

Functional Safety Concept Lane Assistance

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# Document history

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# Purpose of the Functional Safety Concept

The Functional Safety Concept is an important part of reducing the risk of the system to acceptable levels. This document defines the architecture and the safety requirements. It also allocates those safety requirements to the various parts of the architecture. In the process, the Functional Safety Concept defines parameters for the requirements, such as ASIL, fault tolerant time interval, and safe states. These parameters define the requirements for the system’s design and operation. The Functional Safety Concept approaches these tasks from a high level; more in-depth technical details, such as the actual implementation of the requirements, is defined in the Technical Safety Concept.

# Inputs to the Functional Safety Concept

## Safety goals from the Hazard Analysis and Risk Assessment

|  |  |
| --- | --- |
| **ID** | **Safety Goal** |
| Safety\_Goal\_01 | The oscillating steering torque delivered to the steering wheel by the LDW function shall be limited. |
| Safety\_Goal\_02 | The lane keeping assistance function shall be time-limited such that the additional steering torque shall end after a given time interval so that the driver cannot misuse the system for autonomous driving. |
| Safety\_Goal\_03 | The steering torque delivered to the steering wheel by the LKA function shall be limited. |

## Preliminary Architecture



### Description of architecture elements

|  |  |
| --- | --- |
| **Element** | **Description** |
| Camera Sensor | Captures imagery of the road in front of the vehicle. |
| Camera Sensor ECU | Processes camera imagery to detect the car’s position in the ego lane. Requests torque from the Electronic Power Steering ECU. |
| Car Display | Displays the status of the LDW and LKA functions. |
| Car Display ECU | Tracks the status of the LDW and LKA functions and controls the Car Display. |
| Driver Steering Torque Sensor | Senses the torque applied to the steering wheel by the driver. |
| Electronic Power Steering ECU | Handles torque requests from the Camera Sensor ECU. Controls the Motor to deliver torque to the steering wheel, using the Driver Steering Torque Sensor as feedback. |
| Motor | Provides torque to the steering wheel; controlled by the Electronic Power Steering ECU. |

# Functional Safety Concept

The functional safety concept consists of:

* Functional safety analysis
* Functional safety requirements
* Functional safety architecture
* Warning and degradation concept

## Functional Safety Analysis

|  |  |  |  |
| --- | --- | --- | --- |
| **Malfunction ID** | **Main Function of the Item Related to Safety Goal Violations** | **Guidewords (NO, WRONG, EARLY, LATE, MORE, LESS)** | **Resulting Malfunction** |
| Malfunction\_01 | Lane Departure Warning (LDW) function shall apply an oscillating steering torque to provide the driver a haptic feedback | MORE | The LDW applies an oscillating torque with very high amplitude (above limit). |
| Malfunction\_02 | Lane Departure Warning (LDW) function shall apply an oscillating steering torque to provide the driver a haptic feedback | MORE | The LDW applies an oscillating torque with very high frequency (above limit). |
| Malfunction\_03 | Lane Keeping Assistance (LKA) function shall apply the steering torque when active in order to stay in ego lane | NO | The LKA function is not time-limited, allowing its misuse as an autonomous driving function. |

## Functional Safety Requirements

Lane Departure Warning (LDW) Requirements:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ID** | **Functional Safety Requirement** | **ASIL** | **Fault Tolerant Time Interval** | **Safe State** |
| Functional  Safety  Requirement  01-01 | The lane keeping item shall ensure that the lane departure oscillating torque is below Max\_Torque\_Ampliltude. | C | 50ms | LDW disabled (output torque zero) |
| Functional  Safety  Requirement  01-02 | The lane keeping item shall ensure that the lane departure oscillating torque is below Max\_Torque\_Frequency. | C | 50ms | LDW disabled (output torque zero) |

Lane Departure Warning (LDW) Verification and Validation Acceptance Criteria:

|  |  |  |
| --- | --- | --- |
| **ID** | **Validation Acceptance**  **Criteria and Method** | **Verification Acceptance**  **Criteria and Method** |
| Functional  Safety  Requirement  01-01 | With driver testing, confirm that the value of Max\_Torque\_Amplitude is low enough that drivers can maintain control of the vehicle. | Verify that when the torque exceeds Max\_Torque\_Amplitude, the LDW is disabled (torque to zero) within 50ms. |
| Functional  Safety  Requirement  01-02 | With driver testing, confirm that the value of Max\_Torque\_Frequency is low enough that drivers can maintain control of the vehicle. | Verify that when the torque exceeds Max\_Torque\_Frequency, the LDW is disabled (torque to zero) within 50ms. |

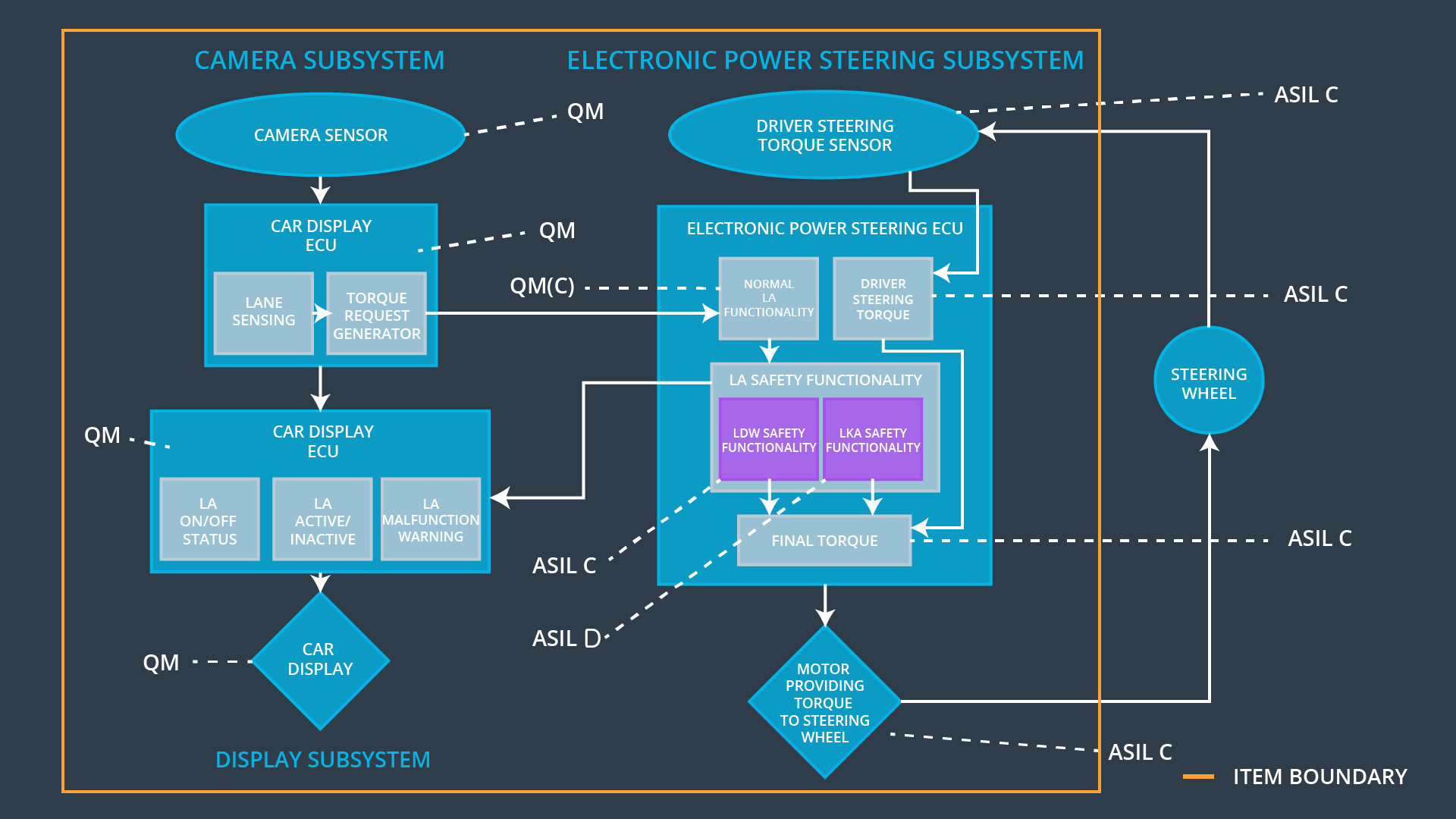
Lane Keeping Assistance (LKA) Requirements:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ID** | **Functional Safety Requirement** | **ASIL** | **Fault Tolerant Time Interval** | **Safe State** |
| Functional  Safety  Requirement  02-01 | The electronic power steering ECU shall ensure that the lane keeping assistance torque is applied for only Max\_Duration. | C | 500ms | LKA disabled (output torque zero) |
| Functional Safety Requirement 03-01 | The electronic power steering ECU shall ensure that the lane keeping assistance torque is below Max\_Torque\_Magnitude. | D | 50ms | LKA disabled (output torque zero) |

Lane Keeping Assistance (LKA) Verification and Validation Acceptance Criteria:

|  |  |  |
| --- | --- | --- |
| **ID** | **Validation Acceptance**  **Criteria and Method** | **Verification Acceptance**  **Criteria and Method** |
| Functional  Safety  Requirement  02-01 | With driver testing, confirm that the Max\_Duration does cause drivers to keep their hands on the steering wheel. | Verify that the system does turn off (torque to zero) after Max\_Duration. |
| Functional  Safety  Requirement  03-01 | With driver testing, confirm that Max\_Torque\_Magnitude is low enough that drivers can override the LKA. | Verify that the system does turn off within (torque to zero) 50ms if the torque exceeds Max\_Torque\_Magnitude. |

## Refinement of the System Architecture



## Allocation of Functional Safety Requirements to Architecture Elements

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ID** | **Functional Safety Requirement** | **Electronic Power Steering ECU** | **Camera ECU** | **Car Display ECU** |
| Functional  Safety  Requirement  01-01 | The lane keeping item shall ensure that the lane departure oscillating torque is below Max\_Torque\_Ampliltude. | **X** |  |  |
| Functional  Safety  Requirement  01-02 | The lane keeping item shall ensure that the lane departure oscillating torque is below Max\_Torque\_Frequency. | **X** |  |  |
| Functional  Safety  Requirement  02-01 | The electronic power steering ECU shall ensure that the lane keeping assistance torque is applied for only Max\_Duration. | **X** |  |  |
| Functional Safety Requirement 03-01 | The electronic power steering ECU shall ensure that the lane keeping assistance torque is below Max\_Torque\_Magnitude. | **X** |  |  |

## Warning and Degradation Concept

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ID** | **Degradation Mode** | **Trigger for Degradation Mode** | **Safe State invoked?** | **Driver Warning** |
| WDC-01 | Turn off LDW | The LDW applies an oscillating torque with very high amplitude (above limit). | Yes | Display shows warning light |
| WDC-02 | Turn off LKA | The LDW applies an oscillating torque with very high frequency (above limit). | Yes | Display shows warning light |
| WDC-03 | Turn off LKA | The LKA function is not time-limited, allowing its misuse as an autonomous driving function. | Yes | Display shows warning light |