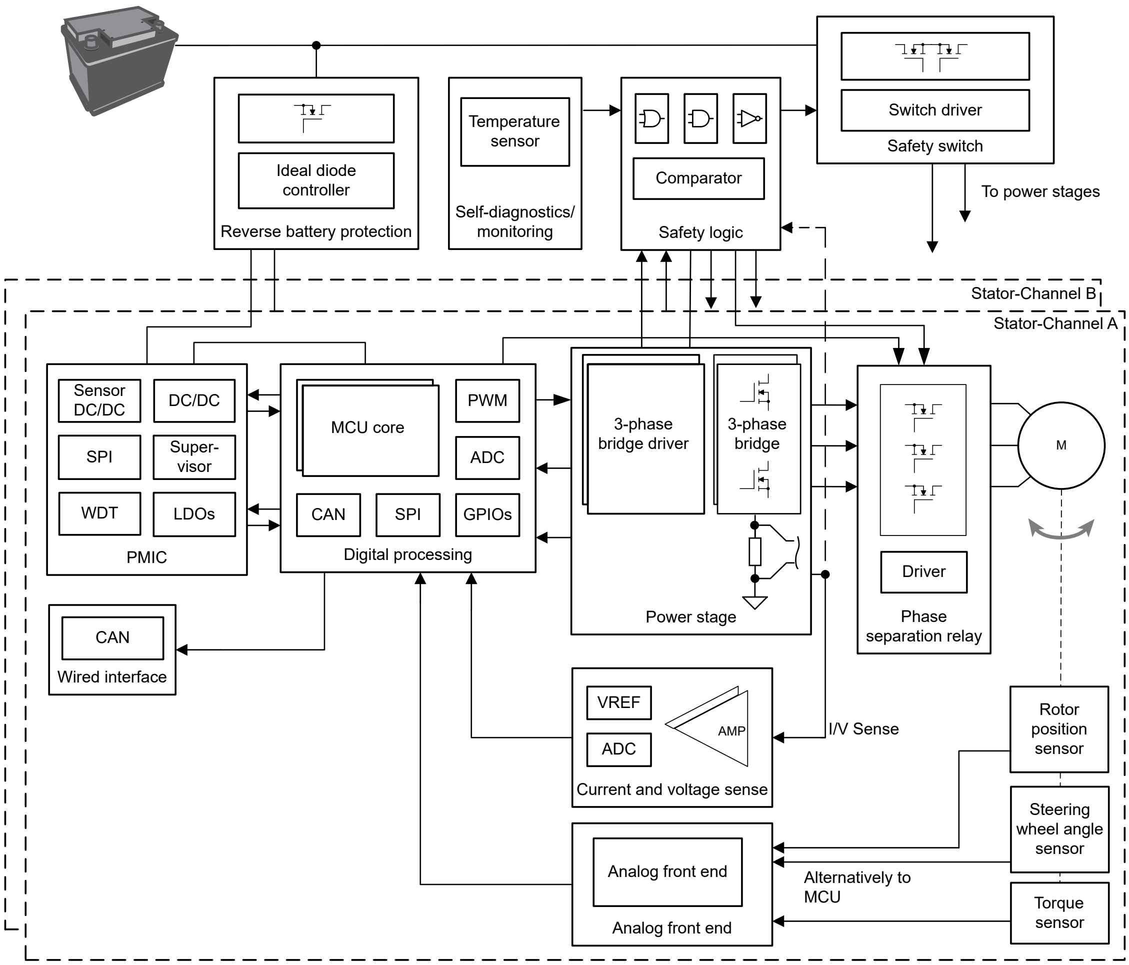

Figure 2. EPS System Block Diagram

The TMAG6181-Q1 is an anisotropic magnetoresistive (AMR) angle sensor featuring integrated signal-conditioning amplifiers that provide differential sine and cosine analog outputs related to the direction of the applied in-plane magnetic field.

The TMAG6181-Q1's <2µs latency and 0.4-degree angle error help boost system performance and efficiency. The sensor's integrated turns counter can track motor turns up to 32,000 revolutions per minute (rpm) in normal operation mode and up to 8,000rpm in low power mode. It also supports several device and system-level diagnostics features to detect, monitor and report failures during device operation. For example, in sleep or failure mode, the TMAG6181-Q1 AMR sensor's outputs move into a high-impedance state. Pulldown or pullup resistors are recommended to ensure the microcontroller is able to detect faults.

Processing AMR output signals and extracting the angular position of an EPS motor or steering wheel typically requires an external microcontroller. The AMR angle sensor in the TMAG6181-Q1 can be used in either single-ended or differential output mode; the latter mode eliminates common-mode disturbances in the system. The differential output sine and cosine signals from the AMR sensor are proportional to the angle of the applied magnetic field. The output voltages of the AMR sensor are ratio metric to the supply voltage to ensure the external ADC can reference the supply voltage.

Figure 3 shows a typical application diagram where the differential output signals SIN_P, SIN_N, COS_P and COS_N connect to four single-ended analog-to-digital converters in an external microcontroller, which communicates to the ECU in an EPS system.

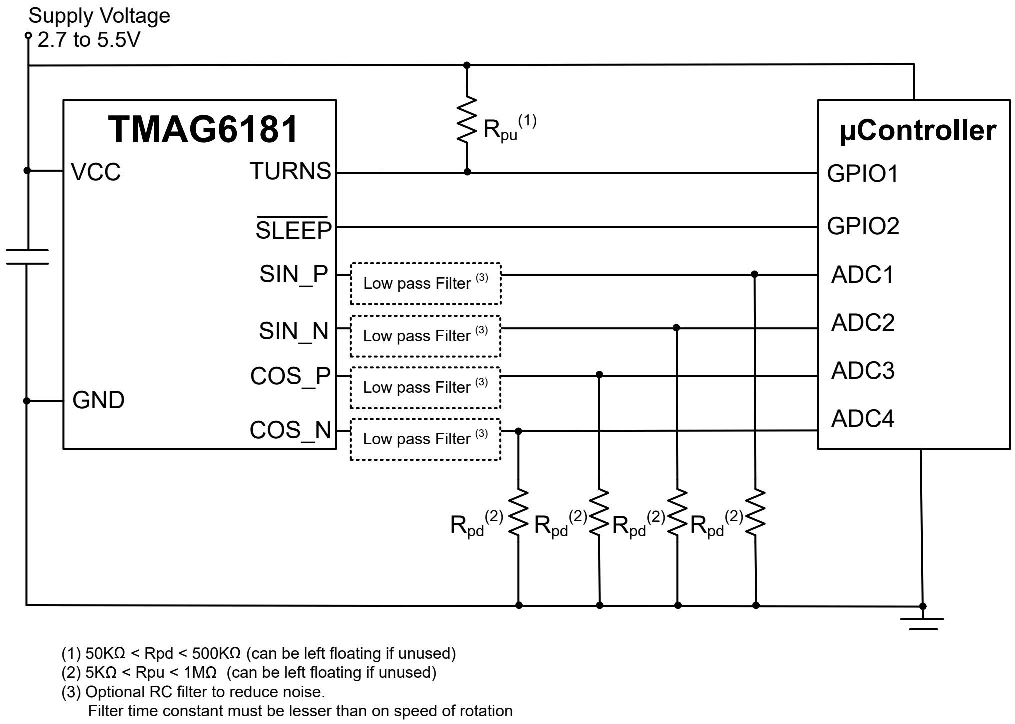

Figure 3. The TMAG6181-Q1 in Single-Ended Output Mode

I recommend differential ADCs if they are available because they increase reliability. For high accuracy, the load capacitors and resistors must match each other. The TMAG6181-Q1 can drive capacitive loads up to 10nF directly on the AMR output pins and resistive loads for source and sink currents up to 1mA.This enables smooth and reliable operation of an EPS system.

Documentation for ISO 26262 system designs up to Automotive Safety Integrity Level B is available for the TMAG6181-Q1 to simplify compliance.

Designing E-Bike and E-Scooter Systems

An e-bike is a bicycle that consists of five key components: an electric motor, battery, controls, sensors and display. Motors are an integral part of e-bikes because they help deliver the extra power needed during pedaling. Efficiently and reliably spinning the motor (which can be front-, center- or rear-mounted) requires an angle sensor, as shown in the block diagram in Figure 4.

An e-scooter is a gas-powered scooter that has been converted to electric. Its motor-drive system design is very similar to an e-bike, except that it is not as complex. An e-scooter design simply needs to provide power to the electric motor when the throttle is engaged, but an e-bike design must also gauge the pedaling power of the cyclist to determine how much power to deliver to the motor.

Different regions are requiring that e-bikes and e-scooters meet safety levels similar to what's required in the automotive industry.

Figure 4 highlights the components needed to develop an e-bike system. Angle sensors provide angle feedback, which is then computed by the microcontroller to efficiently and reliably spin the motor. AMR sensors are typically limited to 180 degrees, but the addition of two independent Hall-effect sensor outputs at the X and Y axes in the TMAG6180-Q1 can help extend the angle range of the sensor to 360 degrees.

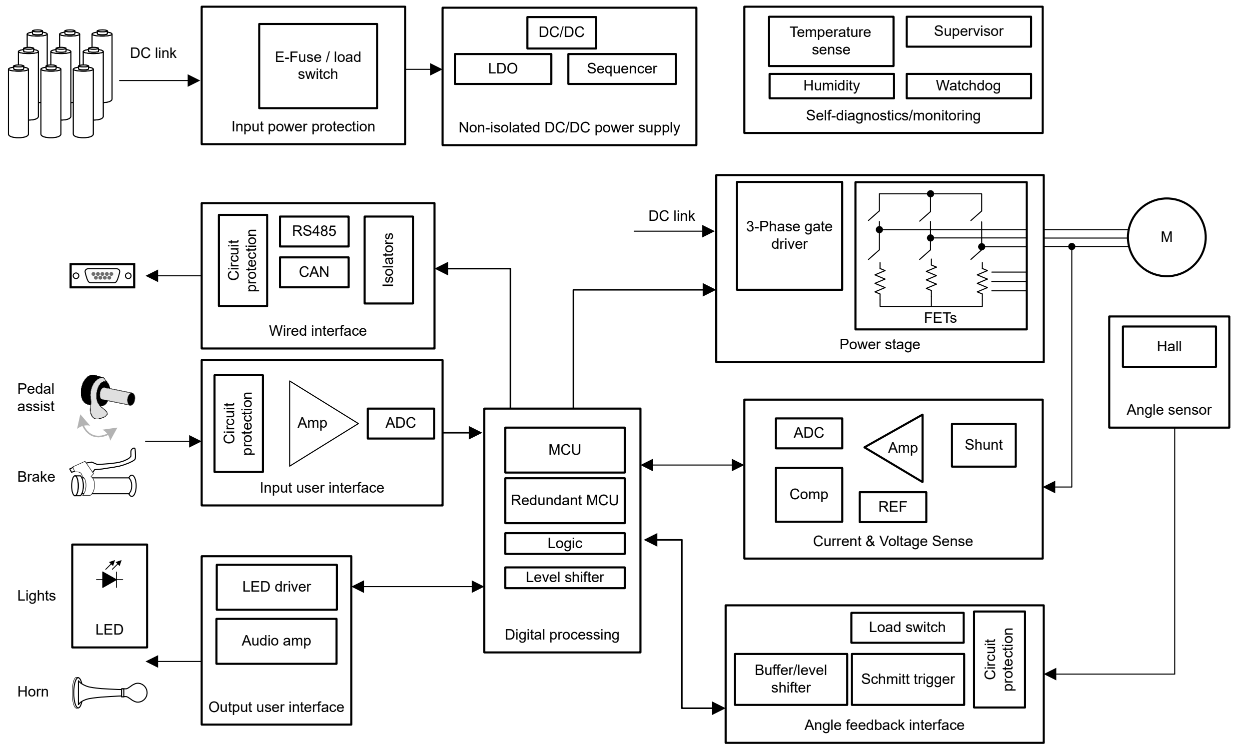

Figure 4. E-Bike Block Diagram

Conclusion

Today's vehicles and e-bikes consist of multiple ECUs to power and control advanced functions. Designing an EPS system, e-bike or e-scooter requires ECUs to accurately control them for efficient and reliable operation. The TMAG6181-Q1 enables faster and more accurate motor control to help improve system performance.

Additional resources

- Texas Instruments, TMAG6180-6181 Evaluation Module tool.
- Texas Instruments, *Automotive Functional Safety and How TI is Helping Customers With High-Precision Position Sensors* technical white paper.
- Texas Instruments, *Benefit of Low-Power Turns Count in AMR Sensing* application brief.

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