

## Introduction

Magnetic sensing is essential in modern technology, as it reduces size and cost while improving performance in position- and current-sensing applications. For position sensing, magnetic sensors provide non-contact solutions that reduce system size, complexity, and maintenance, making them ideal for industries such as automotive, robotics, and industrial automation. For current sensing, magnetic sensors ensure safe and accurate measurements with inherent galvanic isolation, particularly in high-power industries including solar, variable speed drives, and electric vehicle charging and motor control.

As industries demand smaller, more accurate, and interference-resistant sensors, differential sensing topologies will be critical in improving accuracy in environments where stray magnetic fields are otherwise unavoidable. MPS parts, including the [MA900](#) and [MAQ79010FS](#) for position sensing, leverage differential sensing to enhance precision and reliability in critical applications.

## Importance of Accuracy in Magnetic Sensing

Industries such as automotive, robotics, aerospace, and healthcare are increasingly demanding precision in sensing solutions. Accurate measurements are essential for safety and efficiency, particularly in applications such as electric vehicles (EVs), where precise current sensing is vital for battery management and motor drives. Minor inaccuracies can lead to inefficiencies or even system failures. As systems grow more complex, accuracy requirements have tightened — certain applications require a sub-degree precision in angle sensing and 1% to 2% accuracy in current sensing.

Meeting these standards is challenging, as increased sensitivity makes sensors more vulnerable to noise. These challenges necessitate techniques such as differential sensing, noise cancellation, and improved shielding. Temperature stability is also critical, as sensor readings can drift with temperature changes, especially in automotive environments. Additionally, as sensors become smaller for compact system integration, it is more difficult for sensors to maintain accuracy without interference. Balancing high performance with cost constraints is a key challenge, particularly in consumer electronics.

## Sources of Interference in Magnetic Sensing

Magnetic sensors are prone to interference from natural and man-made external magnetic fields. This noise can even come from the Earth's magnetic field, which can distort readings in high-precision applications. In addition, leakage flux from motor stators can interfere with nearby sensors, which may require shielding or differential sensing. If ferromagnetic materials are near the sensor, they can further distort magnetic fields, which may result in inaccurate measurements.

Other sources of interference include magnetic fields generated by current-carrying components such as inductors and transformers, particularly in high-current systems. In multi-phase electric motors, adjacent phase target magnets can interfere with each other, introducing noise and complicating position sensing.

## Differential Sensing Topology

Differential sensing enhances magnetic sensor accuracy by eliminating common-mode interference, which makes this topology effective in environments with significant external magnetic fields and noise. This design uses two or more sensing elements, such as planar Hall cells or TMR elements, to measure magnetic fields at different points, canceling out interference from external sources (e.g. motors or stray fields) while focusing solely on the target signal.

A few of the benefits of differential sensing include:

- Noise reduction cancels external fields affecting both sensors equally.
- Improved signal fidelity focuses on the target magnetic signal for accurate measurements.
- Reduced interference results in enhanced accuracy, offering precise readings in automotive and industrial applications.

**Implementation of Differential Sensing**

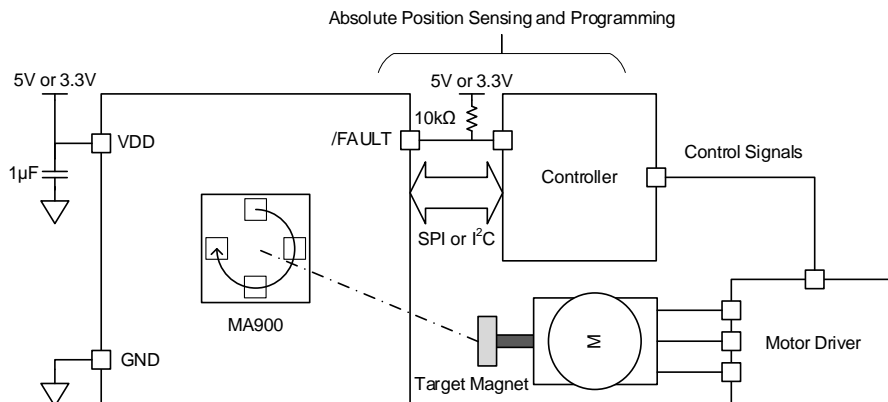
For current sensing, two Hall-effect sensors placed on either side of a current-carrying conductor detect the magnetic field while canceling external noise. This ensures accurate current measurements, especially in noisy environments (e.g. EV battery systems or motor control), and improves efficiency and safety.

In position sensing, a differential topology is also used, comparing magnetic fields at different points to filter interference. However, it requires on-axis alignment with the target magnet, as off-axis magnets are seen as aggressor fields.

In addition to the methods above, multiple Hall cells can be integrated on a single chip to measure magnetic fields symmetrically around the conductor, improving accuracy and enabling the sensor to function effectively in high-EMI environments. Hall cells are ideal for applications that require high precision and reliability.

**Applications with Differential Sensing**

Differential sensing topology is essential for accurate position sensing in noisy environments. For example, in automotive throttle control, magnetic position sensors using differential topology eliminate interference from engine components or external magnetic sources, ensuring precise throttle readings. In electric power steering systems, differential sensors provide accurate feedback on steering angles by detecting the position of a magnet on the steering column, and they are unaffected by external noise. Robotics also benefit from differential position sensors, which accurately detect the position of joints or moving parts even in environments with strong electromagnetic interference. MPS sensors such as the MA900 and MAQ79010 use this technology to provide precise and reliable position detection in automotive and industrial applications. Figure 1 shows the typical application of the MA900.



**Figure 1: Typical Application for the MA900**

In high-current, high-noise environments, differential current sensing is crucial. In battery management systems (BMS) for electric vehicles or renewable energy systems, differential sensors monitor battery current flow for efficient energy management. In motor control systems, these sensors ensure safe and efficient operation by providing accurate current measurements, even when noise from the motor is present. Similarly, in industrial automation, where large machines generate significant electromagnetic interference (EMI), MPS current sensors deliver precise current readings despite challenging conditions.

### **Position Sensing Tradeoffs and Limitations**

Differential position sensing requires precise on-axis alignment with the target magnet for accurate readings. Off-axis placement can result in the magnetic field being misinterpreted as interference, limiting flexibility in systems with complex or variable motion. This constraint demands careful installation but provides high precision, which is key in applications such as automotive steering and throttle control.

Uneven magnetic fields (gradients) can cause inaccuracies in differential sensing, as sensors may detect different field strengths. Mitigating this requires careful sensor placement in areas with minimal gradients or system calibration, especially in environments with multiple magnets or non-uniform sources.

### **Current Sensing Tradeoffs and Limitations**

Differential current sensing does not face the same tradeoffs as position sensing, it only requires more careful upfront design of the IC. It accurately detects magnetic fields around current-carrying conductors without needing special alignment, offering versatility and consistent performance across various applications.

Key factors include ensuring that the sensor matches the expected current range, managing thermal stability to prevent drift, and ensuring that there is an adequate bandwidth and response time for dynamic applications such as motor drives.

### **Case Studies and Examples**

#### ***Automotive Applications***

Magnetic sensing is key to innovation in EVs and advanced driver-assistance systems (ADAS). Differential sensors enhance accuracy and reliability in a number of applications.

- For electric power steering (EPS), sensors such as the MA900 measure steering angles with sub-degree precision to ensure smooth control.
- In battery management systems (BMS), current sensors monitor charging and discharging with high accuracy, even in noisy environments.
- For traction motor control, differential current sensors provide real-time current measurements to optimize motor efficiency and safety in EVs.

Differential sensors in automotive applications provide enhanced control and battery life, reliable operation in noisy environments, and efficient performance in low-power modes, extending the EV driving range.

#### ***Consumer (Low-Power) Applications***

The demand for compact, low-power sensors is rising in consumer electronics, and differential sensors are excellent solutions to meet these demands.

- For gaming controllers and joysticks, the MA900 delivers precise, reliable feedback without moving parts.
- For wearables such as smartwatches and fitness trackers, sensors enable ultra-small, low-power, and accurate dial movement detection.
- In home automation, sensors are used in smart locks and security cameras for low-power, precise position sensing.

Differential sensors in low-power consumer applications provide power-efficient sensors that extend device battery life, compact form factors that enable smaller designs in space-limited devices, and longer lifespan due to the absence of moving parts.

### **Medical Applications**

Differential sensors ensure precision and reliability in challenging medical environments.

- For MRI machines, sensors provide accurate current sensing even in high magnetic fields.
- With prosthetics and wearables, high-precision control and monitoring of movement and rehabilitation exercises.
- For surgical robotics, sensors provide sub-millimeter positioning capability with multiple axes in close proximity.

Differential sensors in medical applications provide high precision in critical environments (which is essential for MRI accuracy in intense magnetic fields), enhanced reliability and safety for motion detection and rehabilitation monitoring, and device longevity.

### **Emerging Technologies**

Magnetic sensing is evolving rapidly to meet the increasing demands for precision, efficiency, and adaptability in industries like automotive, healthcare, and consumer electronics. A few key advancements are listed below.

- New sensors are being developed to detect smaller magnetic field changes with greater accuracy, which is critical for applications in autonomous driving.
- Multi-axis sensing sensors capable of detecting magnetic fields across multiple axes (X, Y, and Z) are enabling more complex applications, such as 3D positioning in robotics and augmented reality (AR).
- New magnetic sensor technology such as tunneling magneto-resistive (TMR) drive accuracy to new limits with higher sensitivity and lower intrinsic noise.

### **Industry Trends**

The demand for precise magnetic sensing is a direct product of increasing application complexity. Consider the automotive industry, in which autonomous vehicles and ADAS rely on accurate magnetic sensors for lane-keeping and collision avoidance. In healthcare, MRI machines and robotic surgery systems require high precision for safety and treatment efficacy. Industrial automation also demands precise sensing for robotic arms and conveyor systems to improve efficiency and reduce errors.

Further magnetic sensing innovations are driven by miniaturization and cost reduction. Smaller sensors enable integration into compact systems (e.g. wearables and drones) without sacrificing accuracy. Additionally, energy-efficient sensors are becoming critical for extending battery life in devices like medical wearables and industrial Internet of Things (IoT) systems, further pushing innovation for low-power design.

### **Conclusion**

Magnetic sensing technology is vital in industries such as automotive, industrial automation, and medical devices, where interference from external magnetic fields can affect accuracy and performance. Differential sensing topology is implemented in MPS's position sensors — such as the [MA900](#) and [MAQ79010FS](#) — and current sensors. These devices cancel out common-mode noise and ensure reliable, high-precision operation.

Looking forward, advances in noise reduction, miniaturization, and material science will further enhance magnetic sensing. These innovations will meet growing demands for higher accuracy, lower power consumption, and smaller sensor sizes, making magnetic sensors increasingly crucial in applications from electric vehicles to medical wearables.

Explore MPS's [current sensors](#) and [position sensors](#) to find a solution for your design.