

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 looking at the item from a higher level of architecture without going into technical details.

Functional safety requirements have a few attributes that need to be specified in the functional safety concept:

* The ASIL level
* The fault tolerant time interval, which measures how quickly a system needs to react to a hazardous situation
* The safe state, which discusses what a system looks like after it has avoided an accident

# 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 from Lane Departure Warning function shall be limited |
| Safety\_Goal\_02 | Lane Keeping Assistance function shall be time limited and the additional steering torque shall end after a given timer interval so that the driver can not misuse the system for autonomous driving |
| Safety\_Goal\_03 | Lane Keeping Assistance function shall be deactivated, when camera sensor is not able to detect lane boundary. Deactivated status shall be displayed to the driver |
| Safety\_Goal\_04 | Lane Departure Warning function shall control not only lane boundaries, but also traffic in neighbor lanes |

## Preliminary Architecture

The following figure shows the Lane Assistance item architecture



### Description of architecture elements

|  |  |
| --- | --- |
| **Element** | **Description** |
| Camera Sensor | Image Processing and providing images to Camera Sensor ECU |
| Camera Sensor ECU | Object perception and recognition, detection of lane boundaries, evaluation of car position in the lane and generation of torque request to the Electronic Power Steering ECU |
| Car Display | Displaying of Lane Assistant item state, activity and warning messaged to the driver |
| Car Display ECU | Generating of warning messages triggered by Camera Sensor ECU and Electronic Power Steering ECU |
| Driver Steering Torque Sensor | Measuring of torque applied to the steering wheel by the driver to Electronic Power Steering ECU |
| Electronic Power Steering ECU | Processing of inputs from Camera Sensor ECU, Driver Steering Torque Sensor and the torque request from the Lane Keeping Assistance and Lane Warning, evaluating of final torque to be applied by motor |
| Motor | Applying the torque evaluated 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** | **Resulting Malfunction** |
| Malfunction\_01 | Lane Departure Warning (LDW) function shall apply an oscillating steering torque to provide the driver a haptic feedback | MORE | Lane Departure Warning function applies an oscillating torque with very high torque amplitude (above limit) |
| Malfunction\_02 | Lane Departure Warning (LDW) function shall apply an oscillating steering torque to provide the driver a haptic feedback | MORE | Lane Departure Warning function applies an oscillating torque with very high torque 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 | Lane Keeping Assistance function is not limited in time duration which lead to misuse as an autonomous driving function |
| Malfunction\_04 | Lane Keeping Assistance (LKA) function shall apply the steering torque when active in order to stay in ego lane | WRONG | Lane Keeping Assistance function shall be deactivated, when camera sensor is not able to detect lane boundary |
| Malfunction\_05 | Lane Departure Warning (LDW) function shall apply an oscillating steering torque to provide the driver a haptic feedback | LATE | Lane Departure Warning function shall control not only lane boundaries, but also traffic in neighbor lanes |

## 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 amplitude is below Max\_Torque\_Amplitude | C | 50ms | Lane departure oscillating torque amplitude is below Max\_Torque\_Amplitude |
| Functional  Safety  Requirement  01-02 | The lane keeping item shall ensure that the lane departure oscillating torque frequency is below Max\_Torque\_Frequency | C | 50ms | Lane departure oscillating torque frequency is below Max\_Torque\_Frequency |
| Functional  Safety  Requirement  01-03 | Lane Departure Warning function shall ensure that the distance to obstacle left or right is more than Min\_Obstacle\_Distance | C | 10ms | Distance to obstacles on sides are more than Min\_Obstacle\_Distance |

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 | Validate, that chosen Max\_Torque\_Amplitude value is high enough to be detected by driver and low enough to continue control of steering | Verify the system does turn off the Lane Departure Warning function when exceeded Max\_Torque\_Amplitude |
| Functional  Safety  Requirement  01-02 | Validate, that chosen Max\_Torque\_Frequency value is high enough to be detected by driver and low enough to continue control of steering | Verify the system does turn off the Lane Departure Warning function when exceeded Max\_Torque\_Frequency |
| Functional  Safety  Requirement  01-03 | Validate, that chosen Min\_Obstacle\_Distance is low enough to still be in lane center and high enough to still have safe control of vehicle (as reference, values can be obtained from Traffic Laws) | Verify the system does turn on the Lane Departure Warning function when reached Min\_Obstacle\_Distance |

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 | B | 500ms | Lane Keeping Assistance is deactivated |
| Functional  Safety  Requirement  02-02 | The electronic power steering ECU shall ensure that the camera sensor is not able to detect lane boundaries not long, than Max\_Not\_Observable\_Time | A | 10ms | Lane Keeping Assistance is deactivated |

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 | Validate, that chosen Max\_Duration is high enough to be detected by driver and low enough to not feel the function is for autonomous drive | Verify the system does turn off the Lane Keeping Assistance function when reached Max\_Duration |
| Functional  Safety  Requirement  02-02 | Validate, that chosen Max\_Not\_Observable\_Time is big enough for real road situations on intersections and low enough to have time of keep control of vehicle in case the function is deactivated | Verify the system does turn off the Lane Keeping Assistance function and warn the driver when reached Max\_Not\_Observable\_Time |

## 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 amplitude is below Max\_Torque\_Amplitude | **X** |  |  |
| Functional  Safety  Requirement  01-02 | The lane keeping item shall ensure that the lane departure oscillating torque frequency is below Max\_Torque\_Frequency | **X** |  |  |
| Functional  Safety  Requirement  01-03 | Lane Departure Warning function shall ensure that the distance to obstacle left or right is more than Min\_Obstacle\_Distance | **X** |  |  |
| Functional  Safety  Requirement  02-01 | The electronic power steering ECU shall ensure that the Lane Keeping Assistance torque is applied only Max\_Duration | **X** |  |  |
| Functional  Safety  Requirement  02-02 | The electronic power steering ECU shall ensure that the camera sensor is not able to detect lane boundaries not long, than Max\_Not\_Observable\_Time | **X** |  |  |

## Warning and Degradation Concept

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ID** | **Degradation Mode** | **Trigger for Degradation Mode** | **Safe State invoked?** | **Driver Warning** |
| WDC-01 | Turn off Lane Departure Warning functionality | Malfunction\_01 | Yes | Lane Assistance malfunction Warning |
| WDC-02 | Turn off Lane Departure Warning functionality | Malfunction\_02 | Yes | Lane Assistance malfunction Warning |
| WDC-03 | Turn off Lane Keeping Assistance functionality | Malfunction\_03 | Yes | Lane Assistance malfunction Warning |
| WDC-04 | Turn off Lane Keeping Assistance functionality | Malfunction\_04 | Yes | Lane Assistance malfunction Warning |
| WDC-05 | Turn off Lane Departure Warning functionality | Malfunction\_05 | Yes | Lane Assistance malfunction Warning |