Elektrobit

UDACITY

Functional Safety Concept Lane Assistance

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Document history

Date	Version	Editor	Description
9/9/2018	1.0	Ajinkya Bhave	Functional Safety Concept for Lane Assistance Item

Table of Contents

Purpose of the Functional Safety Concept

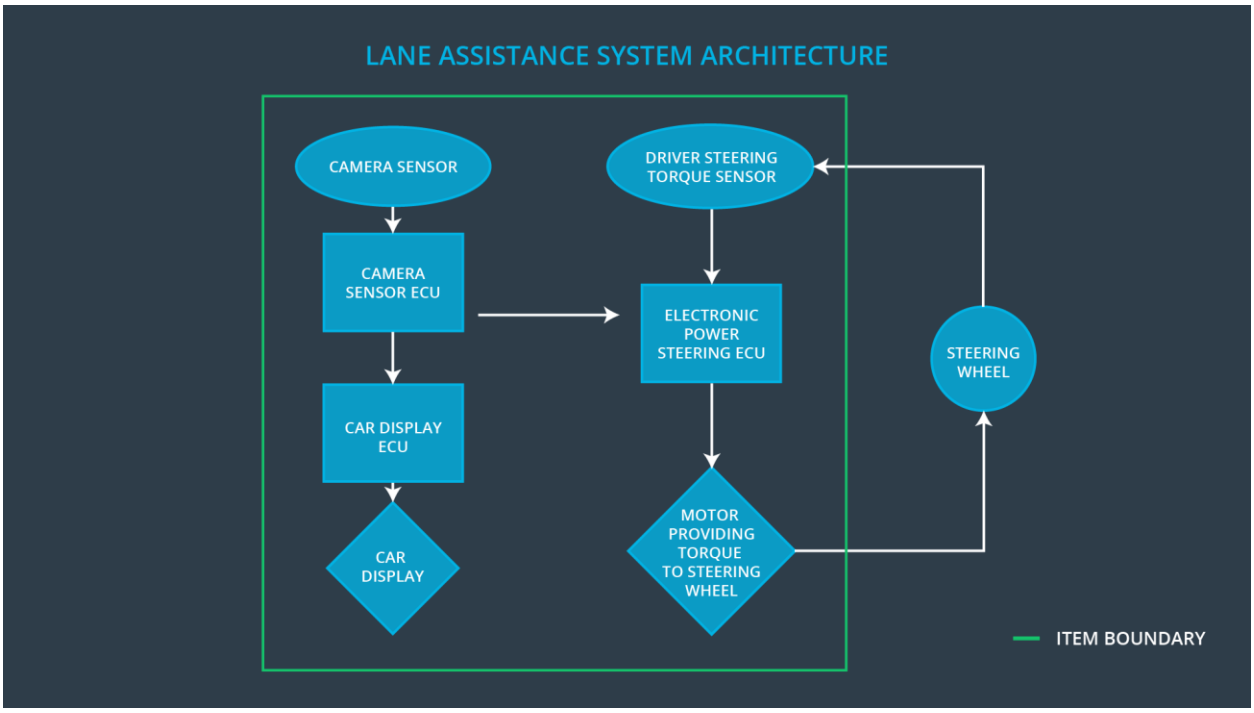
The Functional Safety Concept derives safety requirements at the functional level from safety goals, allocates each functional safety requirement to the right elements in the functional system architecture, and defines the warning and degradation concepts.

Inputs to the Functional Safety Concept

Safety goals from the Hazard Analysis and Risk Assessment

ID	Safety Goal
Safety_Goal_01	Oscillating steering torque from LDW function shall be limited
Safety_Goal_02	LKA function shall be time limited and additional steering torque shall end after a predefined time interval to prevent driver from misusing the system for autonomous driving
Safety_Goal_03	LDW function shall activate within a predefined time interval after receiving a torque request from the camera subsystem
Safety_Goal_04	Steering torque from LKA function shall be adequate to keep vehicle in its lane

Preliminary Architecture



Description of architecture elements

Element	Description
Camera Sensor	Captures images of road in front of the vehicle
Camera Sensor ECU	Calculates when the vehicle is leaving the lane Requests the EPS system to turn and vibrate the steering wheel Requests the car display system to turn on warning light on dashboard
Car Display	Displays warning and status lights for driver
Car Display ECU	Turns on warning and status lights on car display
Driver Steering Torque Sensor	Detects how much torque the driver is applying to the steering wheel
Electronic Power Steering ECU	Processes requests from camera subsystem and driver torque demand and sends final steering torque command to the motor
Motor	Applies commanded torque directly to 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	LDW 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	LDW function applies an oscillating torque with very high torque frequency (above limit)
Malfunction_03	Lane Departure Warning (LDW) function shall apply an oscillating steering torque to provide the driver a haptic feedback	LATE	LDW function applies an oscillating torque after a delay (vehicle has already left the ego lane)
Malfunction_04	Lane Keeping Assistance (LKA) function shall apply the steering torque when active in order to stay in ego lane	NO	LKA function is not limited in time duration which leads to misuse as an autonomous driving function

Malfunction_05	Lane Keeping Assistance (LKA) function shall apply the steering torque when active in order to stay in ego lane	LESS	LKA function applies a torque that is not adequate in magnitude to keep vehicle centered in lane

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 LA Item shall ensure that the LDW oscillating torque amplitude is below *Max_Torque_Amplitude*	C	50 ms	Turn off LDW
Functional Safety Requirement 01-02	The LA Item shall ensure that the LDW oscillating torque frequency is below *Max_Torque_Frequency*	C	50 ms	Turn off LDW
Functional Safety Requirement 01-03	The LA Item shall ensure that the LDW oscillating torque is applied within *Max_ Delay*	C	50 ms	Turn off LDW

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

ID	Validation Acceptance Criteria and Method	Verification Acceptance Criteria and Method
Functional Safety	Normal drivers are able to control the vehicle when torque amplitude is within	*Criterion*: When the torque amplitude crosses *Max_Torque_Amplitude*, the

Requirement 01-01	*Max_Torque_Amplitude*	LA output is set to zero within 50 ms *Method:* Insert torque signal with amplitude greater than *Max_Torque_Amplitude*
Functional Safety Requirement 01-02	Normal drivers are able to control the vehicle when torque frequency is within *Max_Torque_Frequency*	*Criterion:* When the torque frequency crosses *Max_Torque_Frequency*, the LA output is set to zero within 50 ms *Method:* Insert torque signal with frequency greater than *Max_Torque_Frequency*
Functional Safety Requirement 01-03	Normal drivers are able to steer the vehicle back to lane centre when torque is applied within *Max_Delay*	*Criterion:* When the torque request is not applied within *Max_Delay* seconds, the LA output is set to zero within 50 ms *Method:* Delay the torque signal artificially by more than Max_Delay seconds

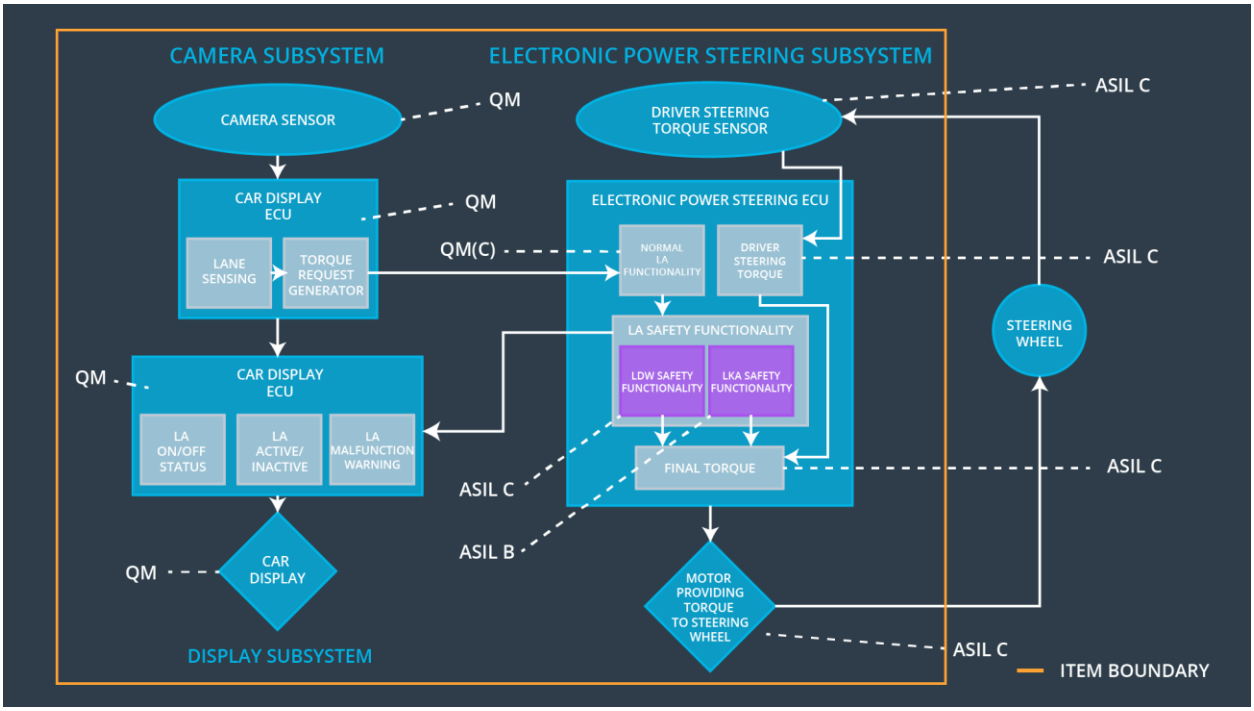
Lane Keeping Assistance (LKA) Requirements:

ID	**Functional Safety Requirement**	**ASIL**	**Fault Tolerant Time Interval**	**Safe State**
Functional Safety Requirement 02-01	The LA Item shall ensure that the LKA torque is applied for only *Max_Duration*	B	500 ms	Turn off LKA
Functional Safety Requirement 02-02	The LA Item shall ensure that the LKA torque amplitude is greater than *Min_Torque_Amplitude*	QM	500 ms	Turn off LKA

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 *Max_Duration* value chosen forces drivers not to take their hands off the steering wheel during driving	*Criterion:* When the LKA torque is applied for more than *Max_Duration* seconds, the LKA output is set to zero within 500 ms *Method:* Artificially inject torque request from LKA system lasting more than *Max_Duration* seconds
Functional Safety Requirement 02-02	The *Min_Torque_Amplitude* value chosen is adequate to physically steer the vehicle back to lane centre each time there is deviation	*Criterion:* When the LKA torque applied is less than *Min_Torque_Amplitude*, the LKA output is set to zero within 500 ms *Method:* Artifically reduce LKA torque amplitude below *Min_Torque_Amplitude*

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 LA Item shall ensure that the LDW oscillating torque amplitude is below *Max_Torque_Amplitude*	**X**		
Functional Safety Requirement 01-02	The LA Item shall ensure that the LDW oscillating torque frequency is below *Max_Torque_Frequency*	**X**		
Functional Safety Requirement 01-03	The LA Item shall ensure that the LDW oscillating torque is applied within *Max_ Delay*	**X**		
Functional Safety Requirement 02-01	The EPS ECU shall ensure that the LKA torque is applied for only *Max_Duration*	**X**		
Functional Safety Requirement 02-02	The EPS ECU shall ensure that the LKA torque amplitude is greater than *Min_Torque_Amplitude*	**X**		

Warning and Degradation Concept

ID	Degradation Mode	Trigger for Degradation Mode	Safe State invoked?	Driver Warning
WDC-01	Turn off LDW functionality	Malfunction_01, Malfunction_02, Malfunction_03	YES	Warning light on car display

WDC-02	Turn off LKA functionality	Malfunction_04, Malfunction_05	YES	Warning light on car display