Automobile Body Control Module

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Module: Hardware in loop

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  Full Details

1.Introduction:

In automotive electronics, body control module or 'body computer' is a generic term for an electronic control unit responsible for monitoring and controlling various electronic accessories in a vehicle's body.

Typically, in a car the BCM controls the power windows, Led rear light, HVAC, immobilizer system, central locking, etc. The BCM communicates with other on-board computers via the car's vehicle bus, and its main application is controlling load drivers – actuating relays that in turn perform actions in the vehicle such as locking the doors

This module can be considered to be the brain controlling different body parts (different ECUs) by sending and receiving signals through the nerves (vehicle BUS).

1.1 Objective:

To develop some automated model of BCM

Car selected: NEXA S-CROSS

Platform: MATLAB includes State flow and Simulink.

1.2 Architecture:

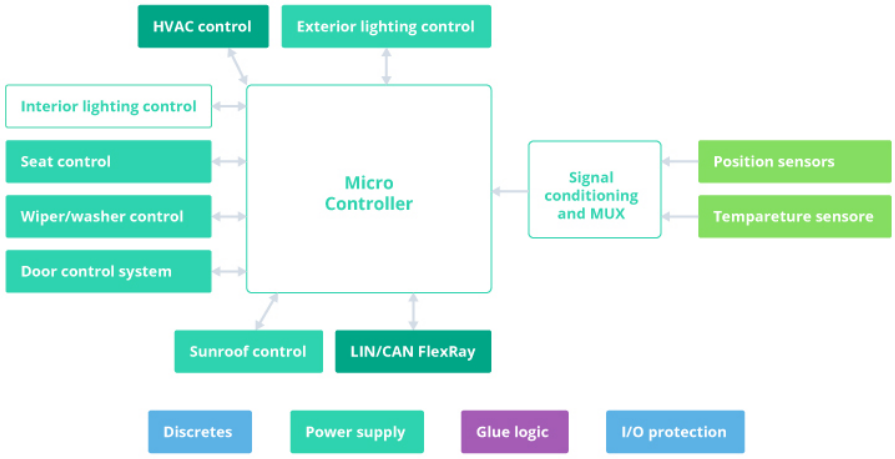


Figure 1: Architecture of BCM [source: www.intellias.com]

The microcontrollers and connectors integrated into a BCM constitute the central structural unit of the system responsible for the controlling part. Operating data is

transmitted to the control module through input devices. These may include sensors, vehicle performance indicators, and variable reactors.

1.3 Features:

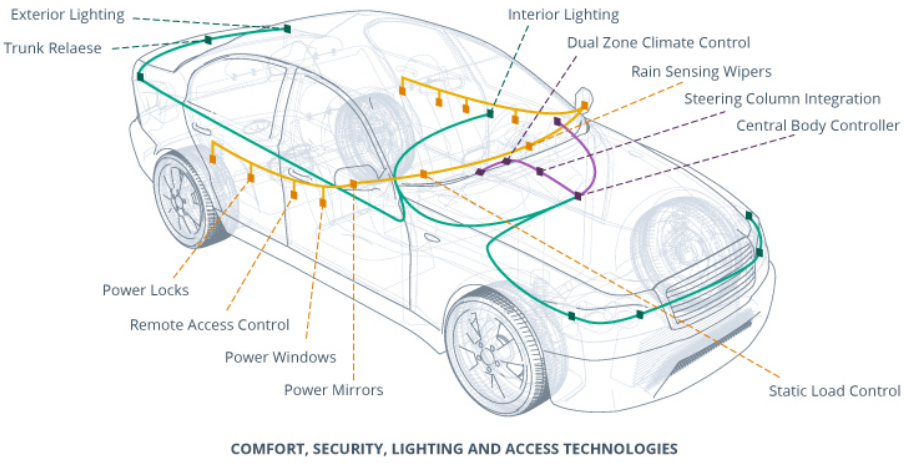


Figure 2: Functions of BCM [source: www.intellias.com]

Features are:

- Power Window Model
- Led Rear Light Model
- HVAC control Model

1.3.1 Power Window module:

Figure 3: Power window module [source: www.Powerwindow]

Smart windows or Power windows came on the scene in the 1940s when they were added as a luxury feature in the 1940 Packard 180 series. Although the name of the actual engineer who invented them is lost in the mists of time, we do know that Packard was the first company to use them in an automobile. The invention came about because of power-assist technology that was developed before World War II.

It was a hydro-electric system that was used to raise and lower vehicle tops. This was the inspiration for the first power window. These windows are automobile windows which can be raised and lowered by pressing a button or switch, as opposed to using a crank handle. Smart window lift controls enable easy and automatic control of window position for the drivers and passengers. The driver has additional control to all the windows with ease.

Objective:

To design and display Smart Window control working found in the **NEXA S-CROSS** series car using Matlab Simulink.

Architecture Philosophy:

1. The driver has controls over all the windows and can press push up window to open window, press pull down to close window and stop to pause the window at the position it is in.
2. The passenger seats can control the windows for their seat alone by pressing the buttons push up or pull down for opening or closing windows respectively.
3. When the passenger seats button is not pressed, the window stays at the position it was in after pressing any buttons.
4. If there is simultaneous press of say push up button both from driver and the passenger for the same window, then the driver is given control and passenger does not get control until drivers control is at stop.
5. Increasing value in display indicated window closing operation and decreasing value indicates window opening condition.

1.3.2 Led Rear Light module:

Figure 4: Led Rear Light module [source: LRLM]

Taillights are the red lights that activate when the front headlights are turned on. Because of this, they are typically inactive during the day. They shine less brightly than brake lights because they're only designed to be active in dim conditions, such as nighttime or heavy rain. These lights exist to indicate other drivers of your presence on the road when visibility is impaired.

Objective:

To design the logic, the model and functional logic for rear light assembly of an automobile.

Architecture Philosophy:

1. The rear taillights of both the sides, i.e., left and right, must glow once the lights are switched ON, and should also turn OFF when the lights are switched OFF.
2. If the driver presses the brake pedal, both the brake lights along with the center mounted stop light must glow instantly, to notify the drivers behind.
3. Once the driver switches the turn lever to the left side, the left indicator must turn ON to notify the drivers behind.
4. Once the driver switches the turn lever to the right side, the right indicator must turn ON to notify the drivers behind.

1.3.3 HVAC Control Module:

Figure 5: HVAC module [source: HVAC]

A heating, ventilation, and air conditioning (HVAC) system in a vehicle is used to control the internal temperature of the vehicle cabin. It includes three subsystems, namely, heating, cooling, and air conditioning, that work together to provide purified air to the vehicle cabin, ensuring thermal comfort for drivers and passengers.

It controls the air temperature, inspects the moisture content in the air, and eliminates excessive humidity from the circulating air.

Objective:

To design HVAC control working found in the **NEXA S-CROSS** series car using Matlab Simulink.

Architecture Philosophy:

1. Based on temperature in car HVAC comes into picture.
2. If the temperature is high then driver presses the AC button then AC will turn ON and we can regulate the speed of Blower.
3. If the temperature is low then driver presses the Heater button then Heater will turn ON

2. Requirements:

2.1 High Level and Low-Level Requirements:

2.1.1 High-Level Requirements:

HLR ID	Description	Status
HLR_01	LRLM shall have a key	Implemented
HLR_02	LRLM shall have a gear	Implemented
HLR_03	LRLM shall have a brake light and brake paddle	Implemented
HLR_04	LRLM shall have a hazard light and hazard switch	Implemented
HLR_05	LRLM shall have steering and left and right indicator lights	Implemented
HLR_06	LRLM shall have a parking light	Implemented
HLR_07	LRLM shall have a reversing light	Implemented
HLR_8	The driver shall have window controls for all windows.	Implemented
HLR_09	Passengers shall have control over their respective side window	Implemented
HLR_10	Driver shall be able to lock window control for the rest of the passengers	Implemented

HLR_11	HVAC shall have a KEY	Implemented
HLR_12	The value temperature of Car should be find based on Inputs	Implemented
HLR_13	HVAC shall have the status of Air conditioner based on value of Temperature	Implemented
HLR_14	HVAC shall have the status of Heater based on value of Temperature	Implemented
HLR_15	AC shall have the status of Blower based on value of Temperature	Implemented

2.1.2 Low-Level Requirements:

HLR ID	LLR ID	Description	Status
HLR_01	LLR_01	Key shall have two modes: On, Off	Implemented
HLR_02	LLR_02	Gear shall have four modes: Neutral, Drive, Park, Reverse	Implemented
HLR_03	LLR_03	Brake paddle shall have two modes: pressed, not pressed	Implemented
HLR_03	LLR_04	Brake light shall have two modes: On, off	Implemented
HLR_03	LLR_05	Brake light shall activate according to logic of brake paddle	Implemented
HLR_04	LLR_06	Hazard switch shall have two modes: pressed, not pressed	Implemented
HLR_04	LLR_07	Hazard light shall have two modes: On, off	Implemented
HLR_04	LLR_08	Hazard light shall activate according to logic of hazard switch	Implemented
HLR_05	LLR_09	Steering shall about to rotate in both directions: right and left	Implemented
HLR_05	LLR_10	Right indicator light shall have two modes: On, off	Implemented

HLR_05	LLR_11	Right indicator light shall activate according to logic of steering	Implemented
HLR_05	LLR_12	Left indicator light shall have two modes: On, off	Implemented
HLR_06	LLR_13	Left indicator light shall activate according to logic of steering	Implemented
HLR_06	LLR_14	LLR_11 Parking light shall have two modes: On, off	Implemented
HLR_07	LLR_15	Parking light shall activate according to logic of key, gear	Implemented
HLR_07	LLR_16	Reverse light shall have two modes: On, off	Implemented
HLR_07	LLR_17	Reverse light shall activate according to logic of key, gear	Implemented
HLR_02	LLR_19	Each window except for the driver seat window shall have two button controls: push up window and pull-down window.	Implemented
HLR_01	LLR_20	The driver window shall have four sets of control for the window and an additional lock button.	Implemented
HLR_03	LLR_21	The lock button on the driver window shall disable the window controls for the passengers	Implemented
HLR_03	LLR_22	If the lock button is in ON position, the driver shall only be able to control all windows	Implemented
HLR_03	LLR_23	If the lock button is in OFF position, passengers can control their side window	Implemented
HLR_01	LLR_24	If driver and passenger both try to control the window position at the same time, the driver control shall be given priority.	Implemented
HLR_01	LLR_25	The positions of the windows status shall be displayed in the scope	Implemented
HLR_11	LLR_26	Key shall have two modes: HVAC On, HVAC Off	Implemented
HLR_11	LLR_27	Based on the key status the HVAC system works	Implemented

HLR_12	LLR_28	Based on the value of the engine speed and engine torque the temperature value changes	Implemented
HLR_12	LLR_29	The value of temperature depends on the Humidity in Atmosphere	Implemented
HLR_13	LLR_30	Based on the value of temperature the status of Air conditioner operates (ON or OFF)	Implemented
HLR_14	LLR_31	Based on the value of temperature the status of Heater operates (ON or OFF)	Implemented
HLR_15	LLR_32	Based on the ON status of Air conditioner the Blower operates (ON or OFF)	Implemented

3.BCM Design:

3.1 V5 and V8 Model Integrated:

Integrated_Version_5 Model:

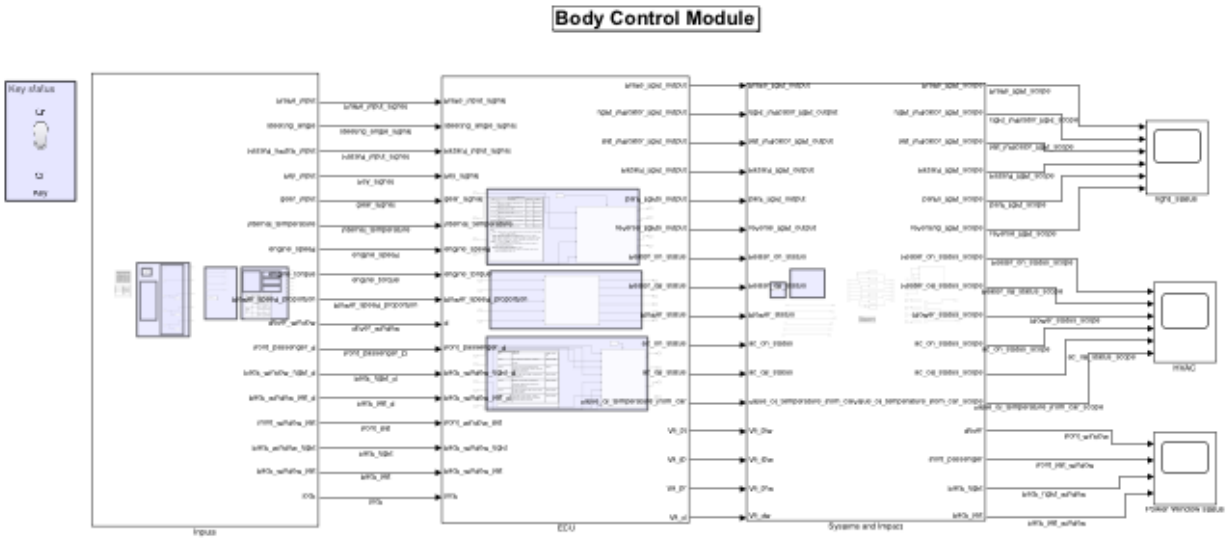


Figure 6: Integrated Version_5 Model

Integrated Version_8 Model:

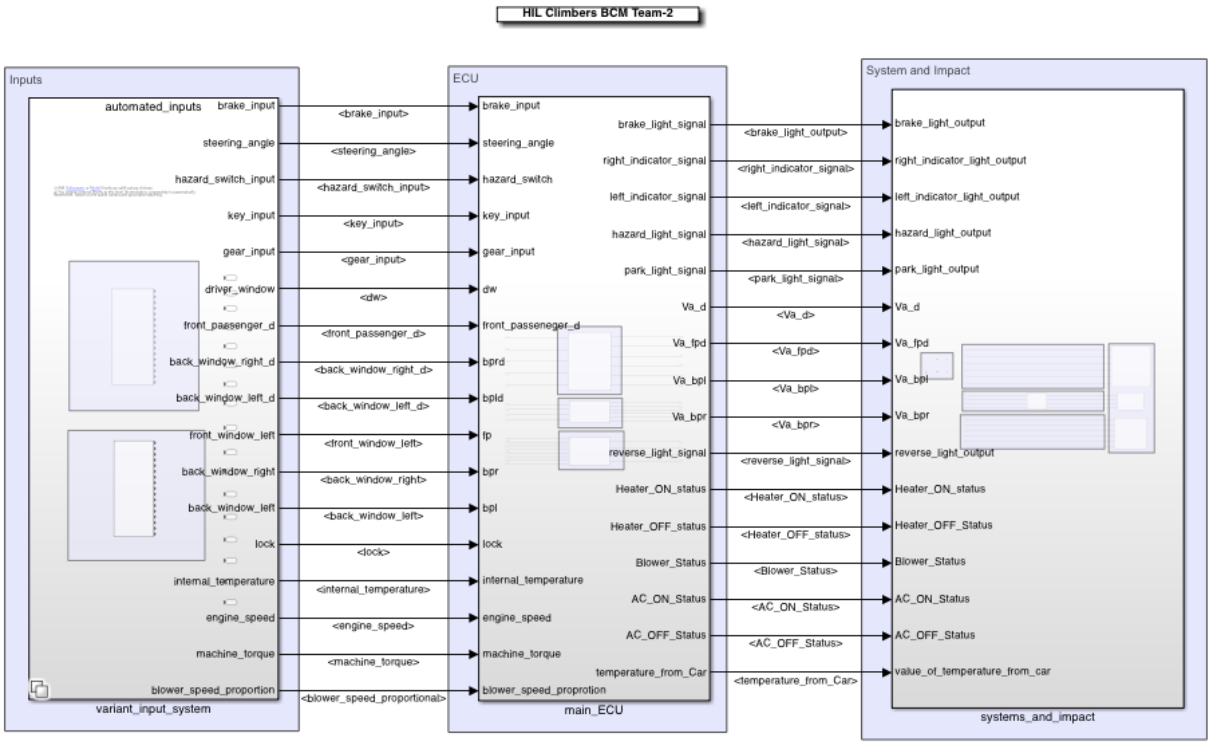


Figure 7: Integrated V8 model

Version_5 Model Input Blocks:

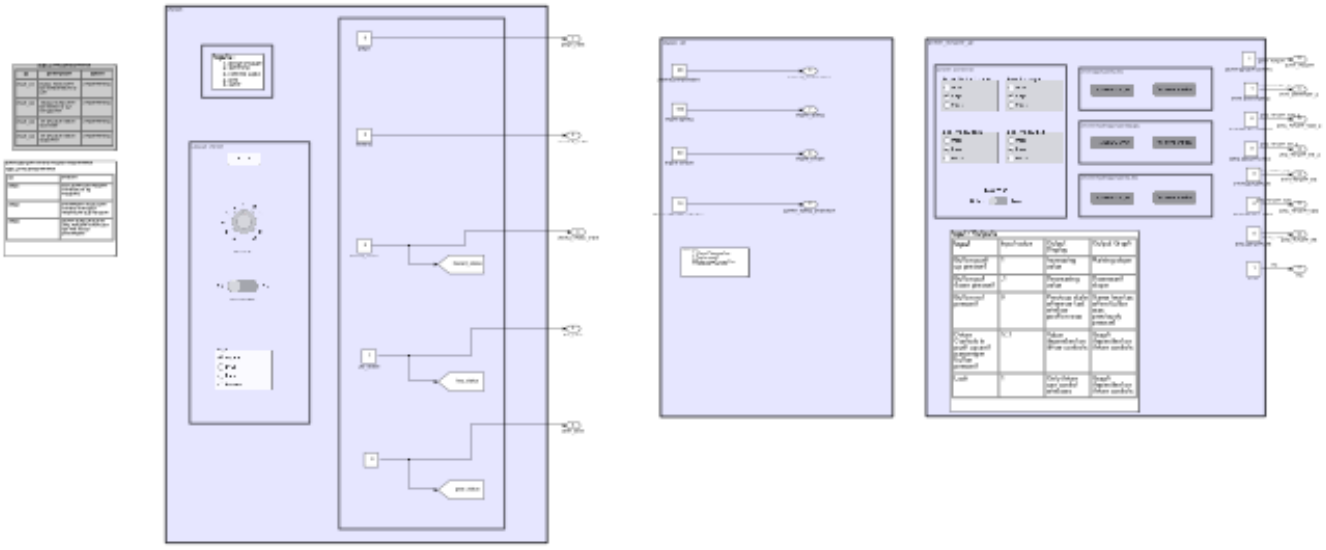


Figure 8: Version_5 Model Input Blocks

Version_8 Model Input Blocks:

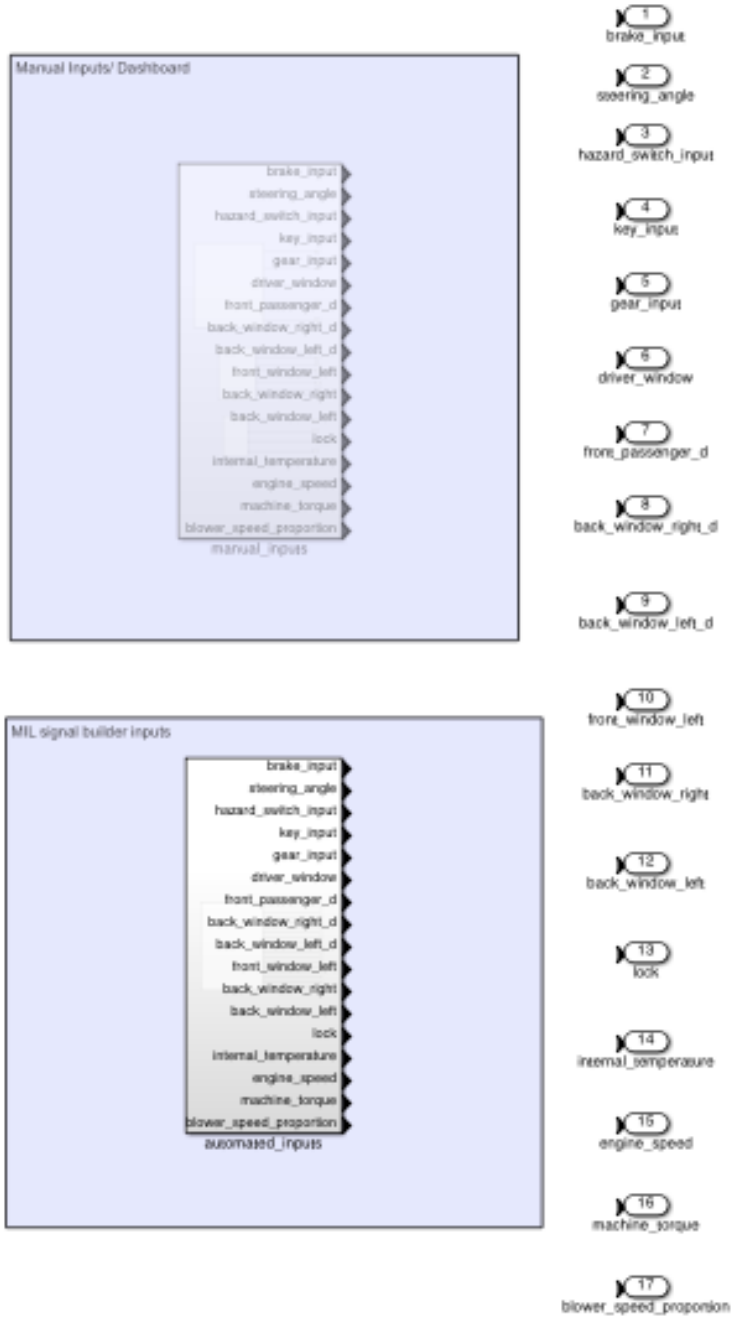


Figure 9: V8 Input Subsystem

Version_5 Model ECU Blocks:

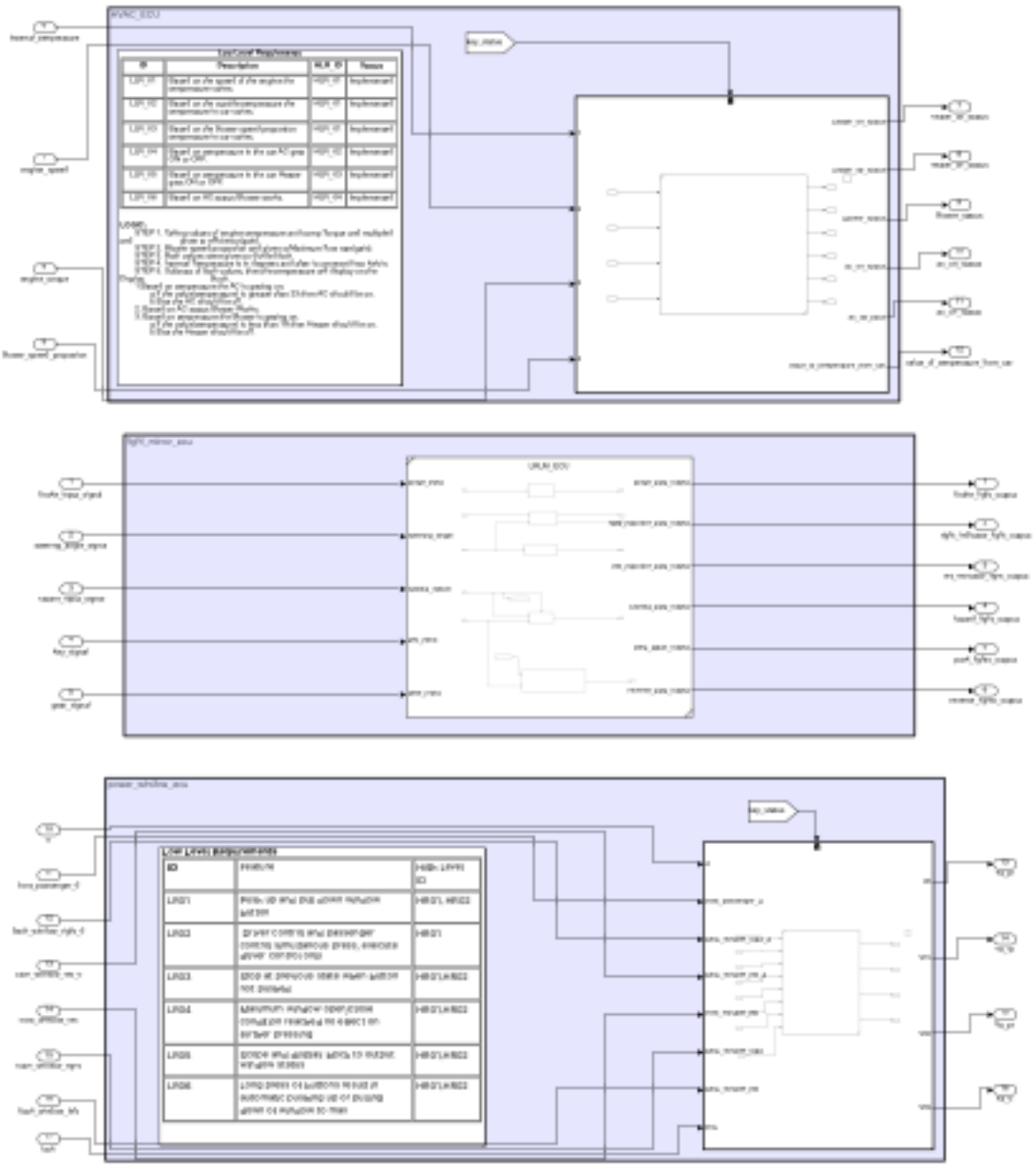


Figure 10: Version_5 Model ECU Blocks

Version_8 Model ECU Blocks:

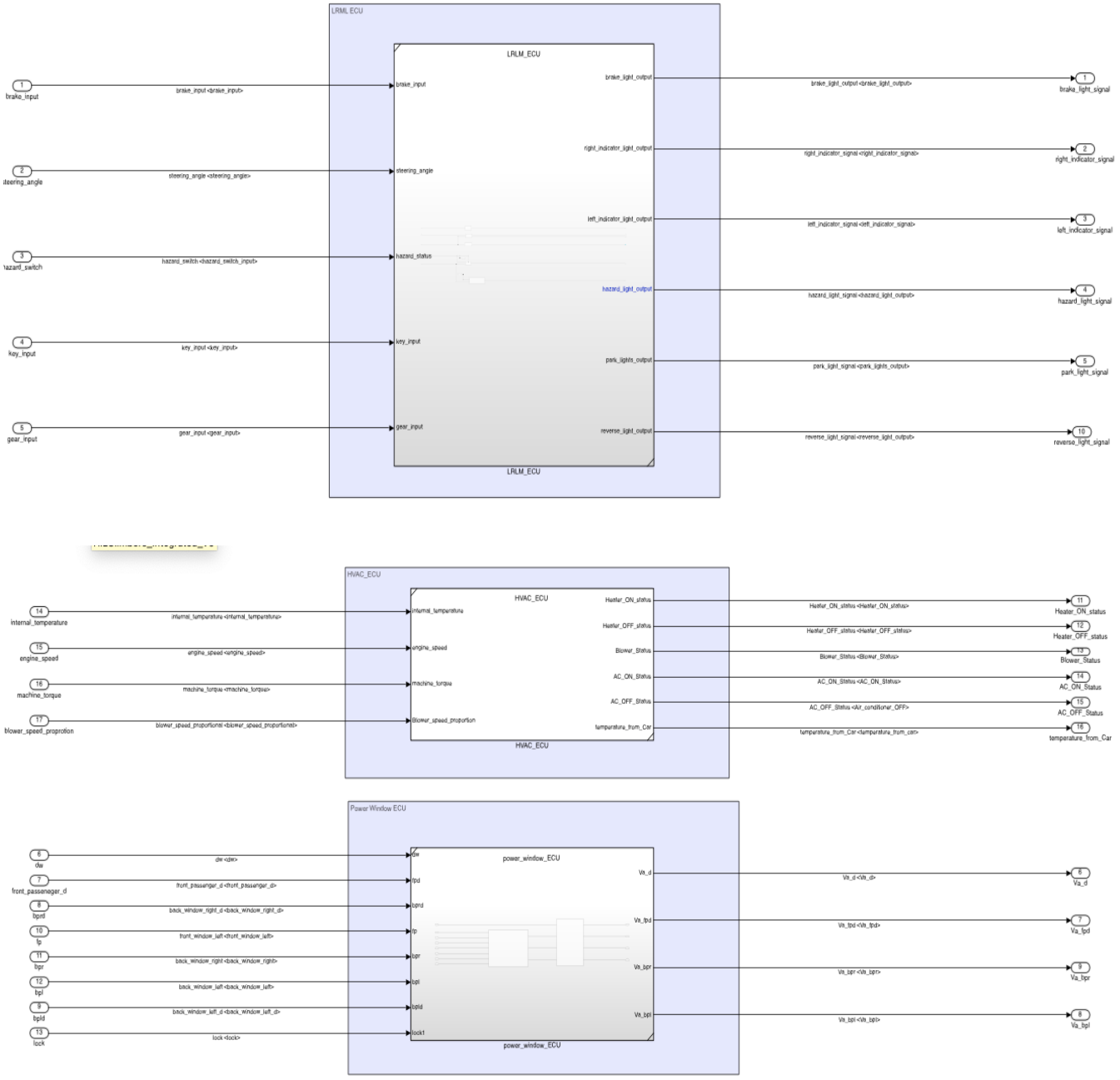


Figure 11: V8 ECU Subsystem

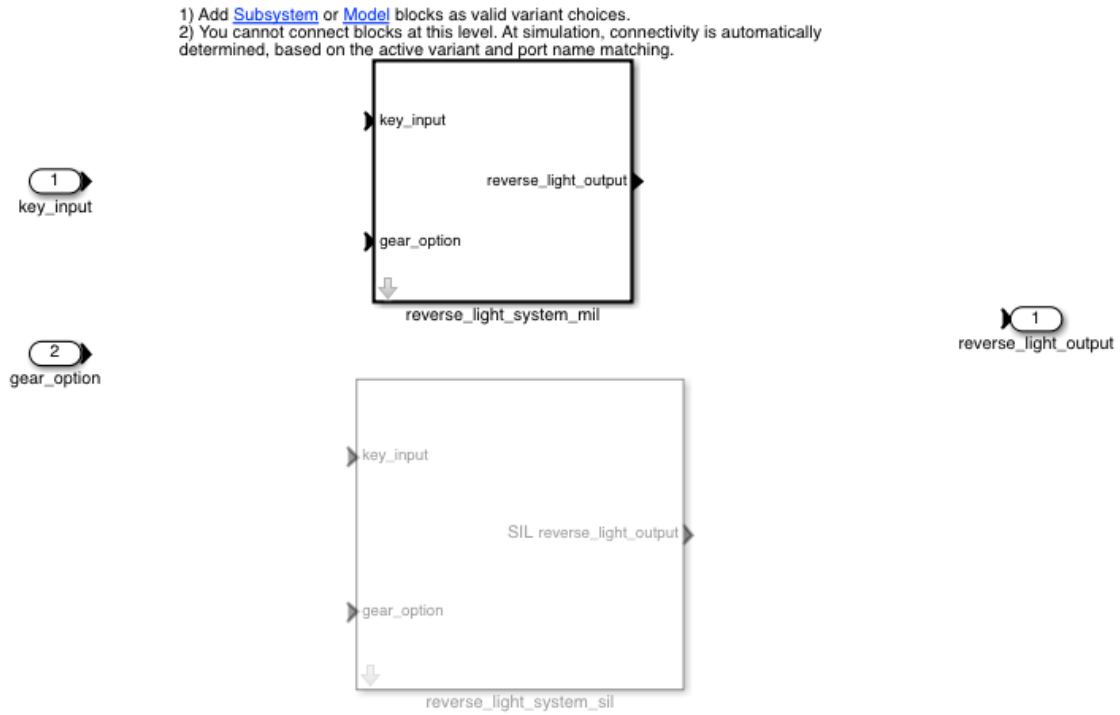


Figure 12: V8 Variant subsystem for SIL testing and manual testing

Version_5 Model Output Blocks:

Figure 13: Version_5 Model Output Blocks

Version_8 Model Output Blocks:

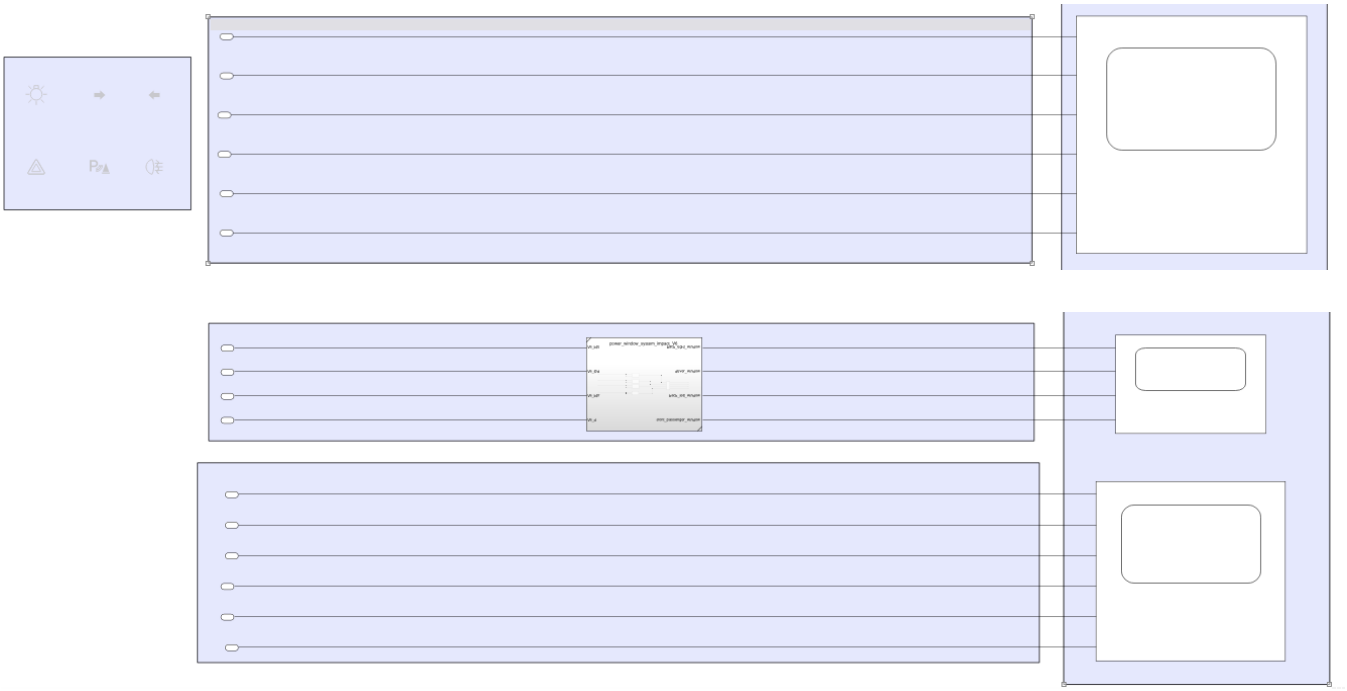


Figure 14: V8 System and Impact Subsystem

4. Compliance Check

4.1 Coverage Check

- V6 Coverage Report – 81%
- V8 Coverage Report – 95%

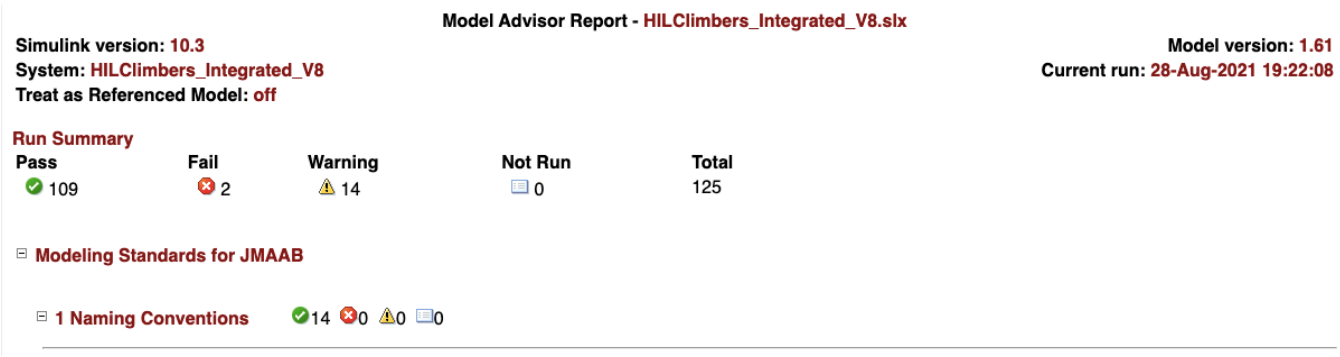
Summary

Model Hierarchy/Complexity

	Decision	Execution
1. HILClimbers_Integrated_V8	55 95%	100%
2. . . . main_ECU	36 93%	100%
3. . . . . HVAC_ECU	3 50%	100%
4. . . . . heater_status_system	1 50%	100%
5. . . . . LRLM_ECU	12 100%	100%
6. . . . . Variant Subsystem	3 100%	100%
7. . . . . reverse_light_system_mil	3 100%	100%
8. . . . . Compare To Constant	NA	100%
9. . . . . Compare To Constant1	NA	100%
10. . . . . brake_system	2 100%	100%
11. . . . . brake_light_output_decider	1 100%	100%

4.2 JMAAB and MAAB Check

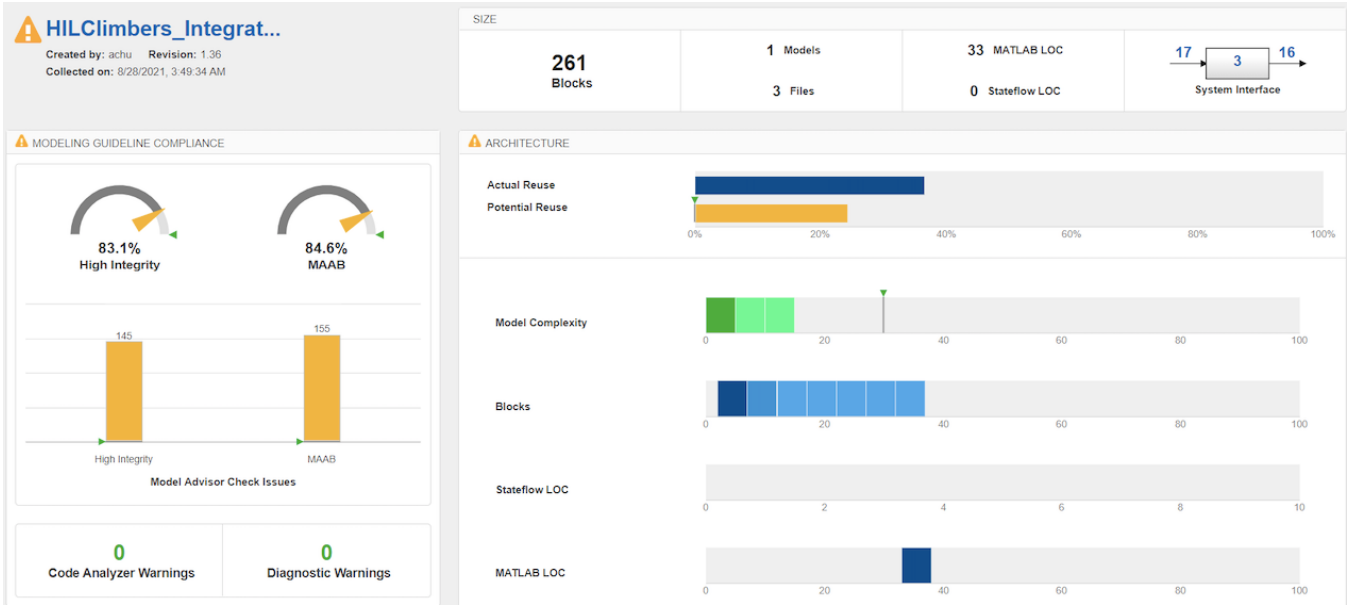
- V6 Model Advisor Report JMAAB warnings – 39
- V8 Model Advisor Report JMAAB warnings – 14



Warning	Fixed solution
Check character usage in block names	Remove spaces in block names
Check Implement logic signals as Boolean data (vs. double)	Add Boolean block, check signal flow data type and make changes
Check font formatting	All font size set to 10
Inport blocks are too far to the right and result in left-flowing signals.	Align input ports to extreme left uniformly
Check diagnostic settings for incorrect calculation results	modify the model configuration parameters to error from none and warning
Check for Simulink diagrams using nonstandard display attributes	Set the format options to the recommended value of on, off and none in information overlays
Check block colors	Set the block colors background to white
Check whether block names appear below blocks	All block names displayed at the bottom
Check the display attributes of block names	Names must be descriptive not default names
Identify blocks that use and fail to display nondefault values.	Changed the display of the nondefault value using the Block Annotation pane of the Block Properties dialog box.
Check definition of signal labels	Name the signals same as source block label

Check Signal name propagation for subsystems	Add the propagation signal name from properties/information overlays
Check block orientation	Remove reverse block orientation using Goto and From
Check for consistency in model element names	Signal name and port names were made same
Check position of signal labels	Signal names were set to center
Check signal line connections and intersections	Remove overlapping signals with Goto and From blocks
Check scope of From and Goto blocks	Goto and From blocks made only for local scope
Division by zero error	Set initial conditions for integrator block to 0.0001 and switch condition to eliminate 0 division
Check outports at the extreme right	Move all outports to extreme left

4.3 Metric Dashboard



4.4 Test Plan

4.5.1 High Level Test Plan

Test ID	Description	Expected Input	Expected Output	Actual Output	Status
H_01	Test the status of Brake Lights	Brake paddle	Indication of Brake lights		Passed
H_02	Test the status of right indicator light	Steering angle, Hazard switch	Indication of Right Indicator light		Passed
H_03	Test the status of left indicator light	Steering angle, Hazard Switch	Indication of Left Indicator light		Passed
H_04	Test the status of Hazard Lights	Hazard Switch	Indication of Hazard lights		Passed
H_05	Test the status of parking lights	Key, Gear	Indication of Parking Lights		Passed
H_06	Test the status of reversing lights	Key, Gear	Indication of Reversing Lights		Passed
H_07	Test the window open	Push up: 1	Decreasing slope indicating closing window in scope		Passed
H_08	Test the window close	Push down: -1	Increasing slope indicating opening window in scope		Passed
H_09	Test the window stop when button not pressed/ at stop	Stop: 0	Straight like/ no increasing/decreasing signal in scope		Passed
H_10	Test the status of key	Key signal activation	Indication of HVAC System Operation		Passed
H_11	Test the status of temperature in a car	Internal Temperature, Engine speed and torque	Value of temperature is shown in display		Passed
H_12	Test the status of HVAC system	Temperature	Indication of HVAC system ON		Passed

4.5.2 Low Level Test Plan

Test ID	Description	Mapping to HL Test Plan	Expected Input	Expected Output	Actual Output	Status
L_01	Brake paddle not pressed	H_01	Brake paddle	Brake lights are OFF		Passed
L_02	Brake paddle pressed	H_01	Brake paddle	Brake lights are ON		Passed
L_03	Steering angle is zero, hazard switch is OFF	H_02, H_03	Steering angle, Hazard Switch	Indicator lights are OFF		Passed
L_04	Steering angle is greater than zero, hazard switch is OFF	H_02	Steering angle, Hazard Switch	Right Indicator light is ON (blinks), Left Indicator light is OFF (blinks)		Passed
L_05	Steering angle is less than zero, hazard switch is OFF	H_03	Steering angle, Hazard Switch	Right Indicator light is OFF (blinks), Left Indicator light is ON (blinks)		Passed
L_06	Steering angle is zero, hazard switch is ON	H_02, H_03	Steering angle, Hazard Switch	Indicator lights are ON (blinks)		Passed
L_07	Steering angle is zero, hazard switch is ON	H_02	Steering angle, Hazard Switch	Indicator lights are ON (blinks)		Passed
L_08	Steering angle is zero, hazard switch is ON	H_02, H_03	Steering angle, Hazard Switch	Indicator lights are ON (blinks)		Passed
L_09	Hazard switch is OFF	H_04	Hazard Switch	Hazard lights are OFF		Passed
L_10	Hazard switch is ON	H_04	Hazard Switch	Hazard lights are ON		Passed

L_11	Key not inserted; gear mode is either drive/neutral	H_05	Key, Gear	Parking lights are OFF	Passed
L_12	Key not inserted; gear mode is park	H_05	Key, Gear	Parking lights are OFF	Passed
L_13	Key inserted; gear mode is either drive/neutral	H_05	Key, Gear	Parking lights are OFF	Passed
L_14	Key inserted; gear mode is park	H_05	Key, Gear	Parking lights are ON	Passed
L_15	Key not inserted; gear mode is either drive/neutral	H_06	Key, Gear	Reverse lights are OFF	Passed
L_16	Key not inserted; gear mode is reverse	H_06	Key, Gear	Reverse lights are OFF	Passed
L_17	Key inserted; gear mode is either drive/neutral	H_06	Key, Gear	Reverse lights are OFF	Passed
L_18	Key inserted; gear mode is reverse	H_06	Key, Gear	Reverse lights are ON	Passed
L_19	Driver window control open: opening window	H_07	Driver window	Driver window decreasing slope in scope	Passed
L_20	Driver window control close, lock OFF: closing window	H_08	Driver window	Driver window increasing slope in scope	Passed
L_21	Driver window control stop, lock OFF: stop at same position	H_09	Driver window, lock OFF	Driver window straight signal indicating no change in position	Passed

L_22	Passenger window control open, lock OFF: opening window	H_07	Passenger window, lock OFF	Passenger window decreasing slope in scope	Passed
L_23	Passenger window control close, lock OFF: closing window	H_08	Passenger window, lock OFF	Passenger window increasing slope in scope	Passed
L_24	Passenger window control stop, lock OFF: stop at same position	H_09	Passenger window, lock OFF	Passenger window straight signal indicating no change in position	Passed
L_25	Passenger window control open, driver control stops, lock ON: opening window	H_7	Passenger window, lock ON	Passenger window straight signal indicating no change in position	Passed
L_26	Passenger window control close, driver control stops, lock ON: closing window	H_08	Passenger window, lock ON	Passenger window straight signal indicating no change in position	Passed
L_27	Passenger window control stop, driver control stops, lock ON: stop at same position	H_09	Passenger window, lock ON	Passenger window straight signal indicating no change in position	Passed

L_28	Passenger window control open, driver control for same window close: closing passenger corresponding window	H_08	Passenger window, driver window control	Passenger window decreasing slope in scope	Passed
L_29	Passenger window control close, driver control for same window open: opening passenger corresponding window	H_07	Passenger window, driver window control	Passenger window increasing slope in scope	Passed
L_30	Driver window/Passenger maximum signal level: window fully closed	H_08	Driver window/Passenger window	No further increase in scope after reaching 10 in y axis	Passed
L_31	Driver window/Passenger minimum signal level: window fully open	H_07	Driver window/Passenger window	No further decrease in scope after reaching 0 in y axis	Passed
L_32	Key not inserted		Key signal	The whole HVAC system should not work	Passed
L_33	Key inserted		Key signal	The whole HVAC system should work	Passed
L_34	Status of temperature in car		Key, Internal Temperature, Engine speed and torque	Based on the input values the temperature obtains	Passed
L_35	Air Conditioner ON status		Temperature value	If the temperature greater than 25 then AC is ON	Passed

L_36	Air Conditioner OFF status		Temperature value	If the temperature less than 25 then AC is OFF	Passed
L_37	Blower Status		Air conditioner status	If AC is ON then Blower status also ON	Passed
L_39	Heater On Status		Temperature value	If the temperature less than 18 then Heater is ON	Passed
L_40	Heater OFF Status		Temperature value	If the temperature greater than 18 then Heater is OFF	Passed

5. Summary of different versions

Version	Features
V5	• additional features from existing V4 versions • three subsystems for inputs, ECU and system and impact • individual subsystems made to reference subsystems
V6	• MIL testing with signal builders • variant subsystem for manual and automated testing for input subsystems • Enable subsystems for dependent features • ran MAAB and JMAAB checks, model coverage and metric dashboard and tried to improve
V7	• C code generated for LRLM ECU subsystem

	• S function block generated for subsystem reverse_light_system • enabled variant subsystem to choose between manual testing and automated testing • Set up projects from git repo • Added startup file to add paths and set variant subsystems choice • Reduce warnings • Improve code coverage
V8	• Eliminate warnings further • Final alignments and model arrangement