Model-Based Software Design

Laboratory 1 Report

Components of the working group (max 2 people)

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Item definition

Skyhook controller

Purpose of this document

The purpose of this document is to be the input for the "Hazard Analysis and Risk Assessment" (HARA) needed to be compliant with the ISO26262 standard. To ensure safety, all activities of the safety life cycle have to be planned to avoid systematic failures.
Therefore, this document describes the assumption on the Skyhook controller (SHC) item you should develop.

An additional purpose of this document is to define and describe the item, its functionality, dependencies on, and interaction with, the driver, the environmental conditions, external measure, the boundary of the item and interfaces to other items as well as assumptions concerning other elements at the vehicle level. In this document, the requirements and recommendations for establishing the definition of the item, including its functionality, interfaces, environmental conditions, legal requirements, and known hazards will be handled.

Purpose of the item

Please describe in this chapter the purpose of the item. Consider laws, standards and regulations in order to describe sufficiently the purpose of the item.

The purpose of the item is the following:

- To improve the performance of a vehicle and to guarantee a better comfort of the vehicle occupants, a semi-active suspension system is adopted where a control low is used to change the Damping c in relation to the suspended mass and wheel speed.

Functional behavior

Thanks to a mechatronic system based on electro valves, the Skyhook controller changes the damping coefficient c of each of the 4 suspensions installed in the car to impose a higher damping coefficient when the suspension itself is expanding and a lower one when it is compressing. It allows to maintain the maximum possible stability for the vehicle body regardless of driving and road conditions: the system damps the vibrating body in comparison to an imaginary line in the horizon.
From a mathematical point of view, the principle is the following:

$$\begin{cases} (\dot{x_1} - \dot{x_2})\dot{x_1} \geq 0 \implies c = c_h \\ (\dot{x_1} - \dot{x_2})\dot{x_1} < 0 \implies c = c_l \\ c_h > c_l \end{cases}$$

Function	Operating elements
Measure Front Left wheel acceleration	FLA
Measure Front Right wheel acceleration	FRA
Measure Rear Left wheel acceleration	RLA
Measure Rear Right wheel acceleration	RRA

Measure chassis acceleration	CA
Changes the damping of the Front Left wheel shock absorber	FLEV
Changes the damping of the Front Right wheel shock absorber	FREV
Changes the damping of the Rear Left wheel shock absorber	RLEV
Changes the damping of the Rear Right wheel shock absorber	RREV
Disable the item functionality when required by the driver	BTN
Warn the driver when the SHC is not functioning/disabled	LED

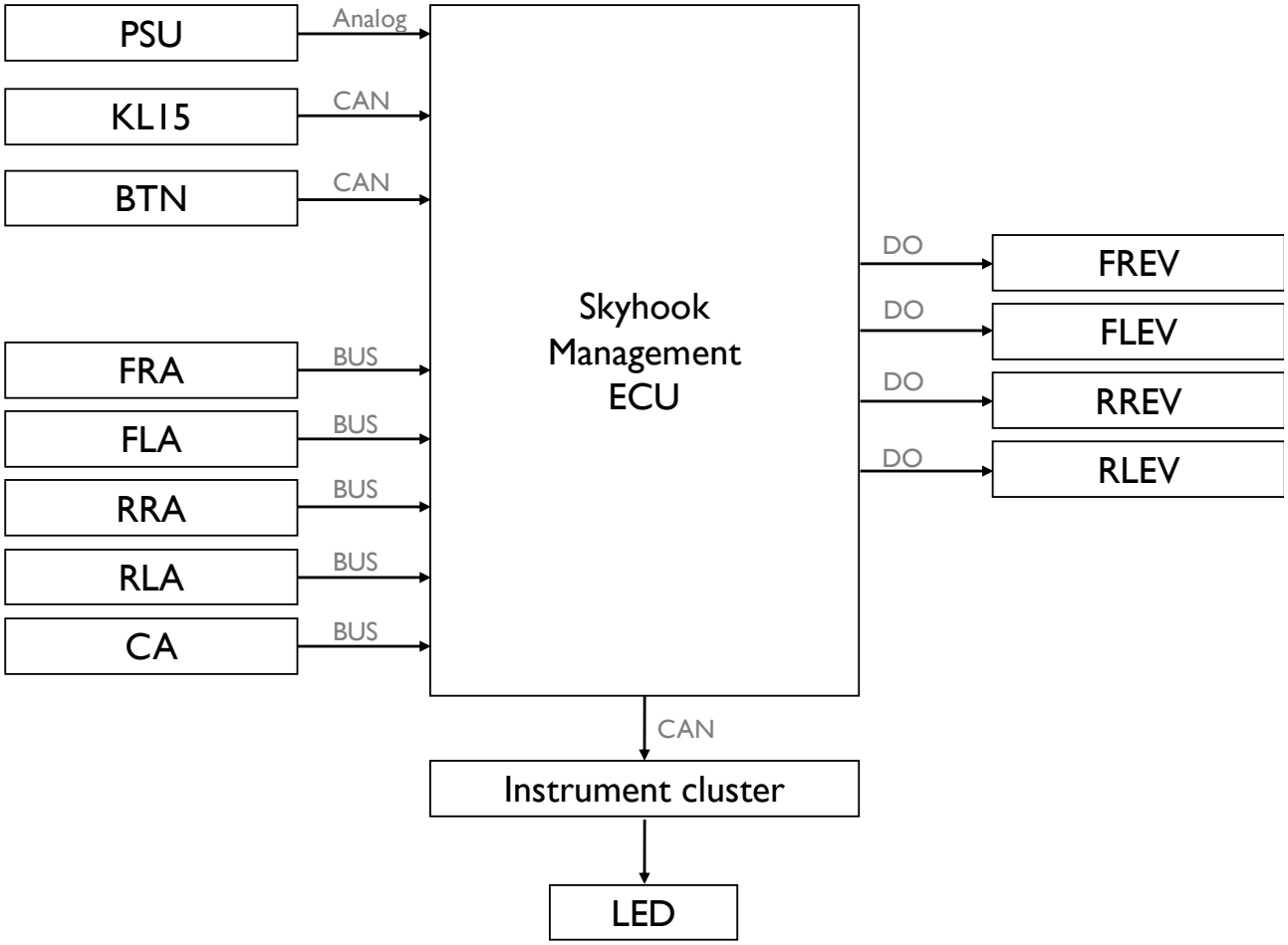
Functional block diagram

Please describe the interaction with external systems or items and/or interfaces to other elements outside the boundary of your item. Please consider the combination of "sensor-logic-actuator" and choose functional names for these elements regarding your item.

The following figure shows the assumed system architecture, including system elements like:

- Ignition Key position (KL15) (via Body Controller)
- Enable/Disable Button (BTN)
- Service request /malfunction indication LED on the instrument cluster to warn the driver (LED)
- Front Left suspension electro valve (FLEV)
- Front Left suspension accelerometer (on unsprung mass) (FLA)
- Front Right suspension electro valve (FREV)
- Front Right suspension accelerometer (on unsprung mass) (FRA)
- Rear Left suspension electro valve (RLEV)
- Rear Left suspension accelerometer (on unsprung mass) (RLA)
- Rear Right suspension electro valve (RREV)
- Rear Right suspension accelerometer (on unsprung mass) (RRA)
- Chassis accelerometer (sprung mass) (CA)
- Power supply (PSU)

The technical interfacing of system elements with FLM ECU is assumed as shown in figure and table:



System element	Interface to FLM ECU
Ignition Key position (KL15) (via Body Controller)	CAN interface
Service request /malfunction indication LED on the instrument cluster to warn the driver (LED)	CAN interface
Front Left suspension electro valve (FLEV)	DO
Front Left suspension accelerometer (on unsprung mass) (FLA)	Serial Bus (e.g., SPI, I2C)
Front Right suspension electro valve (FREV)	DO
Front Right suspension accelerometer (on unsprung mass) (FRA)	Serial Bus (e.g., SPI, I2C)
Rear Left suspension electro valve (RLEV)	DO
Rear Left suspension accelerometer (on unsprung mass) (RLA)	Serial Bus (e.g., SPI, I2C)
Rear Right suspension electro valve (RREV)	DO
Rear Right suspension accelerometer (on unsprung mass) (RRA)	Serial Bus (e.g., SPI, I2C)
Chassis accelerometer (sprung mass) (CA)	Serial Bus (e.g., SPI, I2C)
Power supply (PSU)	Analog
Enable/Disable button (BTN)	CAN

Assumptions:

As a starting point, the following configuration of the system is assumed:

- Implementation of SHC on one ECU
- At the vehicle powering on, the state of the SHC is Enabled.
- The electro-valves are monostable hence when the firing signal is OFF, or the ECU cannot provide it, the shock absorber remains set at the c_h damping coefficient.
- All memories (volatile and non-volatile) is protected against reversible transient faults. It is assumed that mechanisms like ECC are available.
- Hardware means for memory partitioning, like MPU or MMU, are available.
- The microcontroller is considered a Safety Element out of Context (SEooC), hence the analysis of failure modes of the microcontroller is performed, and safety measures are defined and implemented. This analysis is based on data provided by the supplied (safety manual) and the requirements of ISO26262.

Consider only a quarter (one wheel) of the car and not consider the external components like BTN, LED, PSU, and the KL15 signal.

Boundaries of the system responsibility and interfaces

Please describe the boundary of the system responsibility, interaction with external systems or items and interfaces to other elements outside your item in combination with the block diagram above

The system is in charge to stabilize the vehicle trough the actuation of valves that modify the dumping coefficient of the suspensions. Doing this it is in charge to the readings of the accelerometers (e.g. FRA and CA) of wheel and chassis and communication of it through the BUS. It is in charge to send signals to the instrumental cluster in order to warn the drivers about failures.

Other sources of hazards, which influence the safety and reliability of the item

Please describe other sources (not E/E) of hazards, which influence the safety and reliability of the item

Accidental damage leading to mechanical damage, wrong pression of dumping fluid.

Functional requirements

Please describe all already noted functional safety requirements, this is normally output of H&R.

SHC has to be enabled when the KL15 is on, except in case of error state, during which the shock absorber remains set at the c_h damping coefficient and a LED has to warn the driver.
When the system is active, the EVs have to be actuated in other to grant the following value of dumping:

$$\begin{cases} (\dot{x_1} - \dot{x_2})\dot{x_1} \geq 0 \implies c = c_h \\ (\dot{x_1} - \dot{x_2})\dot{x_1} < 0 \implies c = c_l \\ c_h > c_l \end{cases}$$

Other requirements

Other environmental requirements which can influence your item

Law, directive and standard

List the laws, directives and standard which have to be considered

ISO26262

External measure to minimizing risks

Which external measures can be taken in order to minimize the risk:

The vehicle operator is required by law to be properly trained and to obtain a driving license, so he/she verifies, before start driving, that there are not any warnings and errors led on.
The vehicle is required to pass periodical inspection and revisions that control the correct functionality of main security systems like suspensions.

Hazard Analysis and Risk Assessment

Skyhook controller

Consider only a quarter (one wheel) of the car and not consider the external components like BTN, LED, PSU, and the KL15 signal.

Participants

Name, department	Qualification	Experience

Analyses of situations

Definition of possible functional failures

Failure #	Description
F1	The electro valve modifies or left set the shock absorber damping factor at c_h when it should be c_l
F2	The electro valve modifies or left set the shock absorber damping factor at c_l when it should be c_h

Driving scenarios

Describe the possible driving situations and define the status of the vehicle you want to consider

Description of the possible driving situations

- DS1 Driving in city road
- DS2 Driving in a country road
- DS3 Driving in a highway

Definition of the vehicle status

- VS1 Driving at high speed
- VS2 Driving at low speed
- VS3 Performing an evasive maneuver

Considerations

Describe driving situations for each status of the vehicle

Scenario #	Driving situation	Vehicle status
~~S1~~	~~Driving in city road (DS1)~~	~~Driving at high speed (VS1)~~
S2	Driving in city road (DS1)	Driving at low speed (VS2)
S3	Driving in city road (DS1)	Performing an evasive maneuver (VS3)
S4	Driving in a country road (DS2)	Driving at high speed (VS1)
S5	Driving in a country road (DS2)	Driving at low speed (VS2)
S6	Driving in a country road (DS2)	Performing an evasive maneuver (VS3)
S7	Driving in a highway (DS3)	Driving at high speed (VS1)
S8	Driving in a highway (DS3)	Driving at low speed (VS2)
S9	Driving in a highway (DS3)	Performing an evasive maneuver (VS3)

Analysis

Estimation matrix

		Scenarios										
		~~S1~~[1]	S2	S3	S4	S5	S6	S7	S8	S9	**Top event (worst case)**	**ASIL[2]**
Failures	F1	S: x E: x C: x	S: 2 E: 4 C: 0	S:3 E: 2 C: 0	S: 3 E: 2 C: 1	S: 2 E: 4 C: 0	S: 2 E: 2 C: 0	S: 3 E: 4 C: 0	S: 2 E: 2 C: 0	S: 3 E: 3 C: 1	S: 3 E: 3 C: 1	A
	F2	S: x E: x C: x	S: 2 E: 4 C: 0	S:3 E: 2 C: 0	S: 3 E: 2 C: 1	S: 1 E: 4 C: 0	S: 2 E: 2 C: 0	S: 3 E: 4 C: 0	S: 2 E: 2 C: 0	S: 3 E: 3 C: 1	S: 3 E: 3 C: 1	A

Scenarios – Comment of entries

Start with the description of what happens and then assign the parameters.

Please analyze in this way two other scenario/failure associations at your choice.

(S7) Driving in highway (DS3) at high speed (VS1) – **(F2)** The electro valve modifies or left set the shock absorber damping factor at c_l when it should be c_h

Effect	The driving experience of the vehicle worsens	
Statement S	Life-threating injuries (survival uncertain) or fatal injuries due to: • Rear/front collision with another passenger car with high speed	*S3*

[1] Driving at high speed in city roads is forbidden.

[2] Remember that the ASILs are assigned to the Safety Goals and not to failures. These ASILs are reported in the table just for the reader convenience.

	• Side impact with other surpassing vehicle or vehicle entering the highway from acceleration lane	
Statement E	High probability (>10% of average operating time)	*E4*
Statement C	Controllable in general	*C0*

(S9) Driving in highway (DS3) performing evasive maneuver (VS3) – **(F2)** The electro valve modifies or left set the shock absorber damping factor at c_l when it should be c_h

Effect	The driving experience of the vehicle worsens	
Statement S	Life-threating injuries (survival uncertain) or fatal injuries due to: • Rear/front collision with another passenger car with high speed • Side impact with other surpassing vehicle • Side impact with vehicle in the lane in which the driver is entering	*S3*
Statement E	Medium probability (1% to 10% of average operating time)	*E3*
Statement C	More than 99% of the average drivers or other participants are able to avoid harms	*C1*

Hazards

H1	The shock absorber damping factor at c_l when it should be c_h
H2	The shock absorber damping factor at c_h when it should be c_l

H1

This hazard potentially could cause the vehicle to have a worsen handling, causing the driver to lose control of the vehicle, leave the road and collide with other vehicles, pedestrians, or environmental parts.

Exceptions and Boundary Conditions to H1:

- The effects are perceived only at high speeds travelling on curves
- On rough roads where the effect of the SHC is more useful, the driver shall reduce its speed regardless the presence of this functionality

H2

The same as for H1

Safety goals

SG1	H1 -> Ensure a non vibrating and stable dumping factor
SG2	H2 -> Ensure a non vibrating and stable dumping factor

Results

Failure/malfunction	Safety goal	ASIL-level	Safe state	Fault tolerance time interval (FTTI)
F1	SG1	A	Dumping factor = c_h	50 ms [3]
F2	SG2	A	Dumping factor = c_h	50 ms [3]

Relevant failure modes for H1

MF1: Failure of the electrovalves during the modification of the dumping coefficient.
MF2: Failure of the evaluation and implementation of the target value of dumping coefficient.
MF3: Failure of the detection of the acceleration values of wheels.

Relevant failure modes for H2

The same as for H1

[3] Marcelo Menezes Morato, Olivier Sename, Luc Dugard. LPV -MPC Fault Tolerant Control of Automotive Suspension Dampers. LPVS 2018 - 2nd IFAC Workshop on Linear Parameter Varying Systems, Sep 2018, Florianopolis, Brazil. pp.31-36. ffhal-01658662v2f