

Technical Safety Concept Lane Assistance

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# Document history

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# Purpose of the Technical Safety Concept

The Technical Safety Concept defines how the subsystems interact at the massage level and describes how the ECUs communicate with each other.

# Inputs to the Technical Safety Concept

## Functional Safety Requirements

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ID** | **Functional Safety Requirement** | **ASIL** | **Fault Tolerant Time Interval** | **Safe State** |
| Functional  Safety  Requirement  01-01 | The Electronic Power Steering ECU shall ensure that the oscillating torque amplitude requested by the LDW function is below Max\_Torque\_Amplitude. | C | 50 ms | LDW will set the oscillating torque to 0. |
| Functional  Safety  Requirement  01-02 | The Electronic Power Steering ECU shall ensure that the oscillating torque frequency requested by the LDW function is below Max\_Torque\_Frequency. | C | 50 ms | LDW will set the oscillating torque to 0. |
| 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 | 500 ms | LDW will set the oscillating torque to 0. |

## Refined System Architecture from Functional Safety Concept



### 

### Functional overview of architecture elements

|  |  |
| --- | --- |
| **Element** | **Description** |
| Camera Sensor | The camera sensor reads in images from the road. |
| Camera Sensor ECU - Lane Sensing | The Lane Sensing element reads in an image from the Camera Sensor and extracts lane markings from that image. |
| Camera Sensor ECU - Torque request generator | The Torque request generator derives a steering torque based on the sensed lane markings and the current vehicle position and sends it to the Electronic Power Steering ECU. |
| Car Display | The Car Display shows a warning light to the driver, when the vehicle leaves the lane. |
| Car Display ECU - Lane Assistance On/Off Status | The Lane Assistance On/Off Status indicates whether the Lane Assistance System is turned on or off by the driver. |
| Car Display ECU - Lane Assistant Active/Inactive | The Lane Assistant Active/Inactive indicates whether the Lane Assistant System is fully operational (e.g. has found lane markings an is able to apply a steering torque). |
| Car Display ECU - Lane Assistance malfunction warning | The Lane Assistance malfunction warning indicates that the system is deviated, and it is shut down (or degraded). |
| Driver Steering Torque Sensor | The Driver Steering Torque Sensor provides the torque that the driver puts on the steering wheel to the Electronic Power Steering ECU. |
| Electronic Power Steering (EPS) ECU - Driver Steering Torque | The Driver Steering Element reads in the signal from the Driver Steering Torque Sensor which indicates how much (torque) the driver is steering. |
| EPS ECU - Normal Lane Assistance Functionality | The Normal Lane Assistance Functionality |
| EPS ECU - Lane Departure Warning Safety Functionality | This Element receives the torque demand from the Torque request generator in the Camera Sensor ECU and limits the vibration torque to the amplitude and frequency limit. |
| EPS ECU - Lane Keeping Assistant Safety Functionality | The Safety Functionality Element takes care of the functional safety requirements (e.g. it ensures the limits on the vibration torque and the maximum time on the Lane Keeping functionality. |
| EPS ECU - Final Torque | The Final Torque outputs a final torque based on the torque demand from the Normal Lane Assistance Functionality and the driver steering torque. |
| Motor | The Motor applies the demanded torque that is demanded by the Electronic Power Steering ECU onto the steering wheel. |

# Technical Safety Concept

## Technical Safety Requirements

**Lane Departure Warning (LDW) Requirements:**

Functional Safety Requirement 01-01 with its associated system elements

(derived in the functional safety concept)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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 |  |  |

Technical Safety Requirements related to Functional Safety Requirement 01-01 are:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **ID** | **Technical Safety Requirement** | **ASIL** | **Fault Tolerant Time Interval** | **Architecture Allocation** | **Safe State** |
| Technical  Safety  Requirement  01 | The LDW safety component shall ensure that the amplitude of the ‘LDW\_Torque\_Request’ sent to the ‘Final electronic power steering Torque’ component is below ‘Max\_Torque\_Amplitude’. | C | 50 ms | LDW Safety block | LDW shall set the oscillating torque to 0. |
| Technical  Safety  Requirement  02 | As soon as the LDW function deactivates the LDW feature, the ‘LDW Safety’ software block shall send a signal to the car display ECU to turn on a warning light. | C | 50 ms | LDW Safety block | LDW shall set the oscillating torque to 0. |
| Technical  Safety  Requirement  03 | As soon as a failure is detected by the LDW function, it shall deactivate the LDW feature and the ‘LDW\_Torque\_Request’ shall be set to zero. | C | 50 ms | LDW Safety block | LDW shall set the oscillating torque to 0. |
| Technical  Safety  Requirement  04 | The validity and integrity of the data transmission for ‘LDW\_Torque\_Request’ signal shall be ensured. | C | 50 ms | Data Transmission Integrity Check | LDW shall set the oscillating torque to 0. |
| Technical  Safety  Requirement  05 | Memory test shall be conducted at startup of the EPS ECU to check for any faults in memory. | A | Ignition Cycle | Safety Startup Memory Test | LDW shall set the oscillating torque to 0. |

Functional Safety Requirement 01-2 with its associated system elements

(derived in the functional safety concept)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ID** | **Functional Safety Requirement** | **Electronic Power Steering ECU** | **Camera ECU** | **Car Display ECU** |
| Functional  Safety  Requirement  01-02 | The lane keeping item shall ensure that the lane departure oscillating torque frequency is below Max\_Torque\_Frequency | X |  |  |

Technical Safety Requirements related to Functional Safety Requirement 01-02 are:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **ID** | **Technical Safety Requirement** | **ASIL** | **Fault Tolerant Time Interval** | **Architecture Allocation** | **Safe State** |
| Technical  Safety  Requirement  01 | The LDW safety component shall ensure that the frequency of the ‘LDW\_Torque\_Request’ sent to the ‘Final electronic power steering Torque’ component is below ‘Max\_Torque\_Frequency’. | C | 50 ms | LDW Safety block | LDW torque request amplitude shall be set to zero. |
| Technical  Safety  Requirement  02 | As soon as the LDW function deactivates the LDW feature, the ‘LDW Safety’ software block shall send a signal to the car display ECU to turn on a warning light. | C | 50 ms | LDW Safety block | LDW torque request amplitude shall be set to zero. |
| Technical  Safety  Requirement  03 | As soon as a failure is detected by the LDW function, it shall deactivate the LDW feature and the ‘LDW\_Torque\_Request’ shall be set to zero. | C | 50 ms | LDW Safety block | LDW torque request amplitude shall be set to zero. |
| Technical  Safety  Requirement  04 | The validity and integrity of the data transmission for ‘LDW\_Torque\_Request’ signal shall be ensured. | C | 50 ms | Data Transmission Integrity Check | LDW torque request amplitude shall be set to zero. |
| Technical  Safety  Requirement  05 | Memory test shall be conducted at startup of the EPS ECU to check for any faults in memory. | A | Ignition cycle | Safety Startup Memory Test | LDW torque request amplitude shall be set to zero. |

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

|  |  |  |
| --- | --- | --- |
| **ID** | **Validation Acceptance**  **Criteria and Method** | **Verification Acceptance**  **Criteria and Method** |
| Technical  Safety  Requirement  01 | Make a study to test how drivers react to different torque amplitudes/frequencies to prove that we chose an appropriate value for ‘Max\_Torque\_Amplitude’/’Max\_Torque\_Frequency’. | Do a software test by inserting a fault into the system. When the demanded torque amplitude/frequency crosses the limit ‘Max\_Torque\_Amplitude’/’Max\_Torque\_Frequency’, the lane assistance output must be set to zeros within 50 ms. |
| Technical  Safety  Requirement  02 | Make a study to test how drivers react on the warning light when the LDW function deactivates the LDW feature. | Do a software test with Electronic Power Steering ECU, Car Display ECU and its communication. When setting primary ‘LDW\_Torque\_Request’ outside the limits ‘Max\_Torque\_Amplitude’/’Max\_Torque\_Frequency’ the Car Display must show the warning light. |
| Technical  Safety  Requirement  03 | Make a study to test how drivers react on the total loss of steering vibration torque when the LDW function deactivates the LDW feature. | Do a software test with the Electronic Power Steering ECU. When setting the primary ‘LDW\_Torque\_Request’ outside the limits ‘Max\_Torque\_Amplitude’/’Max\_Torque\_Frequency’, the signal ‘LDW\_Torque\_Request’ from the Safety Lane Assistance Functionality Block must be 0. |
| Technical  Safety  Requirement  04 | - no validation possible - | Do a software test with the Electronic Power Steering ECU, Car Display ECU and its communication. The data that is transmitted from EPS ECU to Car Display ECU shall not be deviated. Artificial communication errors shall be detected. |
| Technical  Safety  Requirement  05 | - no validation possible - | Do a software test with the EPS ECU by artificially altering the memory. The memory check shall find all memory deviations. |

**Lane Keeping Assistance (LKA) Requirements:**

Functional Safety Requirement 02-1 with its associated system elements

(derived in the functional safety concept)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ID** | **Functional Safety Requirement** | **Electronic Power Steering ECU** | **Camera ECU** | **Car Display ECU** |
| Functional  Safety  Requirement  02-01 | The lane keeping item shall ensure that the lane keeping assistance torque is applied for only Max\_Duration | X |  |  |

Technical Safety Requirements related to Functional Safety Requirement 02-01 are:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **ID** | **Technical Safety Requirement** | **ASIL** | **Fault Tolerant Time Interval** | **Allocation to Architecture** | **Safe State** |
| Technical  Safety  Requirement  01 | The LKA safety component shall ensure that the signal ‘LKA\_Torque\_Request’ sent to the ‘Final electronic power steering Torque’ component is only active for ‘Max\_Duration’. | B | 500 ms | LKA Safety block | LKA torque request amplitude shall be set to zero. |
| Technical  Safety  Requirement  02 | As soon as the LKA function deactivates the LKA feature, the ‘LKA Safety’ software block shall send a signal to the car display ECU to turn on a warning ligth. | B | 500 ms | LKA Safety block | LKA torque request amplitude shall be set to zero. |
| Technical  Safety  Requirement  03 | As soon as a failure is detected by the LKA function, it shall deactivate the LKA feature and the ‘LKA\_Torque\_Request’ shall be set to zero. | B | 500 ms | LKA Safety block | LKA torque request amplitude shall be set to zero. |
| Technical  Safety  Requirement  04 | The validity and integrity of the data transmission for ‘LKA\_Torque\_Request’ signal shall be ensured. | B | 500 ms | Data Transmission Integrity Check | LKA torque request amplitude shall be set to zero. |
| Technical  Safety  Requirement  05 | Memory test shall be conducted at startup of the EPS ECU to check for any faults in memory. | A | Ignition Cycle | Safety Startup Memory Test | LKA torque request amplitude shall be set to zero. |

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

|  |  |  |
| --- | --- | --- |
| **ID** | **Validation Acceptance**  **Criteria and Method** | **Verification Acceptance**  **Criteria and Method** |
| Technical  Safety  Requirement  01 | Make a study to test that the time ‘Max\_Duration’ chosen really dissuades drivers from taking their hands off the wheel.Make car or software tests that the system really does turn off if the lane keeping assistance ever exceeded max\_duration. | Make car or software tests that the system really does turn off if the lane keeping assistance ever exceeded max\_duration. |
| Technical  Safety  Requirement  02 | Make a study to test how drivers react on the warning light when the LKA function deactivates the LKA feature. | Do a software test with Electronic Power Steering ECU, Car Display ECU and its communication. When the time ‘Max\_Duration’ passes without a torque from the driver, the Car Display must show the warning light. |
| Technical  Safety  Requirement  03 | Make a study to test how drivers react on the total loss of steering support torque when the LKA function deactivates the LKA feature. | Do a software test with the Electronic Power Steering ECU. When the time ‘Max\_Duration’ passes without a torque from the driver, the signal ‘LKA\_Torque\_Request’ from the Safety Lane Assistance Functionality Block must be 0. |
| Technical  Safety  Requirement  04 | - no validation possible - | Do a software test with the Electronic Power Steering ECU, Car Display ECU and its communication. The data that is transmitted from EPS ECU to Car Display ECU shall not be deviated. Artificial communication errors shall be detected. |
| Technical  Safety  Requirement  05 | - no validation possible - | Do a software test with the EPS ECU by artificially altering the memory. The memory check shall find all memory deviations. |

## Refinement of the System Architecture



## Allocation of Technical Safety Requirements to Architecture Elements

All technical safety requirements are allocated to the Electronic Power Steering ECU.

## Warning and Degradation Concept

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **ID** | **Degradation Mode** | **Trigger for Degradation Mode** | **Safe State invoked?** | **Driver Warning** |
| WDC-01 | Turn off the functionality – Set torque request to 0 | The lane departure warning function applies an oscillating torque with very high torque amplitude or torque frequency (above limit). | Yes | A message on the car display shows the driver, that the lane departure warning function is not available. |
| WDC-02 | Turn off the functionality – Set torque request to 0 | The lane keeping assistance function is not limited in time duration which leads to misuse as an autonomous driving function. | Yes | A message on the car display shows the driver, that the lane keeping assistance function is not available. |