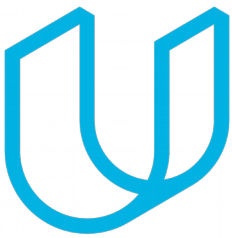
Elektrobit



UDACITY

Functional Safety Concept Lane Assistance

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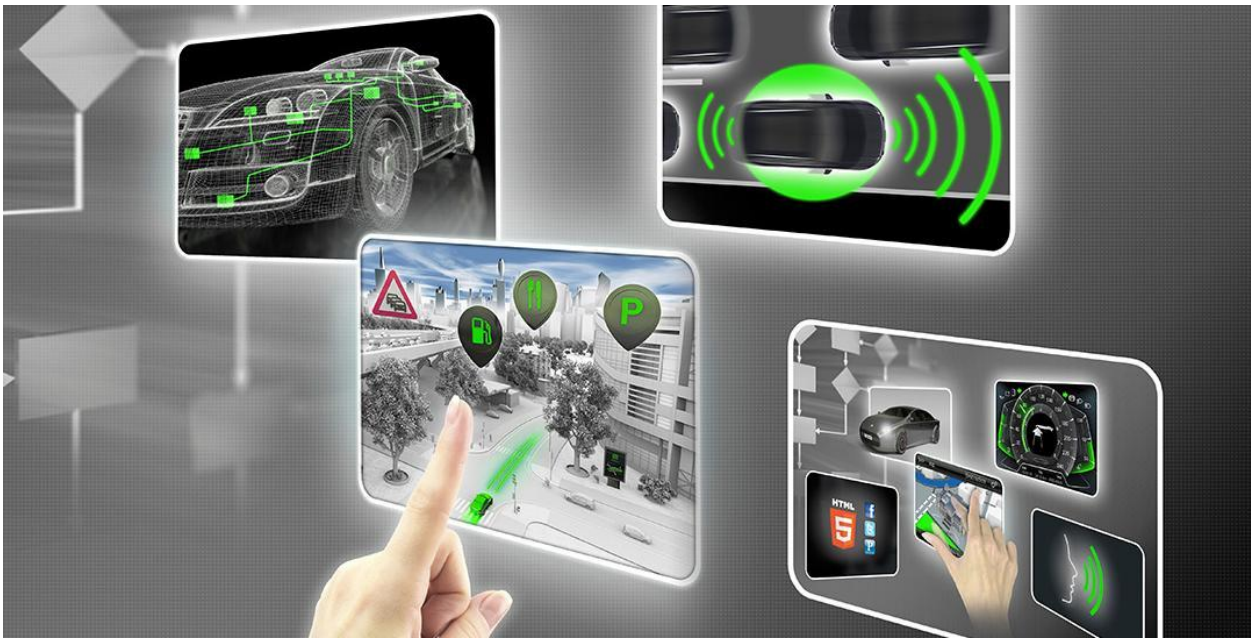


Document history

Date	Version	Editor	Description
2018-06-17	1.0	H. Kube	Initial version
2018-06-21	1.1	H. Kube	Include results of review: Change the safe state of LDW and LKA to set the the torque to 0 instead of switching off the system

Table of Contents

Purpose of the Functional Safety Concept

The purpose of the functional safety concept is to refine safety goals in functional safety requirements and then allocate these requirements to sub-systems in the high-level architecture.

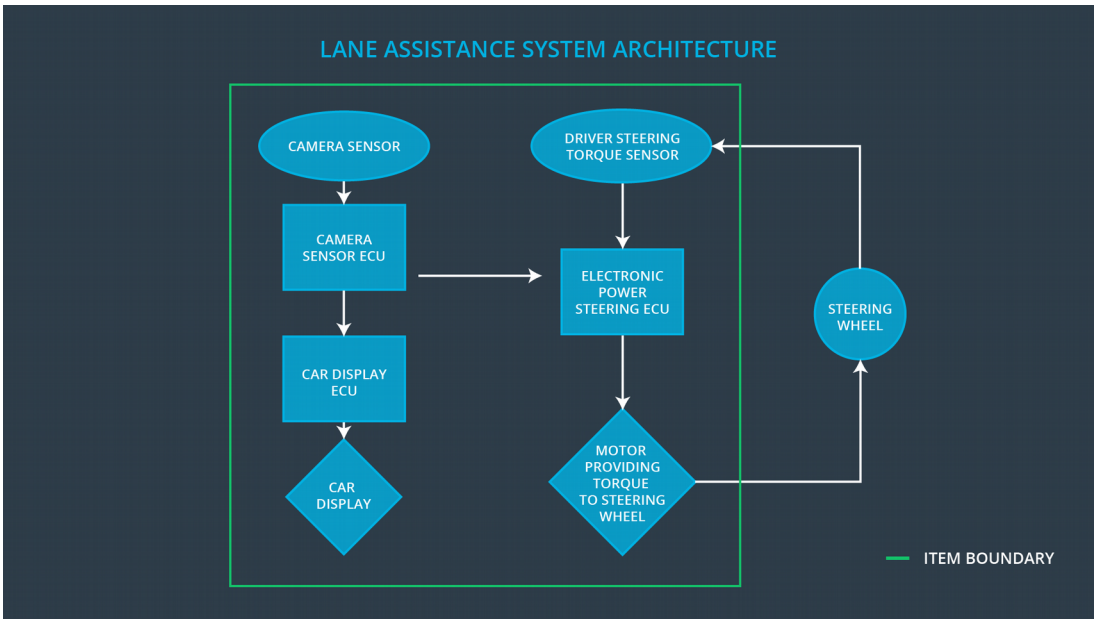
Inputs to the Functional Safety Concept

Safety goals from the Hazard Analysis and Risk Assessment

ID	Safety Goal
Safety_Goal_01	The oscillating steering torque from the lane departure warning function shall be limited.
Safety_Goal_02	The lane keeping assistance function shall be time limited and the additional steering torque shall end after a given time interval so that the driver cannot misuse the system autonomous driving.
Safety_Goal_03	The lane keeping assistance shall be able to detect yellow lane markings and prefer them over white lane markings.
Safety_Goal_04	The lane departure warning shall not apply any torque to the wheel in case the lane markings are not clearly visible.

Preliminary Architecture

The figure below describes the Lane Assistance item architecture.



Description of architecture elements

Element	Description
Camera Sensor	Captures road images and provide them to the Camera Sensor ECU
Camera Sensor ECU	Analyzes the road images, detect the lane markings positions, and calculates the verhicle position in respect to the ego lane.
Car Display	Shows the driver the lane keeping assistance warning and status.
Car Display ECU	Generates warning and status signals and show them on the Car Display.
Driver Steering Torque Sensor	Measures the torque applied by the driver to the wheel.
Electronic Power Steering ECU	Compares the torque measured by the Driver Steering Torque Sensor, compares this with the torque requested by the lane keeping assistance and drives the motor to apply the missing torque.
Motor	Applies the torque requested by the Electronic Power Steering ECU to the wheel.

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 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	The lane departure warning function applies an oscillating torque with very high torque amplitude (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 lane keeping assistance function is not limited in time duration which leads 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	The camera sensor might detect the wrong lane markings in road construction zones

Malfunction_05	Lane Departure Warning (LDW) function shall apply an oscillating steering torque to provide the driver a haptic feedback	WRONG	The camera sensor might detect the lane markings wrong in situation with degraded view (e. G. dense fog).

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	50 ms	The LDW_Torque_Amplitude is set to 0 and a warning is displayed on the dashboard.
Functional Safety Requirement 01-02	The lane keeping item shall ensure that the lane departure oscillating torque frequency is below Max_Torque_Frequency.	C	50 ms	The LDW_Torque_Frequency is set to 0 and a warning is displayed on the dashboard.
Safety Requirement 01-03	The lane keeping item shall not apply any torque to the wheel if the contrast of the road images is below Min_Image_Contrast.	B	50 ms	The LDW_Torque_Amplitude is set to 0 and a warning is displayed on the dashboard.

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	The how different drivers react to different torque value to prove that an appropriate value is chosen.	Verify that the LDW_Torque_Amplitude is set to 0 if the torque amplitude exceeds Max_Torque_Amplitude
Functional Safety Requirement 01-02	The how different drivers react to different torque frequency to prove that an appropriate value is chosen.	Verify that the LDW_Torque_Frequency is set to 0 if the torque frequency exceeds Max_Torque_Frequency
Functional Safety Requirement 01-03	Validate the contrast level of the road images at which the camera is just able to detect the lane markings properly.	Verify that the LDW_Torque_Amplitude is set to 0 if the contrast level is below Min_Image_Contrast

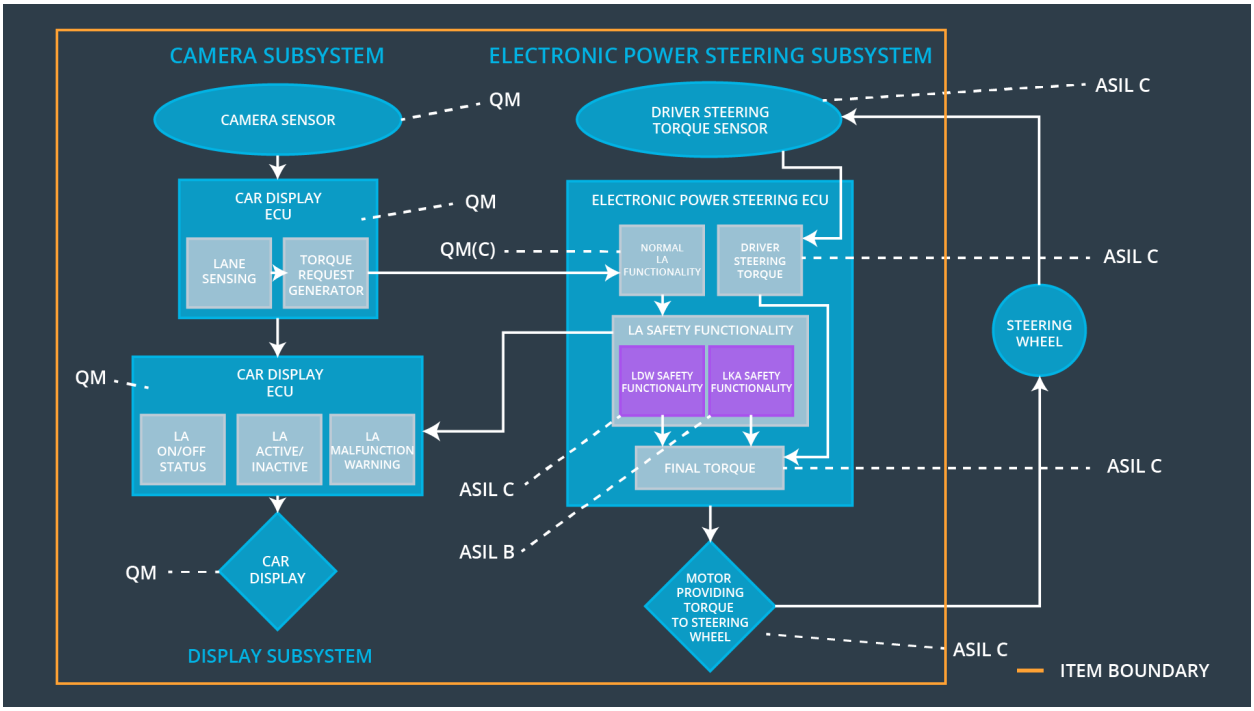
Lane Keeping Assistance (LKA) Requirements:

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	500 ms	The LKA_Torque is set to 0 and a warning is display on the dashboard.
Functional Safety Requirement 02-02	The lane keeping assistance shall detect the color of the line markings and prefer yellow markings over white markings	C	50 ms	Yellow lines are detected

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 the Max_Duration chosen does not allow the driver to use the car as self-driving car.	Verify that the LKA_Torque is set to 0 after the driver does not apply any torque to the wheel for more than Max_Duration
Functional Safety Requirement 02-02	Validate that the camera can clearly distinguish yellow lines from white lines.	Verify that the yellow lines are recognized and used if they are present in the camera image.

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	Validate the contrast level of the road images at which the camera is just able to detect the lane markings properly.		**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 02-02	The lane keeping assistance shall detect the color of the line markings and prefer yellow markings over white markings		**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, Malfunction_02, Malfunction_05	Yes	Lane Departure Warning indicator on car display
WDC-02	Turn off Lane Keeping Assistance functionality	Malfunction_03, Malfunction_04	Yes	Lane Keeping Assistance Malfunction indicator on car display