Functional Safety Concept Lane Assistance

Document Version: 1.0

Template Version 1.0, Released on 2017-06-21

Document history

Date	Version	Editor	Description
5/25/2018	1.0	Rahul Bhartari	First Revision

Table of Contents

Purpose of the Functional Safety Concept

The functional safety concept is a high level approach to look at the general functionality of the item without going into technical details. The goal is to identify new requirements and then allocate those requirements to different parts of the item architecture. Technical safety requirements can be derived from these safety concepts. Functional safety requirements also have a few attributes that need to be specified in the functional safety concept. To prove that a system actually meets the functional safety requirements, verification and validation is also done.

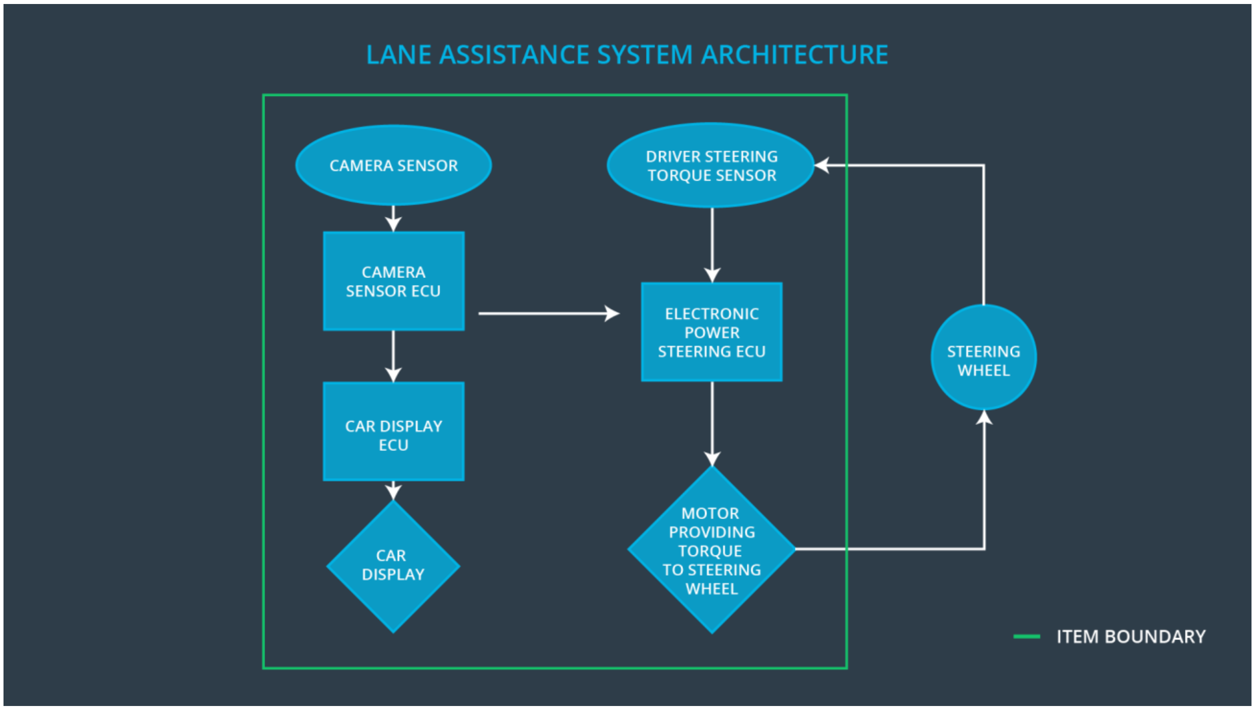
Inputs to the Functional Safety Concept

Safety goals from the Hazard Analysis and Risk Assessment

ID	**Safety Goal**
Safety_Goal_01	Steering wheel oscillations should be limited to reasonable levels
Safety_Goal_02	The Lane Keeping Assistance function must engage for certain number of times in given duration and thereafter alert the driver and disengage to prevent misuse
Safety_Goal_03	The Lane departure warning system should be deactivated when driving on roads with faded or missing lane markings
Safety_Goal_04	The amount of torque applied by Lane Keeping Assistance function on steering wheel should be limited and zero when driver applies torque more than some threshold
Safety_Goal_05	The Lane Departure Warning system must show the status of essential sensors and warn the driver of any discrepancy when switched on, so that driver may not rely completely on the system while driving

Preliminary Architecture

Following diagram shows the preliminary architecture of the Lane Assistance system:


LANE ASSISTANCE SYSTEM ARCHITECTURE
CAMERA SENSOR
CAMERA SENSOR ECU
CAR DISPLAY ECU
CAR DISPLAY
DRIVER STEERING TORQUE SENSOR
ELECTRONIC POWER STEERING ECU
MOTOR PROVIDING TORQUE TO STEERING WHEEL
STEERING WHEEL
ITEM BOUNDARY

Description of architecture elements

Element	**Description**
Camera Sensor	Capture the scene and send the image data to Camera Sensor ECU
Camera Sensor ECU	Calculate the position of car on the road with respect to the lane markings
Car Display	Display the system status and warnings to the driver
Car Display ECU	Drive the Car Display component
Driver Steering Torque Sensor	Measure the torque applied by the driver on the steering wheel
Electronic Power Steering ECU	Get the measurements from Driver steering Torque Sensor and torque requested by Lane Keeping Assistance function and drive the motor to apply torque accordingly
Motor	Apply the 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 a high amplitude oscillating torque(above limits)
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 a high frequency oscillating torque(above limits)
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 by time and number of times engaged, leading to potential misuse
Malfunction_04	Lane Keeping Assistance (LKA) function shall apply limited torque when driver applies opposite torque above certain limit	NO	The Lane Keeping Assistance is not limited by torque amplitude, leading to accident in case an object suddenly comes in ego lane

Malfunction_05	Lane Departure Warning (LDW) function shall be deactivated when not able to find lanes on road and alert the driver	WRONG	The Lane Departure Warning function may give false alerts when used on roads with faded or missing lanes
Malfunction_06	The Lane Departure Warning (LDW) function shall be deactivated in case of any discrepancy with the system and alert the driver	WRONG	The Lane Departure Warning function does not monitor the state of the sensors and does not issue warning when required

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 Departure Warning (LDW) function shall ensure that amplitude of oscillating torque is less than Max_Torque_Amplitude	C	50ms	Oscillation torque amplitude is less than Max_Torque_Amplitude
Functional Safety Requirement 01-02	The Lane Departure Warning (LDW) function shall ensure that frequency of oscillating torque is less than Max_Torque_Frequency	C	50ms	Oscillation torque frequency is less than Max_Torque_Frequency
Functional Safety Requirement 01-03	The Lane Departure Warning (LDW) function shall be deactivated when any discrepancy in sensors or state of Camera Subsystem is Lane_Not_Found	A	50ms	Lane Departure Warning function is off

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	Validate if Max_Torque_Amplitude is chosen such that it is detectable by the driver and does not cause the loss of steering	Verify that system turns off if torque amplitude ever exceeds Max_Torque_Amplitude
Functional Safety Requirement 01-02	Validate if Max_Torque_Frequency is chosen such that it is detectable by the driver and does not cause the loss of steering	Verify that system turns off if torque amplitude ever exceeds Max_Torque_Frequency
Functional Safety Requirement 01-03	Validate if Lane Departure warning function turns off when Lane_Not_Found is set	Verify that system turns off is Lane_Not_Found is set

Lane Keeping Assistance (LKA) Requirements:

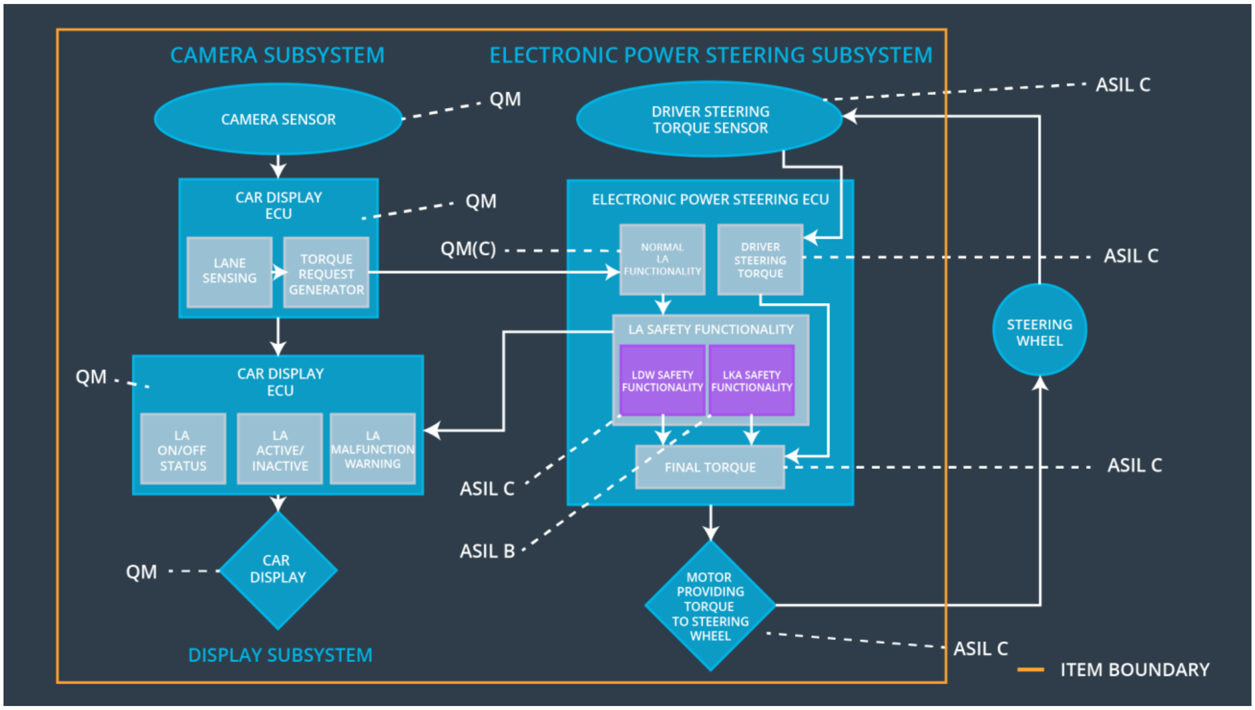
ID	Functional Safety Requirement	ASIL	Fault Tolerant Time Interval	Safe State
Functional Safety Requirement 02-01	The Lane Keeping Assistance (LKA) function must limit the number of times it engages to keep vehicle in lane	B	100ms	The Lane Keeping Assistance Torque is zero
Functional Safety Requirement 02-02	The Lane Keeping Assistance (LKA) function must limit the amplitude of torque it applies on steering wheel and disengage when driver applying opposite torque	B	50ms	The Lane Keeping Assistance Torque is zero

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

ID	Validation Acceptance Criteria and Method	Verification Acceptance Criteria and Method
Functional	Validate if Lane Keeping Assistance	Verify that the system outputs zero

Safety Requirement 02-01	function applies torque for duration Max_Duration, Max_Engage_Count number of times and zero torque threafter	torque after Max_Duration and Max_Engage_Count is exceeded
Functional Safety Requirement 02-02	Validate if Lane Keeping Assistance sends zero torque to motor if Driver applies torque more than Max_Driver_Torque on steering wheel	Verify that Lane Keeping Assistance function sends zero torque when driver torque is more than Max_Driver_Torque

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 than oscillating torque amplitude is less than Max_Torque_Amplitude	**X**		
Functional Safety Requirement 01-02	The Electronic power steering ECU shall ensure than oscillating torque frequency is less than Max_Torque_Frequency	**X**		
Functional Safety Requirement 01-03	The Lane Departure warning function shall turn off when Lane_Not_Found is set		**X**	
Functional Safety Requirement 02-01	The Electronic power steering ECU shall apply torque for duration Max_Duration and Max_Engage_Count number of times	**X**		
Functional Safety Requirement 02-02	The Electronic power steering ECU sends zero torque to motor if Driver applies torque more than Max_Driver_Torque on steering wheel	**X**		

Warning and Degradation Concept

ID	**Degradation Mode**	**Trigger for Degradation Mode**	**Safe State invoked?**	**Driver Warning**
WDC-01	Turn off Lane Departure Warning Function	Malfunction_01 Malfunction_02 Malfunction_05 Malfunction_06	Yes	Lane Departure Warning Malfunction warning on car display
WDC-02	Turn off Lane Keeping Assistance Function	Malfunction_03 Malfunction_04	Yes	Lane Keeping Assistance Malfunction warning on car

				display