Technical White Paper

Automotive Functional Safety and How TI is Helping Customers With High-Precision Position Sensors

Nayeem Mahmud *Position Sensing*

ABSTRACT

From the days of steam-powered vehicles to driverless cars and electric vehicles, the automotive industry has evolved significantly over the years. With this evolution, the importance on safety of the driver and the passengers is becoming increasingly critical for the automotive industry. Because of the rise of electrification of the vehicle and Advanced Driver Assistance Systems (ADAS), the automotive industry has become more and more dependent on semiconductor components for vehicle functionality. As a key player in the semiconductor industry, Texas Instruments (TI) has a critical role to play in supporting automotive Functional Safety. This article explores the concept of automotive Functional Safety, why Functional Safety is important, and the role that TI plays in making sure that the vehicles we drive are safe.

Table of Contents

1 Trademarks

All trademarks are the property of their respective owners.

2 Industry Standards for Automotive Functional Safety

To make sure that the vehicles we drive are safe and reliable, the industry has developed a set of standards for Functional Safety. The most widely recognized standard in the automotive industry is ISO 26262, which provides guidelines for the design and development of the safety-critical systems for the road vehicles. The standard defines functional safety as “the absence of unreasonable risk due to hazards caused by malfunctioning behavior of electrical and electronic systems.”

ISO 26262 defines a development process including the use of risk assessment, failure mode and effects analysis (FMEA), and fault tree analysis (FTA). The standard also requires the use of safety mechanisms, such as redundancy, to make sure that the system can operate in a fail-safe manner.

The goal of ISO 26262 is to confirm that safety is integrated into the entire development process and that safety is considered in all aspects during the design of the vehicle. The standard regulates the system hardware and software through every step of the product life cycle, including development, production, operation, service, and decommissioning. The standard is also intended to provide a common framework for the development of safety-critical systems across the industry.

Texas Instruments’ (TI) involvement with such international standards organizations helps to establish that the company develops products with Functional Safety as a priority from the beginning of the design process.

3 Key Concepts and Principles of Automotive Functional Safety

Automotive Functional Safety is one of the most critical aspects of modern automotive engineering. This process refers to the ability of an electronic system or component to perform the intended function in a safe manner. This includes systems that control braking, steering, and other safety critical functions. Functional Safety is a process that involves the identification of potential hazards in a vehicle, the assessment of the risks associated with these hazards, and the design and development of the safety measures to mitigate these risks. The safety measures developed are aimed at reducing the likelihood of accidents or injuries caused by the vehicle or systems and functions of the vehicle.

Automotive Functional Safety is based on a set of concepts and principles, including:

Hazard and Risk Analysis (HARA): HARA is the process of identifying potential hazards and assessing the associated risks in the design and development of vehicles. HARA helps to identify potential failure modes and potential consequences, and to determine the appropriate measures to mitigate the associated risks.

Safety Requirements: These are the systems level requirements that must be met by a safety function to achieve the required Safety Integrity Level. Safety requirements are derived from the HARA and are used to guide the design and development of safety functions.

Safety Functions: These are the functions within a vehicle that are critical to safe operation. Safety functions are designed to prevent or mitigate the consequences of a potential hazard in the event of a system failure.

Automotive Safety Integrity Level (ASIL): ASIL is a risk classification scheme as defined by the Automotive Functional Safety Standard ISO 26262 for road vehicles. As per ISO26262 Part 3, ASIL is determined by the Severity (S), Exposure (E), and the Controllability (C). Severity has four classes ranging from no injuries (S0) to life-threatening injuries (S3). Exposure has five classes ranging from incredibly unlikely (E0) to the highly probable (E4). Controllability also has four classes ranging from controllable in general (C0) to uncontrollable (C3). A combination of the highest hazards (S3 + E4 + C3) can result in an ASIL D classification for that hazardous event. There are four ASIL levels: ASIL A, ASIL B, ASIL C, and ASIL D, where ASIL A is the lowest safety integrity level and ASIL D is the highest one.

Automotive systems like Electric Power Steering (EPS) or Integrated Brake Control (IBC) systems are required to be an ASIL D functions due to the risks associated with their failure. Conversely, brake lights or headlights are generally an ASIL A function.

Verification and validation: These are the processes of testing and validating the safety mechanisms to confirm that the mechanisms meet the safety requirements to achieve the required Safety Integrity Level.

Historically, the automotive industry has relied on mechanical systems to provide the vehicle safety. However, as vehicles become more and more complex and interconnected, the use of electronic and software-based systems becomes more prevalent. These electronic and software-based systems can be more effective and efficient, but the systems also present unique challenges in terms of addressing Functional Safety.

4 Why is Automotive Functional Safety Important?

The importance of automotive Functional Safety cannot be overemphasized. Every year, thousands of people die or are injured in car accidents. In many cases, these accidents are caused by failures in the functions or systems of the vehicle. Automotive Functional Safety helps to minimize the risk of such accidents by making sure that the functions or systems of the vehicle are safe and operate as intended.

The automotive industry has also seen a growing trend towards Autonomous Driving (AD) in the past decade. While self-driving cars have the potential to revolutionize transportation, self-driving cars also present new safety challenges. Autonomous vehicles must be able to make decisions and take actions that are safe for passengers, other drivers, and pedestrians. Automotive Functional Safety is extremely critical to make sure that these systems are safe and that the risks associated with Autonomous Driving are minimized.

5 Challenges in Providing Automotive Functional Safety

Providing automotive Functional Safety is a complex task that requires a deep understanding of the interaction between hardware, software, and the physical environment. The semiconductor industry faces several challenges to make sure that the components the industry provides are safe and reliable.

One of the primary challenges is the need to make sure that the components can operate in a wide range of ambient conditions. Vehicles are exposed to a variety of environmental harshness, including temperature, humidity, and vibration. These environmental factors can impact the performance and reliability of the semiconductor components, making this crucial to confirm that the components can operate reliably under these conditions.

The complexity of modern vehicles also presents a significant challenge. Vehicles are becoming more and more interconnected, with multiple systems relying on each other to function properly. This creates a complex web of dependencies that must be carefully designed and managed to confirm that the system operates in a safe and reliable manner.

Another challenge is the need to make sure that the components can operate in a fail-safe manner. Fail-safe means that the system or function continues to operate in a safe manner even if a fault or error occurs. This requires fault detection mechanisms and the use of redundancy to confirm that the system can detect and respond to any faults that occur.

TI helps address these challenges by continuing to develop relevant products and by making all of the necessary data and documentation about these products available to enable their use in Functional Safety applications. For example, the TMAG5170D-Q1, is a dual-die, high-precision, linear 3D Hall-effect sensor, designed for a wide range of automotive safety critical position sensing applications. The two identical dies in one package enables the system integrator to utilize this fully-redundant 2-channel sensor architecture for the highest Functional Safety requirements. The TMAG5170D-Q1 offers multiple diagnostic features to detect and report both system and device-level failures which help to achieve ASIL D safety ratings for systems like e-shifter or Electric Power Steering (EPS). By using the redundancy feature of this high-performance 3D position sensor, the system integrator can achieve higher levels of safety and availability.

6 The Role of Texas Instruments (TI) in Automotive Functional Safety

Semiconductor manufacturers play a critical role to make sure that their semiconductor components are safe and reliable. This requires a deep understanding of the automotive industry and the specific requirements for Functional Safety. TI works very closely with automotive manufacturers to make sure that their components are compatible with the latest systems and technologies.

To make sure that their components meet the required standards, TI follows a rigorous process for the development of safety-critical components. TI's Functional Safety development flow is derived from ISO 26262 and IEC 61508. This development flow is certified by Technischer Überwachungsverein (TÜV) SÜD. This certification helps to make sure that products in this category were developed following specifications prescribed by the Functional Safety standards, ISO 26262 and IEC 61508. To find these certifications, see Functional safety.

For example, consider the following complex Functional Safety-Compliant devices which were developed using the above-mentioned development flow:

TMAG5170-Q1 - TI's most accurate 3D Hall-effect sensor is designed for real-time measurement and data conversion for precision electromechanical and safety-critical applications. With the help of numerous built-in safety mechanisms, this sensor is able to achieve ASIL B level safety rating for safety critical applications like Electric Power Steering column control modules or e-shifters.

TMAG6181-Q1 - Automotive high-precision analog AMR angle sensor is developed for safety critical motor applications. This product supports several device and system-level diagnostics features to detect, monitor, and report failures during the device operation. With the help of built-in safety mechanisms, this sensor is able to achieve ASIL B level safety ratings for applications like Belt Starter Generator or steering angle sensor modules.

LDC5072-Q1 - Inductive Position Sensor Front-End with Sin/Cos Interface. This inductive sensor with SIN/ COS outputs is designed for safety-critical high-speed motor position sensing. The device can also be used for linear, partial rotation, and torque-sensing applications. The device employs over 25 diagnostic and safety mechanisms and can be used in ASIL C rated safety systems or with two devices the device satisfies the demands of ASIL D applications.

TI has a growing Functional Safety portfolio with the most precise Hall and Inductive Sensors. This list also includes the TMAG5173-Q1, TMAG6180-Q1 devices which are developed for different automotive and industrial safety-critical applications with ASIL B to ASIL D safety ratings.

7 Conclusion

Providing automotive Functional Safety is a critical task that requires the collaboration of a variety of stakeholders, including semiconductor manufacturers. To meet the requirements for Functional Safety, semiconductor manufacturers must follow a rigorous process for the development of safety-critical components. This includes the use of advanced simulation and testing techniques, as well as the development of redundant and fail-safe mechanisms.

As the automotive industry continues to evolve, TI continues to play a critical role in making sure that the vehicles we drive are safe and reliable. By working closely with automotive manufacturers and following the latest standards and guidelines for Functional Safety, TI is making that possible.