Elektrobit

UDACITY

Functional Safety Concept Lane Assistance

Document Version: [Version]

Template Version 1.0, Released on 2017-06-21

Document history

Date	Version	Editor	Description
June 21, 2017	1.0	Udacity, EB	Template version
April 22, 2019	1.1	Ahmed Belal	Finalize the document

Table of Contents

Purpose of the Functional Safety Concept

The purpose of the functional safety concept (FSC) is the following:

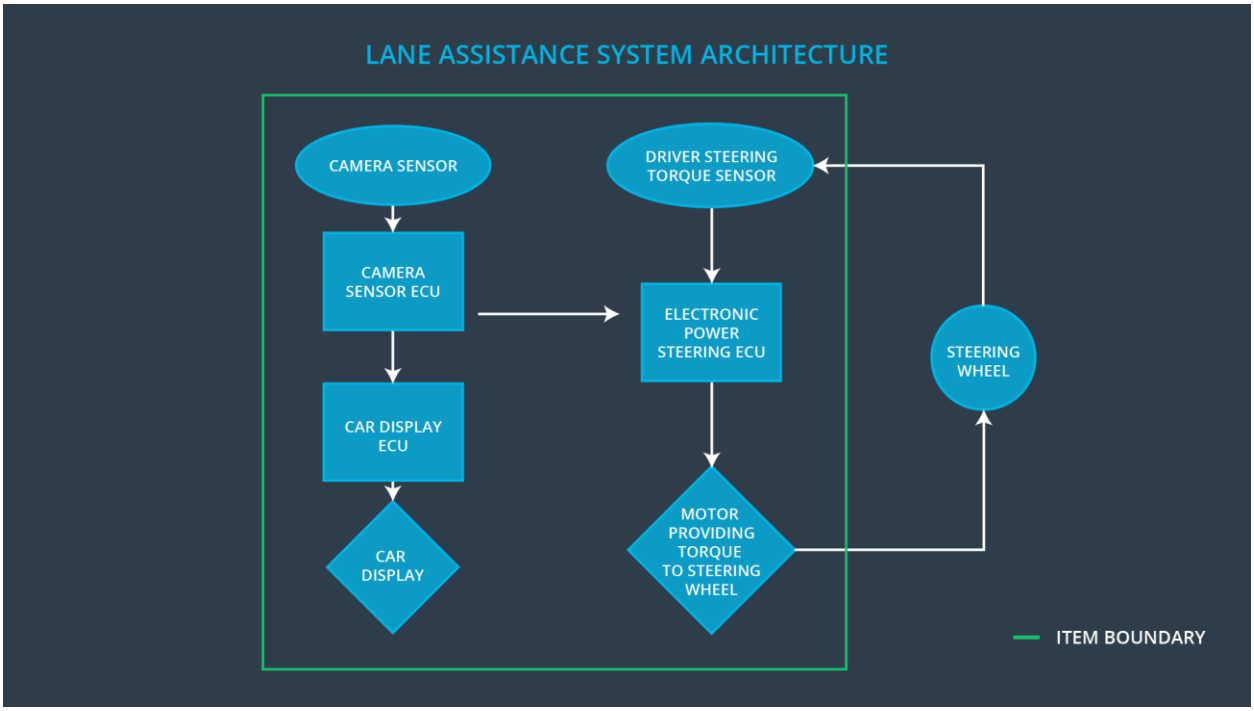
- Derive functional safety requirement from the safety goals to refine the safety goals
- Allocating these safety requirements to the relevant parts of the system diagram which means defining which part of the system architecture will implement each requirement
- Refine the system architecture to handle the new requirements
- Assigning ASIL level to the system architecture blocks which will inherit the highest assigned requirement ASIL
- The fault tolerant time interval, which measures how quickly a system needs to react to a hazardous situation
- And the safe state, which discusses what a system looks like after it has avoided an accident

Inputs to the Functional Safety Concept

Safety goals from the Hazard Analysis and Risk Assessment

ID	Safety Goal
Safety_Goal_01	Lane Departure Warning (LDW) function shall apply a limited oscillating steering torque to provide the driver with haptic feedback
Safety_Goal_02	The Lane Keeping Assistance (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	Lane Keeping Assistance (LKA) function shall apply a limited steering torque when active in order to stay in ego lane
Safety_Goal_04	Lane Keeping Assistance (LKA) function shall apply the steering torque in the correct direction when active in order to stay in ego lane

Preliminary Architecture



Description of architecture elements

Element	Description
Camera Sensor	Capture the road images (video)
Camera Sensor ECU	Processing the images (video) provided by the camera sensor for detecting the lane lines and determining when the vehicle leaves the lane by mistake
Car Display	Screen for showing the notification, warnings and vehicle status for the driver
Car Display ECU	Control the displayed data on the car display
Driver Steering Torque Sensor	Measure the steering torque applied on the steering wheels
Electronic Power Steering ECU	Control the steering wheels by sending the appropriate steering torque control signal to the steering motor driver
Motor	Apply the steering torque based on the received steering control signal from the Electronic power steering (EPS) ECU

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 a limited oscillating steering torque to provide the driver with haptic feedback	MORE	The lane departure warning (LDW) function applies an oscillating torque with very high torque amplitude (above limit)
Malfunction_02	Lane Departure Warning (LDW) function shall apply a limited oscillating steering torque to provide the driver with haptic feedback	MORE	The lane departure warning (LDW) function applies an oscillating torque with very high torque frequency (above limit)
Malfunction_03	The Lane Keeping Assistance (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	NO	The Lane Keeping Assistance (LKA) 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 a limited steering torque when active in order to stay in ego lane	MORE	Lane Keeping Assistance (LKA) function applies a steering torque with very high torque amplitude which affect the driver ability to steer the vehicle(above limit)
Malfunction_05	Lane Keeping Assistance (LKA) function shall apply the steering torque in the correct direction when active in order to stay in ego lane	WRONG	Lane Keeping Assistance (LKA) function applies the steering torque in the wrong direction

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 (EPS) ECU shall ensure that the lane departure oscillating torque amplitude is below the MAX_TORQUE_AMPLITUDE	C	50ms	Shut the system down by setting lane assistance output is set to zero
Functional Safety Requirement 01-02	The electronic power steering (EPS) ECU shall ensure that the lane departure oscillating torque frequency is below the MAX_TORQUE_FREQUENCY	C	50ms	Shut the system down by setting lane assistance output is set to 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	Validate the LDW MAX_TORQUE_AMPLITUDE of the oscillating steering torque	Verify that the LDW will shut down if the MAX_TORQUE_AMPLITUDE exceeded
Functional Safety Requirement 01-02	Validate the LDW MAX_TORQUE_FREQUENCY of the oscillating steering torque	Verify that the LDW will shut down if the MAX_TORQUE_ FREQUENCY exceeded

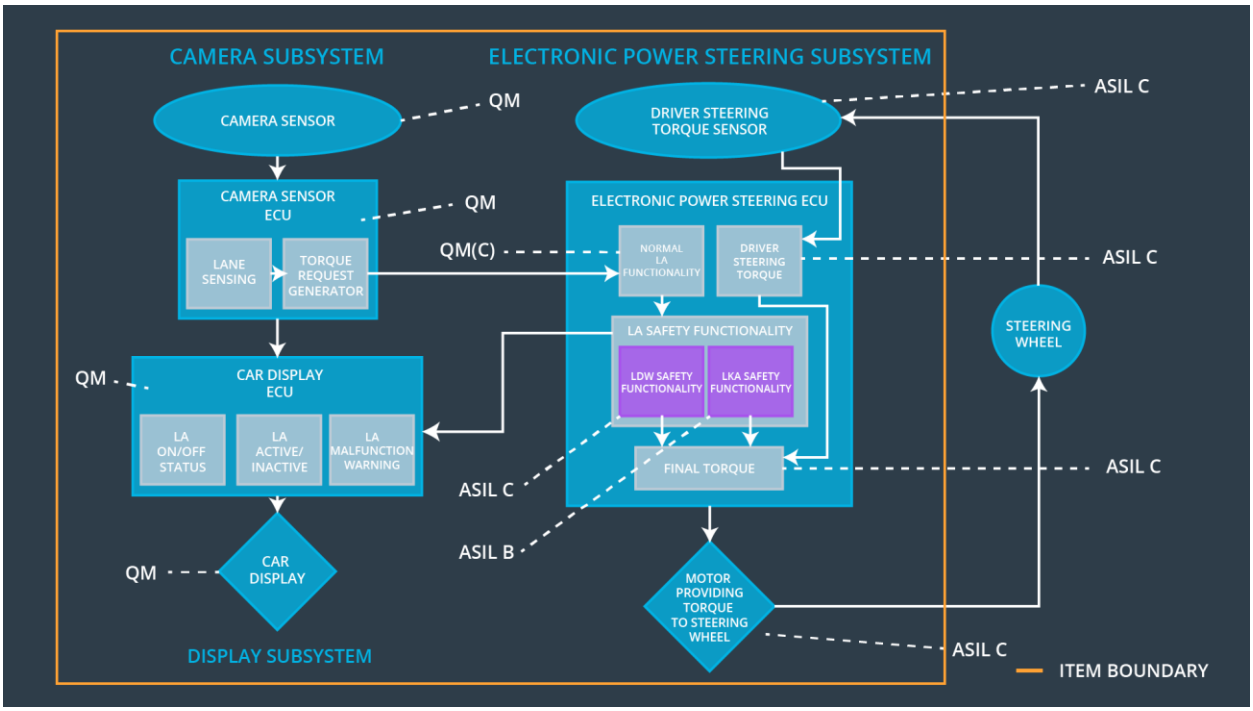
Lane Keeping Assistance (LKA) Requirements:

ID	Functional Safety Requirement	ASIL	Fault Tolerant Time Interval	Safe State
Functional Safety Requirement 02-01	The electronic power steering (EPS) ECU shall ensure that the lane keeping assistance (LKA) torque is applied for only MAX_DURATION	B	500ms	Shut the system down by setting lane assistance output is set to zero
Functional Safety Requirement 03-01	The electronic power steering (EPS) ECU shall ensure that the lane keeping assistance (LKA) torque is below the MAX_TORQUE_AMPLITUDE when active in order to stay in ego lane	C	500ms	Shut the system down by setting lane assistance output is set to zero
Functional Safety Requirement 04-01	The electronic power steering (EPS) ECU shall ensure that the lane keeping assistance (LKA) torque is applied in the correct direction when active in order to stay in ego lane	C	500ms	Shut the system down by setting lane assistance output is set to 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	Validate the LKA MAX_DURATION of the steering torque	Verify that the LKA will shut down if the steering torque MAX_DURATION exceeded
Functional Safety Requirement 03-01	Validate the LKA MAX_TORQUE_AMPLITUDE of the steering torque	Verify that the LKA will shut down if the MAX_TORQUE_AMPLITUDE exceeded
Functional Safety Requirement 04-01	Validate the LKA correct steering torque direction	Verify that the LKA will shut down if the steering torque applied in the wrong direction

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 (EPS) ECU shall ensure that the lane departure oscillating torque amplitude is below the MAX_TORQUE_AMPLITUDE	✓		
Functional Safety Requirement 01-02	The electronic power steering (EPS) ECU shall ensure that the lane departure oscillating torque frequency is below the MAX_TORQUE_FREQUENCY	✓		
Functional Safety Requirement 02-01	The electronic power steering (EPS) ECU shall ensure that the lane keeping assistance (LKA) torque is applied for only MAX_DURATION	✓		
Functional Safety Requirement 03-01	The electronic power steering (EPS) ECU shall ensure that the lane keeping assistance (LKA) torque is below the MAX_TORQUE_AMPLITUDE when active in order to stay in ego lane	✓		
Functional Safety Requirement 04-01	The electronic power steering (EPS) ECU shall ensure that the lane keeping assistance (LKA) torque is applied in the correct direction when active in order to stay in ego lane	✓		

Warning and Degradation Concept

ID	Degradation Mode	Trigger for Degradation Mode	Safe State invoked?	Driver Warning
WDC-01	Shut the system down by setting lane assistance output is set to zero	Malfunction_01 Malfunction_02	Yes	Display LDW warning on driver dashboard
WDC-02	Shut the system down by setting lane assistance output is set to zero	Malfunction_03 Malfunction_04 Malfunction_05	Yes	Display LKA warning on driver dashboard