Functional Safety Concept Lane Assistance

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Document history

Date	Version	Editor	Description
23AUG17	1.0	Jim Reynolds	Initial version

28AUG17	1.1	Jim Reynolds	WIP

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Purpose of the Functional Safety Concept

The functional safety concept specifies the general (high-level) safety functionality of the item. It specifies the ASIL level, fault tolerant time interval and the safe state for each functional safety requirement.

Inputs to the Functional Safety Concept

Safety goals from the Hazard Analysis and Risk Assessment

ID	Safety Goal
Safety_Goal_01	The magnitude of the oscillating torque from the LDW shall be limited
Safety_Goal_02	The frequency of the oscillating torque from the LDW shall be limited
Safety_Goal_03	Continous activation of the LKA shall be prevented

Safety_Goal_04	Steering angle and rate-of-change of steering angle of the LKA shall be limited as a function of the current vehicle speed

Preliminary Architecture

Description of architecture elements

Element	Description
Camera Sensor	A sensor that outputs an image of the scene in front of the vehicle
Camera Sensor ECU	A control module responsible for processing the camera sensor output, determine lane line position and trajectory, and requesting steering wheel torque for Lane Departure Warning (LDW) and Lane Keep Assistance (LKA)
Car Display	An actuator that displays information and messages to the driver via warning lamps or LCD display
Car Display ECU	A control module responsible for illuminating lamps or activating LCD display messages based on the LDW or LKA activation status
Driver Steering Torque Sensor	A sensor that outputs the torque that the driver is applying to the steering wheel
Electronic Power Steering ECU	A control module that is responsible for taking the driver steering torque signal, requested steering wheel torque from the camera sensor ECU, and the motor plant characterstics to create an actuator output signal to the motor that corresponds to the desired torque
Motor	An actuator that adds torque to the steering system in either direction (clockwise or counterclockwise)

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 Keeping Assistance (LKA) function shall apply the steering torque when active in order to stay in ego lane	MORE	The lane keeping assistance function applies a torque resulting in a steering angle too great for the vehicle speed (above limit)
Malfunction_05	Lane Keeping Assistance (LKA) function shall apply the steering torque when active in order to stay in ego lane	MORE	The lane keeping assistance function applies a torque resulting in a rate-of-change steering angle too great for the vehicle speed (above limit)

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 keeping item output torque = 0
Functional Safety Requirement 01-02	The lane keeping item shall ensure that the lane departure oscillating torque amplitude is below Max_Torque_Frequency	C	50ms	Lane keeping item output torque = 0

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	Criteria 100% of drivers are able to regain steering control Event Manual override of requested torque at limit (with buffer) 1.2 * Max_Torque_Amplitude 1.0 * Max_Torque_Frequency Method Vehicle on test track with driving coaches and various drivers	Criteria Lane_Keep_Torque = 0 within 50ms of event Event Fault injection by RAM address write, requested torque amplitude exceeds limit Method Hardware-in-the-loop verification
Functional Safety Requirement 01-02	Criteria 100% of drivers are able to regain steering control Event Manual override of requested torque at limit (with buffer) 1.0 * Max_Torque_Amplitude 1.2 * Max_Torque_Frequency	Criteria Lane_Keep_Torque = 0 within 50ms of event Event Fault injection by RAM address write, requested torque frequency exceeds limit Method Hardware-in-the-loop verification

	Method Vehicle on test track with driving coaches and various drivers	

Lane Keeping Assistance (LKA) Requirements:

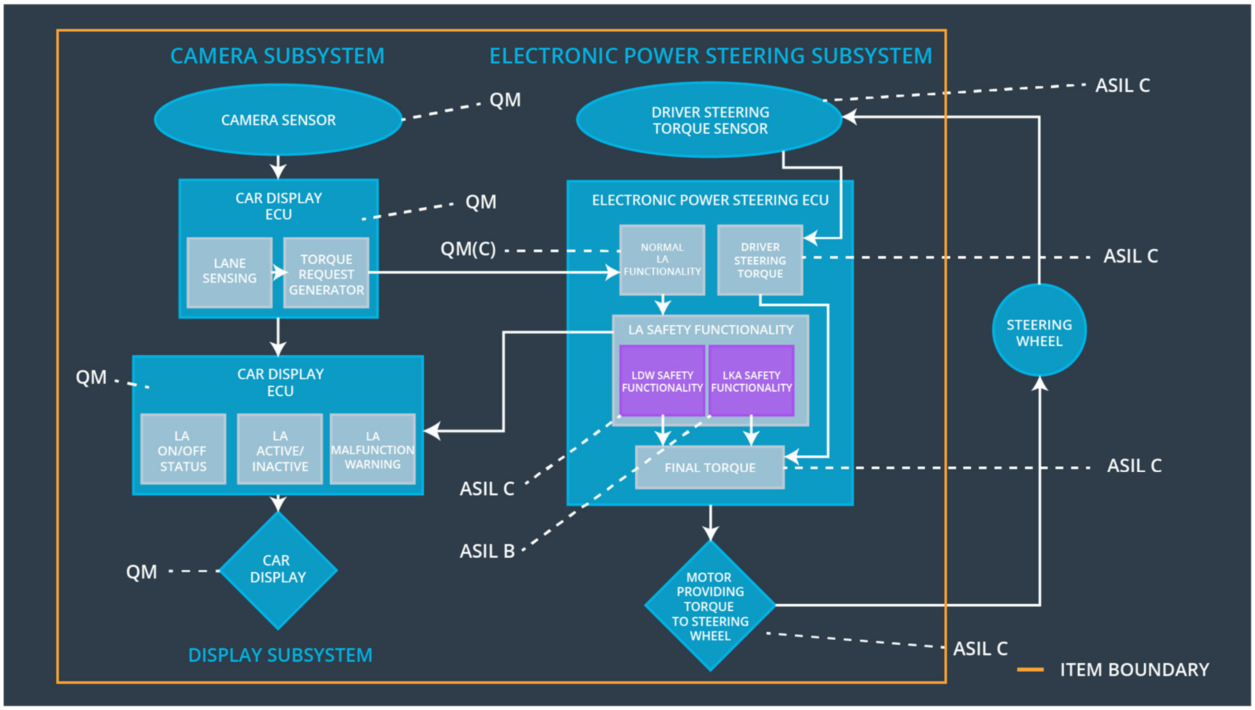
ID	Functional Safety Requirement	ASIL	Fault Tolerant Time Interval	Safe State
Functional Safety Requirement 02-01	The electronic power steering ECU shall ensure that the lane keeping assistance torque is applied for only Max_Duration	B	500ms	Lane keeping item output torque = 0
Functional Safety Requirement 02-02	The lane keeping item shall ensure that the total absolute steering angle does not exceed Max_Steering_Angle(Vehicle_Speed)	B	500ms	Lane keeping item output torque = 0
Functional Safety Requirement 02-03	The lane keeping item shall ensure that the rate-of-change of steering angle does not exceed Max_Steering_Rate(Vehicle_Speed)	B	500ms	Lane keeping item output torque = 0

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	Criteria 100% of drivers are able to regain steering control Event Driver removes hands from wheel with system active, retakes control after system is disabled by functional safety feature Method Vehicle on test track with driving coaches and various drivers	Criteria Lane_Keep_Torque = 0 within 500ms of event Event Fault injection by RAM address write, requested lane keep assistance torque remains active indefinitely Method Hardware-in-the-loop verification

Functional Safety Requirement 02-02	Criteria No loss of traction, all wheels remain on the ground Event Manual override of requested torque at limit (with buffer) 1.2 * Max_Steering_Angle(Vehicle_Speed) Method Vehicle on test track, unmanned, remotely controlled due to rollover risk	Criteria Lane_Keep_Torque = 0 within 50ms of event Event Fault injection by RAM address write, requested steering angle exceeds limit Method Hardware-in-the-loop verification
Functional Safety Requirement 02-03	Criteria No loss of traction, all wheels remain on the ground Event Manual override of requested torque at limit (with buffer) 1.2 * Max_Steering_Rate(Vehicle_Speed) Method Vehicle on test track, unmanned, remotely controlled due to rollover risk	Criteria Lane_Keep_Torque = 0 within 50ms of event Event Fault injection by RAM address write, requested rate-of-change of steering angle exceeds limit Method Hardware-in-the-loop verification

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 amplitude 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 02-02	The lane keeping item shall ensure that the total absolute steering angle does not exceed Max_Steering_Angle(Vehicle_Speed)	**X**		
Functional Safety Requirement 02-03	The lane keeping item shall ensure that the rate-of-change of steering angle does not exceed Max_Steering_Rate(Vehicle_Speed)	**X**		

Warning and Degradation Concept

ID	Degradation Mode	Trigger for Degradation Mode	Safe State invoked?	Driver Warning
WDC-01	System disabled until module reset	Malfunction_01	Yes, immediately	1. Audible Chime 2. Pop-up message on instrument cluster
WDC-02	System disabled until module reset	Malfunction_02	Yes, immediately	1. Audible Chime 2. Pop-up message on instrument cluster
WDC-03	System disabled until module reset	Malfunction_03	Yes, immediately	1. Audible Chime 2. Pop-up message on instrument cluster
WDC-04	System disabled until module reset	Malfunction_04	Yes, immediately	1. Audible Chime 2. Pop-up message on instrument cluster

WDC-05	System disabled until module reset	Malfunction_05	Yes, immediately	1. Audible Chime 2. Pop-up message on instrument cluster