Functional Safety Concept Lane Assistance

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Document history

Date	Version	Editor	Description
2018-03-04	1.0	Maximilian Wenger	Initial version

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Purpose of the Functional Safety Concept

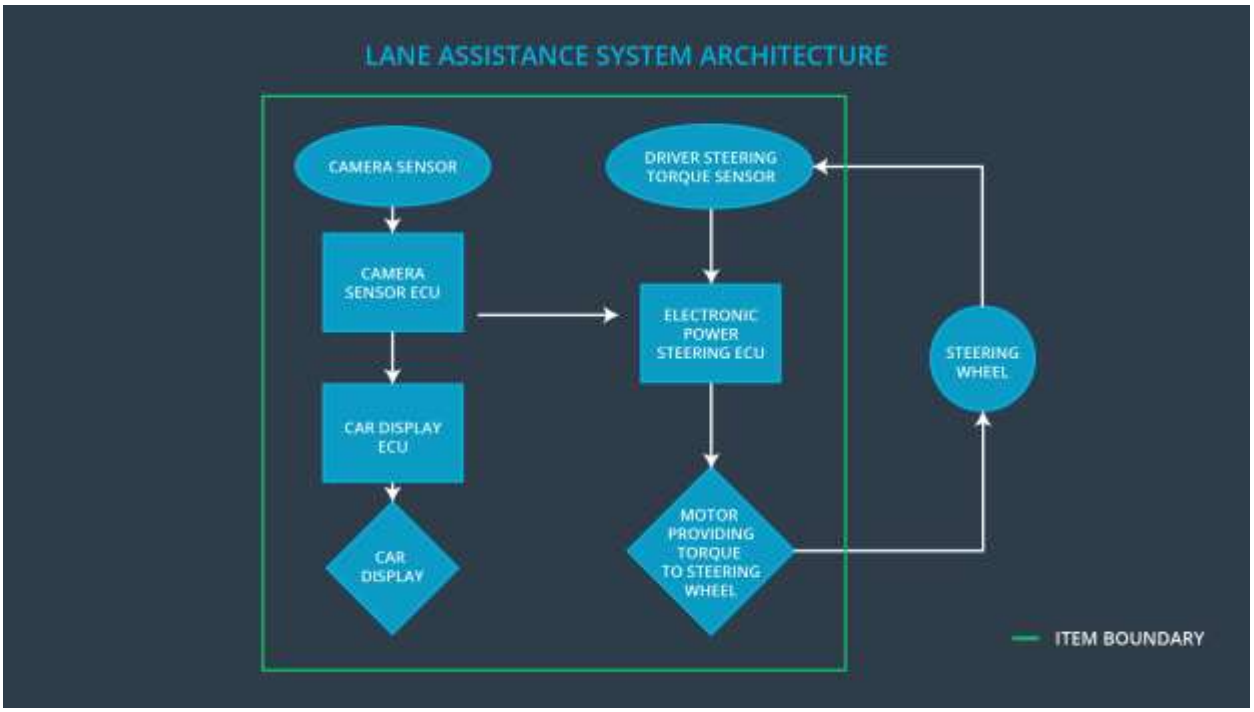
This document specifies how the subsystems of the lane assistance item will be used to achieve functional safety goals by implementing the identified functional safety requirements.

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 LDW function shall be limited.
Safety_Goal_02	The LKA 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 for autonomous driving.
Safety_Goal_03	The oscillating steering torque from the LDW function shall be over a certain threshold.
Safety_Goal_04	The LKA shall warn the driver when it's sensor cannot see lane markings due to poor visibility.

Preliminary Architecture



Description of architecture elements

Element	Description
Camera Sensor	Provide images of the road to the ECU.
Camera Sensor ECU	Detect lane markings and position of vehicle in relation to them.
Car Display	Show visual information to the driver (e.g. warning light).
Car Display ECU	Receive information from the Camera ECU and trigger the appropriate visualization in the display.
Driver Steering Torque Sensor	Measure the torque applied to the steering wheel by the driver.
Electronic Power Steering ECU	Calculate the steering torque the motor should apply to the steering wheel from the camera and torque sensor inputs.
Motor	Apply torque to the steering 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 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 lane keeping assistance function is not limited in time duration which leads to misuse as an autonomous driving function.
Malfunction_04	Lane Departure Warning (LDW) function shall apply an oscillating steering torque to provide the driver a haptic feedback	LESS	The lane departure warning function applies an oscillating torque with not enough torque amplitude (below driver's sensation threshold)
Malfunction_05	Lane Departure Warning (LDW) function shall apply an oscillating steering torque to provide the driver a haptic feedback	LESS	The lane departure warning function applies an oscillating torque with not enough torque frequency (below driver's sensation threshold)

Malfunction_06	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 does not work due to low visibility.

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 electronic power steering ECU shall ensure that the oscillating torque amplitude is below Max_Torque_Amplitude.	C	50ms	LA off (torque zero)
Functional Safety Requirement 01-02	The electronic power steering ECU shall ensure that the oscillating torque frequency is below Max_Torque_Frequency.	C	50ms	LA off (torque zero)
Functional Safety Requirement 01-03	The electronic power steering ECU shall ensure that the oscillating torque amplitude is above Min_Torque_Amplitude.	B	50ms	LA off (torque zero)
Functional Safety Requirement 01-04	The electronic power steering ECU shall ensure that the oscillating torque frequency is above Min_Torque_Frequency.	B	50ms	LA off (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	When applying the chosen Max_Torque_Amplitude value, over 95% of drivers must be able to sustain control over the vehicle.	If the requested torque is above Max_Torque_Amplitude, the commanded torque is zero.
Functional Safety Requirement 01-02	When applying the chosen Max_Torque_Frequency value, over 95% of drivers must be able to sustain control over the vehicle.	If the requested torque is above Max_Torque_Frequency, the commanded torque is zero.
Functional Safety Requirement 01-03	When applying the chosen Min_Torque_Amplitude value, over 95% of drivers must be able to feel the vibration easily.	If the requested torque is below Min_Torque_Amplitude, the commanded torque is zero.
Functional Safety Requirement 01-04	When applying the chosen Min_Torque_Frequency value, over 95% of drivers must be able to feel the vibration easily.	If the requested torque is below Min_Torque_Frequency, the commanded torque is zero.

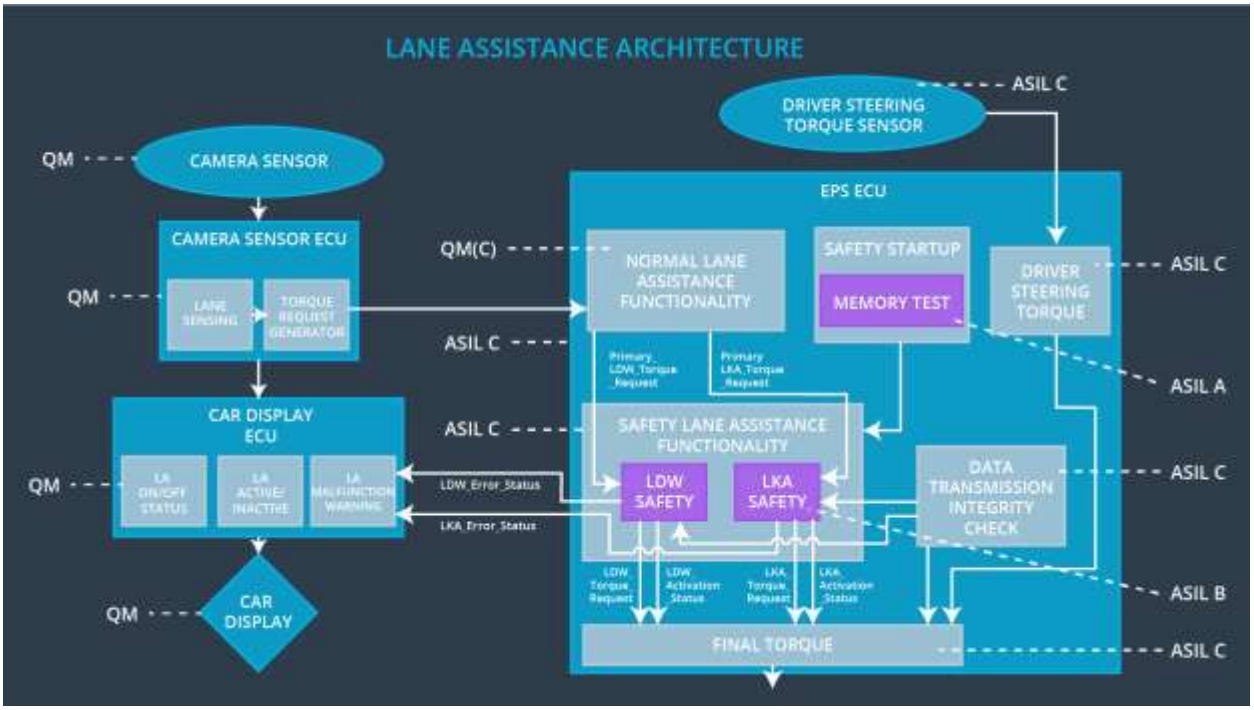
Lane Keeping Assistance (LKA) Requirements:

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	LA off (torque zero)
Functional Safety Requirement 02-02	The camera ECU shall warn the driver that the lane keeping assistance function is not available by setting the Low_Visibility flag.	QM	500ms	LA off (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	The chosen value of Max_Duration must be sufficiently short to dissuade drivers to assume the vehicle is fully autonomous.	If the duration of applying torque is above Max_Duration, the commanded torque is zero.
Functional Safety Requirement 02-02	The camera ECU sets the Low_Visibility flag if it's lane detections are not confident enough.	If the Low_Visibility flag is set, the commanded torque is zero.

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 electronic power steering ECU shall ensure that the oscillating torque amplitude is below Max_Torque_Amplitude.	**x**		
Functional Safety Requirement 01-02	The electronic power steering ECU shall ensure that the oscillating torque frequency is below Max_Torque_Frequency.	**x**		
Functional Safety Requirement 01-03	The electronic power steering ECU shall ensure that the oscillating torque amplitude is above Min_Torque_Amplitude.	**x**		
Functional Safety Requirement 01-04	The electronic power steering ECU shall ensure that the oscillating torque frequency is above Min_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 02-02	The car display shall warn the driver that the lane keeping assistance function is not available in a low visibility environment.		**x**	

Warning and Degradation Concept

ID	Degradation Mode	Trigger for Degradation Mode	Safe State invoked?	Driver Warning
WDC-01	Turn LA off (additional torque set to zero)	Malfunction_01 Malfunction_02 Malfunction_04 Malfunction_05	Yes	LA malfunction warning light
WDC-02	Turn LA off (additional torque set to zero)	Malfunction_03	Yes	LA malfunction warning light
WDC-03	Turn LA off (additional torque set to zero)	Malfunction_06	Yes	LA malfunction warning light