Elektrobit

UDACITY

Technical Safety Concept Lane Assistance

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Document history

Date	Version	Editor	Description
June 21, 2017	1.0	Udacity, EB	Template version
April 23, 2019	1.1	Ahmed Belal	Finalize the document

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Purpose of the Technical Safety Concept

The purpose of the technical safety concept (TSC) is to get into more details of the functional safety concept (FSC) including:

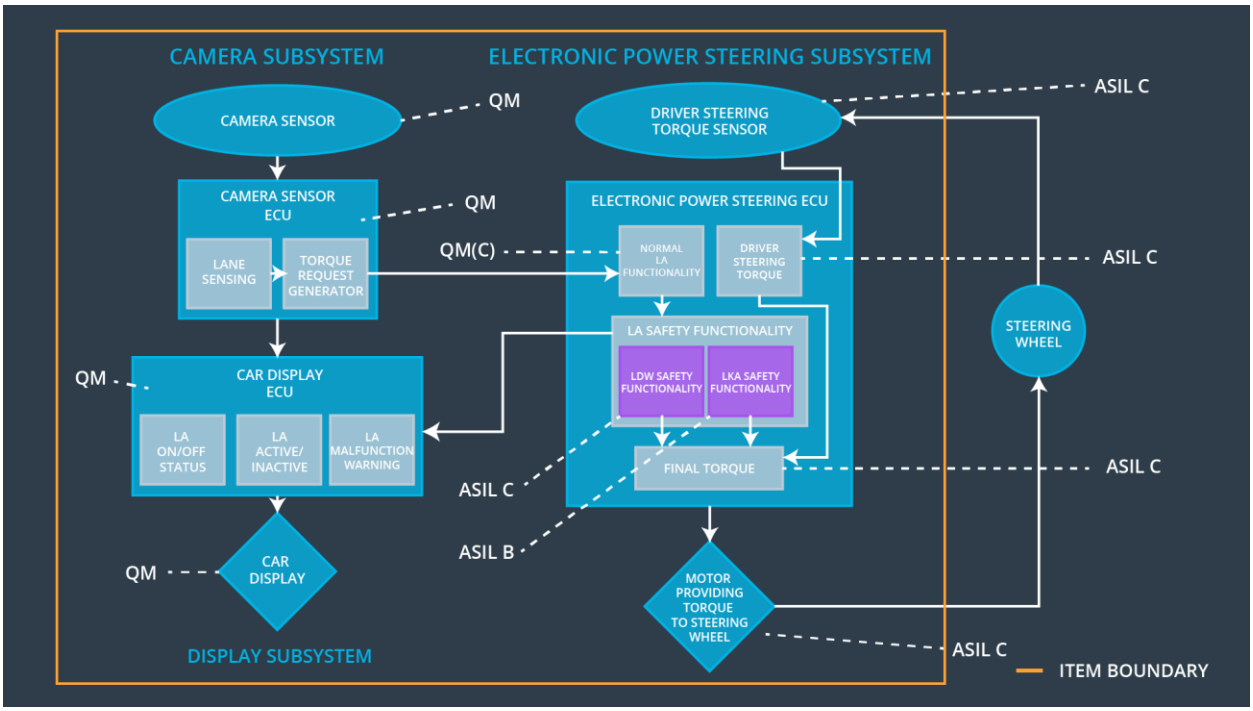
- Turning functional safety requirements into technical safety requirements
- Allocating the technical safety requirements to the system architecture

Inputs to the Technical Safety Concept

Functional Safety 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
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	50ms	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	50ms	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	50ms	Shut the system down by setting lane assistance output is set to zero

Refined System Architecture from Functional Safety Concept



Functional overview of architecture elements

Element	Description
Camera Sensor	Capture the road images (video)
Camera Sensor ECU - Lane Sensing	Processing the images (video) provided by the camera sensor for detecting the lane lines
Camera Sensor ECU - Torque request generator	determines when the vehicle leaves the lane by mistake, and calculate/send the appropriate torque request to the electronic power steering (EPS) ECU
Car Display	Screen for showing the notification, warnings and vehicle status for the driver
Car Display ECU - Lane Assistance On/Off Status	Shows on Car display an indicator for Lane Assistant Active/Inactive
Car Display ECU - Lane Assistant Active/Inactive	Shows on Car display an indicator for Lane Assistance On/Off Status
Car Display ECU - Lane Assistance malfunction warning	Shows on Car display an indicator for Lane Assistance malfunction warning
Driver Steering Torque Sensor	Measure the steering torque applied on the steering wheels
Electronic Power Steering (EPS) ECU - Driver Steering Torque	Receives the measured steering torque by the driving steering torque sensor
EPS ECU - Normal Lane Assistance Functionality	Responsible for the normal functionality for the lane assistance features including receiving the camera images and calculating the primary LKA/LDW torque request
EPS ECU - Lane Departure Warning Safety Functionality	The functional safety module that ensures that LDW primary torque amplitude and frequency is below the specified limit, otherwise it will go to the specified safe state
EPS ECU - Lane Keeping Assistant Safety Functionality	The functional safety module that ensures that LKA primary torque amplitude is applied gradually, below the specified limit, and applied in the correct direction, otherwise it will go to the specified safe state
EPS ECU - Final Torque	Sends the final LKA/LDW torque request to the motor to be applied on the steering wheel
Motor	Apply the steering torque based on the received steering control signal from the Electronic power steering (EPS) ECU

Technical Safety Concept

Technical Safety Requirements

Lane Departure Warning (LDW) Requirements:
Functional Safety Requirement 01-01 with its associated system elements (derived in the functional safety concept)

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	✓		

Technical Safety Requirements related to Functional Safety Requirement 01-01 are:

ID	Technical Safety Requirement	ASIL	Fault Tolerant Time Interval	Architecture Allocation	Safe State
Technical Safety Requirement 01	The lane departure warning (LDW) safety component shall ensure that the amplitude of the 'LDW_Torque_Request' sent to the 'final electronic power steering torque' component is below MAX_TORQUE_AMPLITUDE	C	50ms	LDW Safety block	Shut down the LDW system by setting 'LDW_Torque_Request' to zero
Technical Safety Requirement 02	The validity and integrity of data transmission for 'LDW_Torque_Request' signal shall be ensured	C	50ms	Data Transmission Integrity Check	Shut down the LDW system by setting 'LDW_Torque_Request' to zero
Technical Safety Requirement 03	As soon as failure detected by lane departure warning (LDW) function, it shall deactivate the LDW feature and the 'LDW_Torque_Request' shall set to zero	C	50ms	LDW Safety block	Shut down the LDW system by setting 'LDW_Torque_Request' to zero

Technical Safety Requirement 04	As soon as the LDW function deactivate the LDW feature, the 'LDW Safety' software block shall send a signal to the car display ECU to turn on a warning light	C	50ms	LDW Safety block	Shut down the LDW system by setting 'LDW_Torque_Request' to zero
Technical Safety Requirement 05	Memory tests shall be conducted at startup of the EPS ECU to check for any faults in memory	A	Length of the vehicle ignition cycle	Memory Tests Check	Restart the LDW system, if this repeated for 3 times, display error signal on the car display

Functional Safety Requirement 01-2 with its associated system elements (derived in the functional safety concept)

ID	Functional Safety Requirement	Electronic Power Steering ECU	Camera ECU	Car Display ECU
Functional Safety Requirement 01-02	The electronic power steering (EPS) ECU shall ensure that the lane departure oscillating torque frequency is below MAX_TORQUE_FREQUENCY	✓		

Technical Safety Requirements related to Functional Safety Requirement 01-02 are:

ID	Technical Safety Requirement	ASIL	Fault Tolerant Time Interval	Architecture Allocation	Safe State
Technical Safety Requirement 01	The lane departure warning (LDW) safety component shall ensure that the frequency of the 'LDW_Torque_Request' sent to the 'final electronic power steering torque' component is below MAX_TORQUE_FREQUENCY	C	50ms	LDW Safety block	Shut down the LDW system by setting 'LDW_Torque_Request' to zero
Technical Safety Requirement 02	The validity and integrity of data transmission for 'LDW_Torque_Request' signal shall be ensured	C	50ms	Data Transmission Integrity Check	Shut down the LDW system by setting 'LDW_Torque_Request' to zero

Technical Safety Requirement 03	As soon as failure detected by lane departure warning (LDW) function, it shall deactivate the LDW feature and the 'LDW_Torque_Request' shall set to zero	C	50ms	LDW Safety block	Shut down the LDW system by setting 'LDW_Torque _Request' to zero
Technical Safety Requirement 04	As soon as the LDW function deactivate the LDW feature, the 'LDW Safety' software block shall send a signal to the car display ECU to turn on a warning light	C	50ms	LDW Safety block	Shut down the LDW system by setting 'LDW_Torque _Request' to zero
Technical Safety Requirement 05	Memory tests shall be conducted at startup of the EPS ECU to check for any faults in memory	A	Length of the vehicle ignition cycle	Memory Tests Check	Restart the LDW system, if this repeated for 3 times, display error signal on the car display

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

Verification and validation are identified for each technical safety requirement (TSR).
"Validation" asks whether or not you chose the appropriate parameters.
"Verification" involves testing to make sure the vehicle behaves as expected when the parameter value is crossed.
Lane Departure Warning (LDW) Verification and Validation Acceptance Criteria as the same as Functional Safety Concept.

ID	Validation Acceptance Criteria and Method	Verification Acceptance Criteria and Method
Technical Safety Requirement 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
Technical Safety Requirement 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:
Functional Safety Requirement 02-1 with its associated system elements (derived in the functional safety concept)

ID	Functional Safety Requirement	Electronic Power Steering ECU	Camera ECU	Car Display ECU
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 time duration	✓		

Technical Safety Requirements related to Functional Safety Requirement 02-01 are:

ID	Technical Safety Requirement	ASIL	Fault Tolerant Time Interval	Allocation to Architecture	Safe State
Technical Safety Requirement 01	Lane Keeping Assistance (LKA) safety component shall ensure that the torque of the 'LKA_Torque_Request' sent to the 'final electronic power steering torque' component is applied for only MAX_DURATION time duration	C	500ms	LKA Safety block	Shut down the LDW system by setting 'LKA_Torque_Request' to zero
Technical Safety Requirement 02	The validity and integrity of data transmission for 'LKA_Torque_Request' signal shall be ensured	C	500ms	Data Transmission Integrity Check	Shut down the LDW system by setting 'LKA_Torque_Request' to zero
Technical Safety Requirement 03	As soon as failure detected by Lane Keeping Assistance (LKA) function, it shall deactivate the LKA feature and the 'LKA_Torque_Request' shall set to zero	C	500ms	LKA Safety block	Shut down the LDW system by setting 'LKA_Torque_Request' to zero

Technical Safety Requirement 04	As soon as the LKA function deactivate the LKA feature, the 'LKA Safety' software block shall send a signal to the car display ECU to turn on a warning light	C	500ms	LKA Safety block	Shut down the LDW system by setting 'LKA_Torque_ Request' to zero
Technical Safety Requirement 05	Memory tests shall be conducted at startup of the EPS ECU to check for any faults in memory	A	Length of the vehicle ignition cycle	Memory Tests Check	Restart the LKA system, if this repeated for 3 times, display error signal on the car display

Functional Safety Requirement 03-1 with its associated system elements (derived in the functional safety concept)

ID	Functional Safety Requirement	Electronic Power Steering ECU	Camera ECU	Car Display ECU
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	✓		

Technical Safety Requirements related to Functional Safety Requirement 03-01 are:

ID	Technical Safety Requirement	ASIL	Fault Tolerant Time Interval	Allocation to Architecture	Safe State
Technical Safety Requirement 01	Lane Keeping Assistance (LKA) safety component shall ensure that the amplitude of the 'LKW_Torque_Request' sent to the 'final electronic power steering torque' component is below MAX_TORQUE_AMPLITUDE	C	500ms	LKA Safety block	Shut down the LDW system by setting 'LKA_Torque _Request' to zero

Functional Safety Requirement 04-1 with its associated system elements (derived in the functional safety concept)

ID	Functional Safety Requirement	Electronic Power Steering ECU	Camera ECU	Car Display ECU
Functional Safety Requirement 03-01	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	✓		

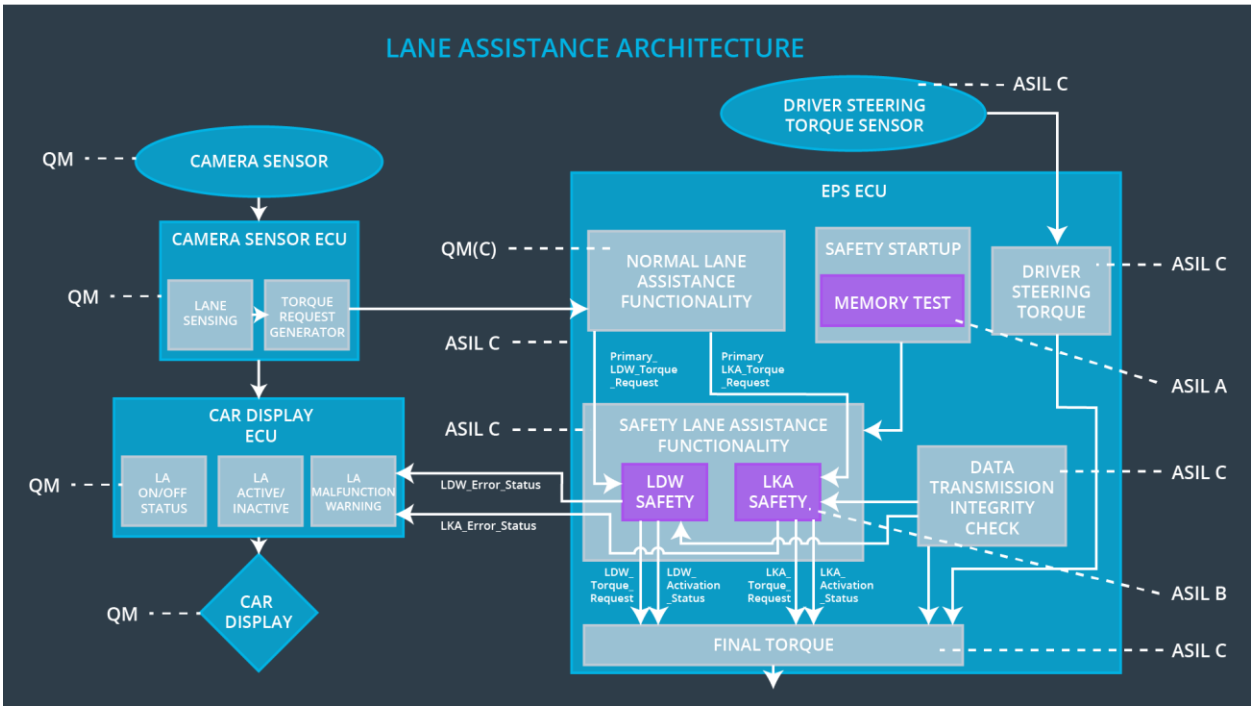
Technical Safety Requirements related to Functional Safety Requirement 04-01 are:

ID	Technical Safety Requirement	ASIL	Fault Tolerant Time Interval	Allocation to Architecture	Safe State
Technical Safety Requirement 01	Lane Keeping Assistance (LKA) safety component shall ensure that the torque of the 'LKW_Torque_Request' sent to the 'final electronic power steering torque' component is applied in the correct direction when active in order to stay in ego lane	C	500ms	LKA Safety block	Shut down the LDW system by setting 'LKA_Torque_Request' to zero

Lane Keeping Assistance (LKA) Verification and Validation Acceptance Criteria:
Verification and validation are identified for each technical safety requirement (TSR).
“Validation” asks whether or not you chose the appropriate parameters.
“Verification” involves testing to make sure the vehicle behaves as expected when the parameter value is crossed.
Lane Keeping Assistance (LKA) Verification and Validation Acceptance Criteria as the same as Functional Safety Concept.

ID	Validation Acceptance Criteria and Method	Verification Acceptance Criteria and Method
Technical 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
Technical 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
Technical 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 Technical Safety Requirements to Architecture Elements

Technical safety requirements already allocated to the architecture elements in the technical safety requirements tables. Generally, all technical safety requirements are allocated to the electronic power steering (EPS) ECU.

Warning and Degradation Concept

We've already identified that for any system malfunction, the lane assistance functions will be turned off and the driver will receive a warning light indication. The technical safety requirements have not changed how functionality will be degraded or what the warning will be.

So in this case, the warning and degradation concept is the same for the technical safety requirements as for the functional safety requirements.

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

For more information about the list of malfunctions, please check the Functional safety concept (FSC) document page 5.