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Validation of automotive centrals using hardware in the loop -BCM and Lights

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Abstract

The race for electrification and the need for innovation to attract customers has driven the automotive industry to do something different in vehicles, emerging emission control challenges and efficient technological availability are the pillars of innovation. With the need to upgrade industrial manufacturing systems, directly impacting vehicle production, established the search for new prototyping methodologies and use of virtual tools for testing, validation of components and vehicle systems are developed. The demand for electronic components controls units (ECU) is growing, due to the availability of intelligence and security in today's vehicles, directly impacting their development and the performance and functionality tests. To meet this new reality, in addition to the automotive test prototypes used during development, the automotive industry has been using different virtual environments to produce, verify, and validate its vehicles. Therefore, this paper applied integration and validation using the HIL test platform, focusing on the ECU Body Control Unit (BCM), analyzing its functionalities and possible failures of the internal and external light loads. After, a brief commentary will be made exposing other test medium platforms given as the Plywood Buck (PWB), checking the reliability, flexibility, installation time, and costs of the three test platforms Software in the loop (SIL), Model in the loop (MIL) , Hardware in the loop (HIL), in order to verify their advantages, challenges, and problems in the use and information to optimize the use of each platform and test medium.

Keywords: Automotive; Validation; xIL; Optimization

1. Introduction

Globalization has increased the speed of information sharing between other global regions and localities, causing society to face a technological evolution that grows at an exponential rate. In this context, a revolution has occurred in the digital age in various consumer sectors such as services, commerce, and industry. As a result, technological advances have provided more product options and possibilities. With the advancement come new physical and virtual characteristics requiring regulations and standards to ensure performance and safety to the customer. The automotive industry is a business model that applies these features following government regulations, safety needs, comfort, and performance requirements. safety to the customer. The automotive industry is a business model that applies these features following government regulations, safety needs, comfort, and performance requirements.

The increased implementation of automated functions linked to software has awakened in the automotive industry the need for investment and support in the development of simulation-based virtual environments. Currently SIL development strategies is directly related to the design of the basic model used in the in some cases, it was used in hardware in the loop (HIL) testing, platforms, where MathWorks modeling tools are used, everything is designed in MatLab/Simulink in various stages of development from the implementation of libraries for integration in box simulating power plants, sensors, and actuators in [1]. It is possible to verify in figure [2] the growth of the use of HIL simulators in the industry in recent years, this increase is a result of research and investment in new means of automatic

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testing, not only aiming the availability time of the system or component, but also raising the quality of the product for the customer and allowing more security and efficiency for the validator, to perform tests that in some cases require extreme use of the component or vehicle.

In this scenario, different types of platforms and test media using HIL have been adopted for different purposes, such as:

Test, validate and evaluate only one behavior of the Electronic Control Unit, BCM using one component HIL.

- Test, validate and evaluate a vehicle system including the simulated powertrain subsystem, Lights, Control Units that the vehicle contains and various electrical components using a Component HIL.
- Evaluate and analyze drivability in the software and implementation versions of the BCM using a load box integrated component HIL.

Often, as the use of the HIL system increases, the validation team will request improvements and upgrades, increasing the cost, complexity, and effort required to have an application available.

in this context, knowing the customer demand, when and how to use the different types of xIL systems, helps to optimize the time and effort of the manufacturing process, and consequently the cost, as well as raising quality and performance, making it efficient and competitive.

To answer these questions, the initial step is to create a test case, targeting the xIL platform that best applies the test, planning involves cost x time. Once this is done, several aspects must be taken into consideration, such as:

- The time required to develop and set up the test environment.
- The flexibility and availability in the execution of the procedures.
- Complexity and mastery in the execution of the procedures.
- Time of commissioning and execution of procedures.
- Cost of physical and virtual environment.
- The representativeness of the environment for the desired tests and procedures.

Thus, this paper analyzes the BCM control unit, and the internal and external light loads of the vehicle using the HIL platform to validate and verify system functions to optimize its use during the development process and integration with other control units. In addition, the loadbox is presented as the structure to connect to the simulator to perform the tests of the light loads available in the car, as it represents an environment whose characteristics are closer to the final product.

The structure of the paper is organized as follows:

- "Theoretical frameworks" presents the xIL platforms, the environments analyzed in this paper (xIL Simulation Platforms, National and International xIL testing Scenario) as well as the representativeness estimation methodology.
- "Applications & Tools" presents the available test system tools being hardware and software, when and how to use the different types of environments analyzed in this paper; (Platform Model, Platform Software, Virtual application, and Software).
- "Model Based design" (MDB Function Modeling Case, Hardware Integration of the Model).
- "Case Study" Hardware and software configuration used in testing and an analysis of a practical case stud, benefits of using HIL Component for BCM ECU validation.
- "Validation & Verification" Case PWB x HIL
- "Conclusion" presents the final considerations of the work.

2. Theoriocal frameworks

Before delving into the aspects that optimize the way of validating and verifying automotive centrals, it is necessary to better understand some concepts about xIL platforms and their differences, such as

- xIL Simulation Platforms.
- The National and International xIL Testing Scenario (National Scenario using HIL simulation, International Scenario using HIL Simulations)

2.1. Simulation Platforms

The HIL, platform is one of the examples of a testbed described in this paper, being a means of testing used in the development process of electronic systems to validate real or simulated components and enable permutations between them. The simulation involves the operation of electronic and mechanical systems, particularly ECUs in a closed loop circuit controlling physical components and subjected to real-time testing to analyze operation and in certain cases inserted faults to test possible occurrences.

Among validation and verification tools the HIL platform allows reusable and scalable testing of real and simulated ECU control in a test environment closer to the real thing. This provides testing with autonomy and availability in the lab, shortens validation times, and increases the range of test scenarios [3]. Additionally, HIL allows testing critical and complex cases compared to other systems, avoiding safety issues, due to no human dependence present to perform, that the device under-test or the closed-loop environment, as well as in open-loop test setups, e.g., repeat data testing [2]. The complexity and increasing changes in architectures and topologies development reflects the evolution of embedded systems and influence in communication protocols between CAN networks, it is important to highlight the electrification and dependence on security systems compatible with current technology, systems that demand present in simulators.

The simulator has the flexibility to update modules for different applications, making it possible to meet most of the tests required in the development. Its operation depends on physical installation and software integration, application model, in this article we chose to demonstrate the tool developed by the German company dSPACE.[4] The hardware developed by this company contains several modules and configuration units, being divided into power supply system, processing and logic module, input and output and signal modulation boards, fault insertion and network communication boards.

Its configuration is related to the project application, where all hardware is customized with the vehicle information, containing all analog and digital signals required for integration of sensors and actuators, the power supply boards with the necessary voltage levels to feed different ECUS and components. The development of the HIL is linked to the development of the model used in the system, it contains signal information and the test logics, everything is modeled in Matlab/Simulink and parameterized with the defined hardware. The software used is developed by the company dSPACE to do integration and load the necessary information to start the tests.

2.2. National and International xIL Testing Scenario

Real-time simulation platforms are being increasingly used to accelerate product development in the industrial area, for applications in several engineering areas, such as energy process control, power electronics, automation, and micro-grids. Among the available technologies, the HIL systems allow a plant developed with characteristics close to the real model to be emulated in a simulator in real time [5]. This enables the implementation of tests to perform validation of plants integrating control systems to sensors and actuators, with this it is possible to obtain satisfactory results. In addition, the platform is configurable for the emulation of different types of systems, offering flexibility and adaptation for study and research in different areas, reducing costs and project time.

Among the large national technology industries in the Brazilian market, EMBRAER is a successful reference in the use of validation and verification tools with HIL, being responsible for citations and business models among companies and universities, collaborating with the knowhow of the application of complex systems with high reliability and justifying the investment in automated simulators [6]. Emphasizes the importance of usability of simulators to perform tests on complex systems, stating the gain that the simulator delivers in simulating subsystems that cannot be included in the tests physically, allowing it to be possible to test every embedded control device thoroughly before putting the system in a real environment. Thus, the reliability of the system can be guaranteed while considering the necessary requirements and at the same time reducing testing costs and the time to market.

The design of products on a global scale is complex and requires versatile tools to maintain quality and performance, through simulation tools, it is possible to have quality and cost benefit talking, due to the possibility of performing virtual tests [5]. The simulated system has programmable in-frame drives and ports. (FPGA) and digital signal processor (DSP). A HIL model can bypass serious damage by reducing debugging costs, and ultimately reducing overall effort during testing.

In the international scenario the historical view of the use of xIL simulators is drawn due to the challenges encountered by engineering teams, i.e., within the automotive sector, power electronic systems, and different areas of expertise have contributed to this evolution [7]. Several vendors such as National Instruments, dSPACE, Typhoon HIL are simulator manufacturers, soon software developers such as MATLAB Simulink Real-Time toolboxes and Speed goat hardware systems, offer powerful tools for efficient and successful investigations in different industrial areas [4]. Therefore, the international scenario started the practice of HIL simulation long time ago and has the premise of investment in research and development in partnership with education to prepare students for professional engagements in industry.

Through different challenges encountered by engineering, that is, within the automotive industry, therefore, the international scenario has started the practice of HIL simulation long ago compared nationally and has the premise of investment in research and development in partnership with education to prepare students with professional commitments in the industry [8]. The automotive industry currently invests heavily in electric mobility and has as its main demand and search for improvements and renewal of systems, where power electronics is the main component, from the topology of vehicle architecture and connection to communication, battery and of course powertrain [9]. Through sophisticated power electronics, central control units work with sensors and actuators to operate the vehicle. In [4], dSPACE one of the giant international simulator providers offers safe testing through the hardware systems, robust and modular, where its tools impact the history of power plant simulation figure 2 to validate ECUs with software (SIL) in HIL environments requires adaptations and changes from virtual to real environment.

The ECU software is critical for HIL and SIL solutions, impacting both virtual and physical environments. The platform software can then be approved without any ECU hardware due to the ability to emulate the signals. The requested object model is the software running on a virtual platform using vendor-specific tools and sharing by GitHub.

The work proposal used by them is to use the simulator to validate telemetry and remote-control systems. A modular architecture is being implemented, composed of control centers and simulation of sensors, actuators, and web servers for remote control. Positive point is the possibility of changing and removing modules that simulate sensors and actuators creating a controlled testing environment, like the testing methodology for validation of the ECU BCM [8].

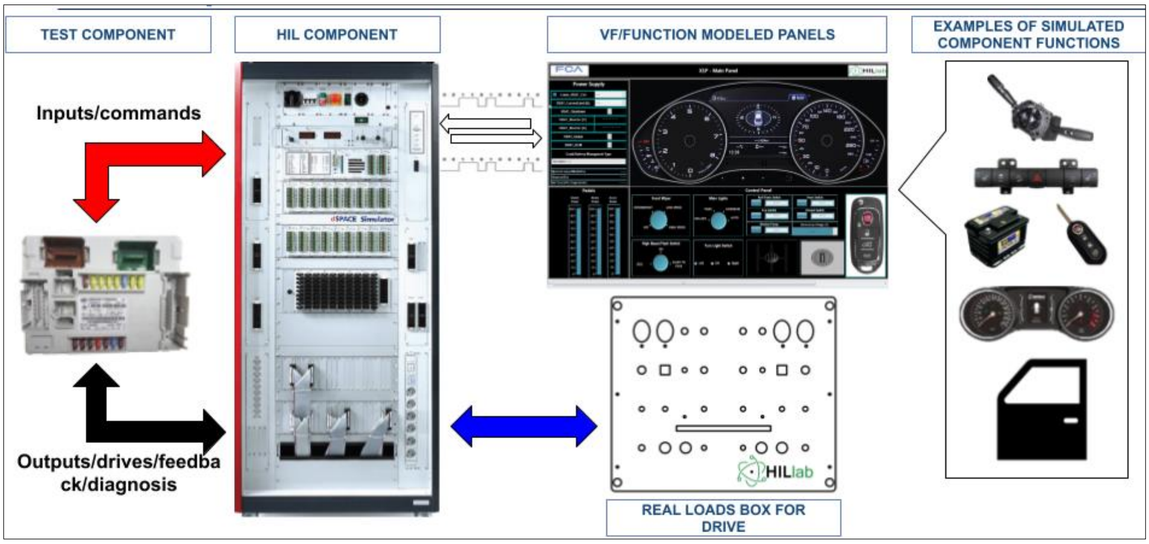

Figure 1 Hardware in the Loop Test Platform

3. xIL Applications & TOOLS

3.1. Platform Model

The xIL platforms can be physical or virtual depending on the application and design phase, this will define which platform to use, systems like (MIL)Modeling in the loop, (SIL) Software in the loop, (PIL) Processor in the loop are virtual systems and that some cases have the switching function in two modes, real or simulated, so Hardware (HIL) in the loop, (VHIL) Vehicle in the loop platform are physical structures that depend on the physical hardware and have the real vehicle components, electronic circuits, sensors and actuators. But this could be divided more didactically into options such as MIL,

SIL and HIL, for example. in figure 2, you can make a simple comparison between these three options.

It is very important to consider the application to define which platform model to use, enabling the reuse of simulators and providing for reduced development and labor costs. Initially in the described process it is possible to see the modeling in the loop (MIL) platform, then, it is possible to compile and test the model within the Simulink tool, its development and testing is independent of software state or physical component. MIL is self-sufficient and independent, but it demands high processing and specific knowledge for its development, since it is not only the libraries of the central units that are being applied in this platform, but all the signals that compose the vehicle [3]. MIL performs tests in the early stages of the project, is a powerful tool for reuse, and can be applied among other projects until the development phase of the SIL.

The SIL has the versatility to test in a virtual environment using vendor software, compatible with Matlab / Simulink, there is the VEOS virtual testing platform is widely used in the automotive industry and the trend is to increase over the years, following the image is HIL, you can see the dependence on the physical structure, but it is noted the reuse of models between platforms, facilitates integration between development teams, increases reliability in its use and motivates its use by the validation and verification team in the testing stage [5] and validation and verification at the testing stage. In summary, xIL platforms can be considered real and/or virtual test media for performing Verification and Validation(V&V) of electronic and mechanical systems, composed of central electronic units, protection and power systems, sensors and actuators, and associated software. When dependent on the physical structure, these devices include drive and power control for the communication system and AC power supply [10]. The composite devices are real and of high significance to represent those present in the vehicle, have power systems and controllers to improve concealability and increase the ability to transfer information between CAN/LIN or CAN FD networks, depending on the application.

A system that needs no hardware present and has all system variables modeled in Matlab/Simulink where they are present from the engine control system, the drives, gears, differential to the vehicle starting system can be considered a MIL model, as well as, for example, a battery charge and discharge energy control system designed entirely in matlab. When integrating a test medium, for example a physical battery bank, this system changes from SIL to HIL. In the case of switching from virtual to Real, a test application is compatible with xIL systems. An xIL platform can be represented with shared sub-systems. However, each has its own particularity, and both run remotely and have no local infrastructure links. Systematic utility SIL and MIL platforms cover a larger area compared to the HIL platform due to facility dependency [5].

3.2. Platform Software

The simulator developer xIL a dSPACE provides the software for configuration and operation of the simulators. The two software's used in this proposal are Configuration Desk and Control Desk, responsible for integrating the model developed in Matlab/Simulink and other data entry tools, for example Excel. Configuration Desk is an intuitive graphical configuration and implementation tool, ideal for handling applications from small Rapid Control Prototyping (RCP) developments to large HIL tests based on real-time dSPACE hardware such as SCALEXIO or PHS, including the implementation of behavior models and I/O function code [4].

The configuration desk provides a clearly structured overview of external devices, for example the BCM used in this project, configured hardware with all signals and functions.

Among the functionalities present in the software is the possibility to configure applications in real time graphically, allowing the automation of tests. The management of the inclusion and modification of signals between the external devices given example in the previous chapter in the configuration of the physical structure by the hardware team, with the model interface developed by the modeling team.

The Control Desk tool, responsible for controlling the simulator where it integrates all the information of signals and parameters of the Configuration Desk, enabling the validation team to perform their work where tests and analysis of the project are performed. The Control Desk software is currently at Version 7.0, the dSPACE visualization and experiment software.

Control Desk supports Wireshark plug-ins for decoding in bus navigator ethernet monitoring. In addition, signals from UDP Ethernet PDUs can now be easily instrumented and measured on layouts using the Ethernet Bus Monitoring Device and supports two new FPGA boards for SCALEXIO [4].

Figure 2 Software Control Desk [4]

The software responsible for instrumentation and development of modular experiments applied to ECU, the main function of this software is to bring the simulator operator closer to the hardware, enabling total control of the simulator from the beginning of commissioning where power and function tests are performed, until the execution of test loop where the validation team performs its tests.

The application involves the option of data acquisition performing measurement, calibration and diagnosis of the ECU, access to the CAN network, important functionality of the Control Desk and the application of the SIL platform in the virtual validation with VEOS [14].

3.3. Virtual application

First, before presenting the solution with Model-based design (MDB), it is interesting to review V&V solutions without the need for physical hardware, which are consolidated and spread across all systems.

The virtual platform simulation provides a test view that is independent of the hardware and physical structure available, since it is virtualized and requires less dependence on physical components. In the case of a connection between the user and the system, the use of configuration desk and control desk software brings user autonomy and ease of execution. All this and the fact that there are signals generated of system identity, functions, and operating states to make the system operational [14]. Successively, VEOS systems became the basis in the development of the design for other simulation platforms in the presence of neutral conductors and transformers for the same previous reason. In summary, HIL, and Vehicle in the loop (VHIL), the more complete the virtual development, the easier it is to integrate with the other platforms and the development time is spent on other applications. The more complete a VEOS system is, the more secure the testing is and its reuse on other platforms saves time.

The test solution when compared to other economically more viable today is SIL due to its flexibility of application and independence of robust hardware physical structure, in addition to the remote use anywhere to perform the testing activities. The development of VEOS platforms is intended to create an alternative path for electronic control unit validation, avoiding delays due to component supplier shortages, and performing initial testing to predict future design flaws. In general, VEOS systems are composed of a model-based design of each ECU, sensors, and actuators of the vehicle, dimensioned in a way that the model is closer to the real thing because of a teamwork between software, modeling and supplier teams. Figure 5 brings an example that illustrates the allocation of virtual plants seen by the system.

4. Model based design case

System modeling is fundamental to the development of the MIL, SIL - HIL system and depends on inputs generated by the project team. It is composed of libraries and functions of each central electronic unit, sensors and actuators are represented virtually with their characteristics and power, control, and communication signals in CAN network. In [12] it is proposed the application of vehicular propulsion models, controlled with xIL simulators in [5] this same technique is used to control vehicular interior systems with the example of the application of this work that aims to demonstrate the tests in the central BCM.

The modeling technology consists of the synthesis of the virtual components of the vehicle itself, the voltage signals of the components in relation to the battery is configured, inserting, the communication block referring to the communication protocol and the path of sending and receiving messages between the central units, the vehicle dynamic block is responsible for the implementation of the software and calibration of the ECU´s simulating its functionality and operating states, any update and implementation is performed in this block. For this, GitHub is the standardization tool between the teams, whose every change is documented in the repository platform and the model is accessed by multiple platforms.

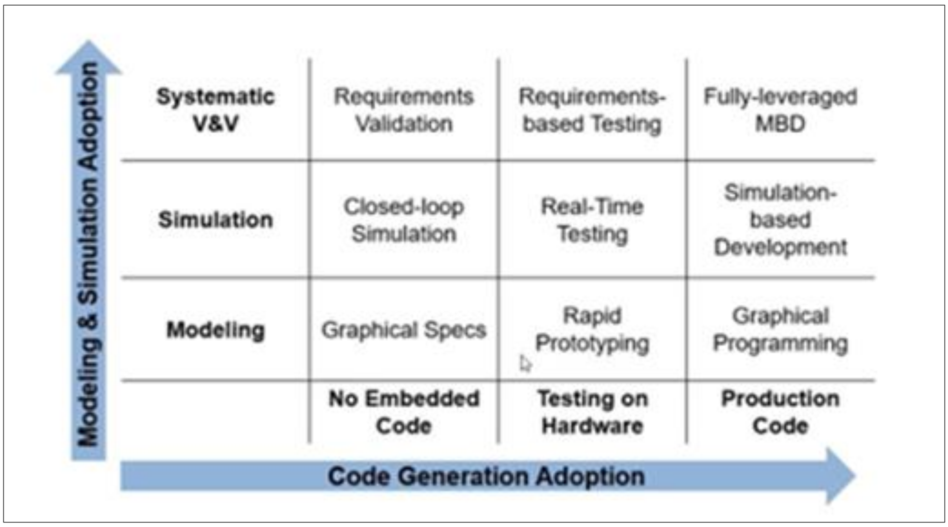

Figure 3 MDB Development Process [15]

The possibility of inserting a new component in the model and making these changes is due to the standardization of control blocks and the compatibility between tools. It is important to point out that the use of this tool has a lot of versatility and can, therefore, facilitate the execution of simple, or in some cases complex, updates. These updates depend on the needs of the validation team due to the emergence of some problem by design errors or even in the case that the component is completely new and updates are necessary for its better functioning [10]. In the case of a new project an impact study is performed, and all necessary documentation to perform the work is reviewed.

This methodology can provide a multitude of applications and, as mentioned, the model can be applied on different xIL platforms. In the present study, the benefit found was the improvement of HIL testing using a modular LoadBox structure through simulation management in the model integration. It is interesting to determine a strategy to dynamically define the reference values of all ECU circuits, based on the document available for development and connection with the teams present in the project.

It is possible to analyze in figure 8 the development cycle of the MDB, its versatility due to its modular characteristics and of course, the integration with multi-access systems facilitates its implementation in real time. The model is developed in Matlab/Simulink software where the integration with the DSPACE tools responsible for developing the simulators is done.

Problem: Simple control (On/Off) of the activation of an external light for 30s. Objective of the model: To test/validate the control system.

Features: Enclosed box:

Actuators: Touch buttons on the internal faces of the vehicle.

- Sensors: Touch sensor inside the case.
- Control: External control unit.

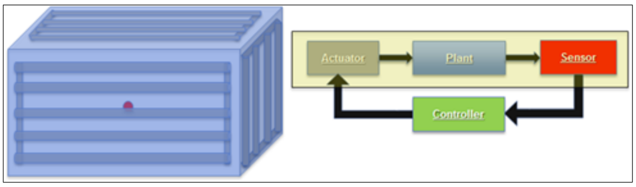

Figure 4 Creating the Model

The model should represent the causes and effects of the system actuator, plant, and sensor to test the actual controller.

Control action:

- On: Electric power P= W.
- Off: Electric Power P= W.

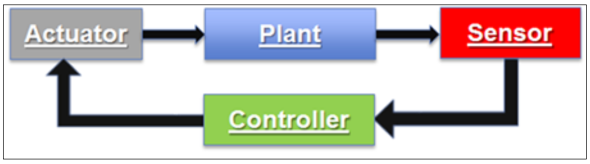

Figure 5 Toolbox Create

The demand for processing requires adequate control for each application, but the proposal to use mathematical systems with precision facilitates the development of the models and makes the MDB close to the real value, as a possible solution below demonstrates.

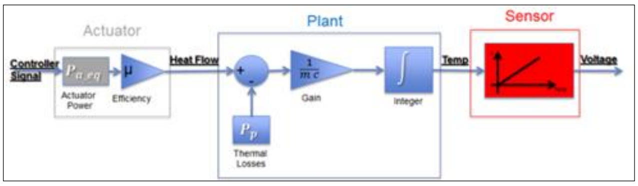

Figure 6 System Control Block

The implementation of functions in the tests depends on the complexity of the dynamic system and its actual characteristics in the environment.

4.1. Hardware Integration Model

The components present in the model are the same described in the hardware document, each electronic unit of the plant has its configuration block where the characteristics of the physical hardware can be virtualized the connection interface between hardware and software is visible in Figure 1. In an installation like the one in Figure 11, this plant is composed of central units and possible sensors/actuators, transforming physical signals into simulated signals.

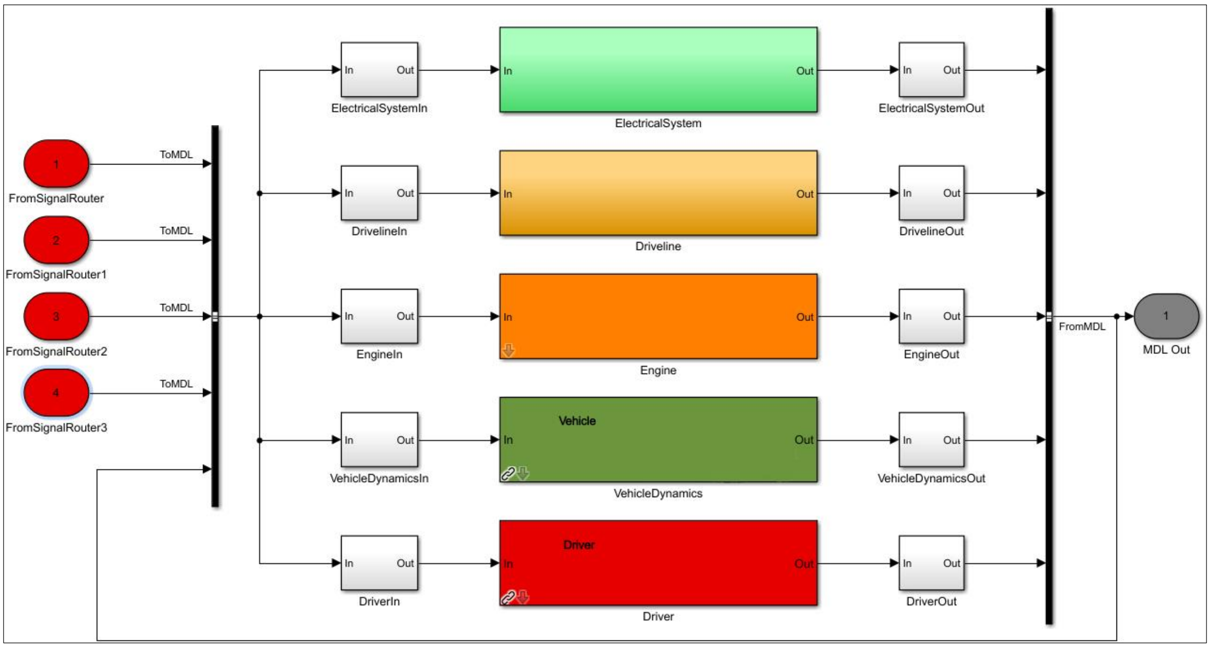

Figure 7 Environment Representativeness

In this case, the connection is defined internally in the simulator by choosing the type of signal and resistance to simulate other real loads and consequently identifying the available ports for applications [15]. In addition, the power ports are produced on the buses with the identity of each ECU and named the voltage level, depending on each signal applied in the project.

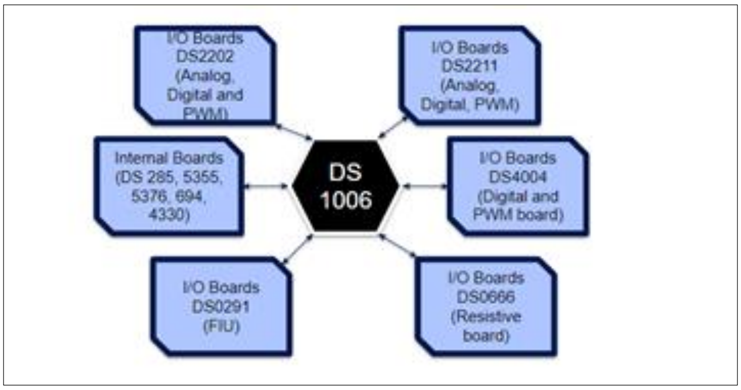

Figure 8 Hardware & Software Integration

Available I/Os -D SPACE From Project									
CARD	Digital Output	Digital Input	PWM Output	PWM Input	Analog Output	Analog Input	Resistive	FIU	CAN
DS 2202	16	14	9	24	20	17	0	0	2
DS 2211	14	6	9	18	20	15	10	0	2
DS 4004	80	72	3	37	0	0	0	0	0
DS 0666	0	0	0	0	0	0	32	0	0
DS 291	0	0	0	0	0	0	0	180	0

Figure 9 Table I/O Available in Simulator

The construction of the test system depends on the functions to be tested in the vehicle, initially the document containing all the I/O is developed and the simulator supports a certain application, the table above shows the boards available in the platform.

5. Case study

5.1. Benefits using HIL component BCM validation

The real ECUs embedded in the simulation environment have the information from the actual component. This supports and facilitates the development of tests and increases the scope of test scenarios. Additionally, Hil allows testing of critical cases, which involves maximum speed in a closed-loop environment, as well as open-loop test setups, e.g., repeat data testing [13]. The increasing complexity of I/O architectures, electric vehicles, and ADAS/AD active safety systems make HIL testing crucial to ensure overall system reliability.

Key benefits of using them:

- HIL solutions ranging from component testing to system integration testing.
- For all vehicle domains, including e-mobility and autonomous driving.
- End-to-end tool chain for efficient automated testing
- Comprehensive consulting, engineering, and training offerings.
- Decades of experience with a wide range of customer projects.

Key points to define the application:

- Real-time scalable platforms.
- Support for the latest bus and automotive network standards.
- Comprehensive simulation models for applications ranging. from combustion engines to autonomous vehicles and electric vehicles.
- High-fidelity solutions for e-mobility applications.
- Realistic camera, lidar and radar models can be calculated in real-time with dSPACE HIL systems.

ECU test systems require scalable I/O and CAN/LIN interfaces, the possibility to simulate electrical faults helps catch possible product errors. In addition, automatic testing and network control helps in creating simulation tests by configuring between the simulators.

Figure 10 Hardware Integration [4]

5.2. Electronic Control Unit - BCM

The Body Computer Module is one of the main control devices of the vehicle, because it has the responsibility of managing the exchange of information from the other central units on the CAN network, it controls all the electronics of the vehicle connected to the protection and configuration relays between the battery and other circuits.

The BCM is a complex hardware with integrated circuits, data memory, protection circuits, and processing units. The automotive industry considers it as the brain of the vehicle not only for all the responsibility in managing communication between the ECUs, but for its importance in the entire operation of the vehicle. vehicle, from vehicle drive control, internal and external lights to temperature information, and connectivity.

5.3. External and Internal Lights

The vehicle's internal and external lights are the headlights, lanterns, and other lights present in the car, which have the function of alerting and communicating the driver with other vehicles on the road, but also with the driver's comfort and practicality. Being considered one of the most critical components in the development of the car due to all the onboard electronics and compatibility with drivers and power supply modules of the system.

5.4. Load Box

The Loadbox is a metallic structure planned to allocate the loads and the real electronic control unit of the vehicle, its connections are made by terminal blocks that are detailed in the topic below, it has 2 terminal blocks that interface with the ECU BCM and the Simulator, the first connection terminal interfaces the ECU to the light loads of the project and the second terminal makes the connection between the ECU and the Simulator. The simulator is connected to the external structure that contains the physical signals of the light loads and the real ECU, the proposal is to realize the connection between the external and internal loads with their power and control circuits. The test bench applies the HIL methodology being fundamental for the validation phase. The text includes instructions and details about the construction of the Light Box with all the connections of the BCM with the HIL and the light loads of the Project

The purpose of using the loadbox in the project is due to its flexibility in performing hardware upgrades and easy access to the power and signal connections to both the ECU and the light loads, helping the validator to perform its tests as close to the component as possible.

- Practicality in maintenance.
- Robust low-cost structure.
- Simple operation for BCM V&V Team.

Initially, a survey was made of all the material used in the construction of the light load panel, coupled to a structure developed for testing. Assuming that the set would be positioned near the BCM simulator, the metrics, and parameters for the construction of the product were defined.

5.5. Structure Load Box

The box was built with structural aluminum profiles attached by universal connectors.

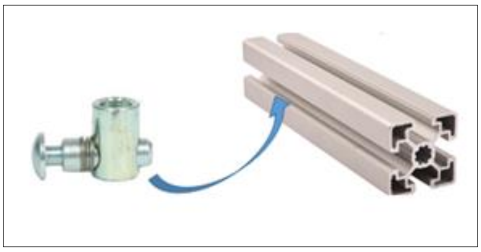

Figure 11 Universal Connector

Table contains information on the materials needed to assemble the physical structure where the central BCM and the internal and external lighting loads of the vehicle will be placed, the test bench developed and connected to the simulator to perform tests

Table 1 Load Box Structural components

Units	Model - mm	Component
1	700x700x4 mm	Acrylic sheet
20	90 4.5x16 mm	Universal Connector
12	6x16 mm	Chipboard Screw
6	720x40x40 mm	Pan ChipBoard Aluminum Structural Profile
4	700x40x40 mm	Aluminium Strucutral Profile PVC Swivel Casater
4	100 mm – 65kg	Metalic Support p/BCM

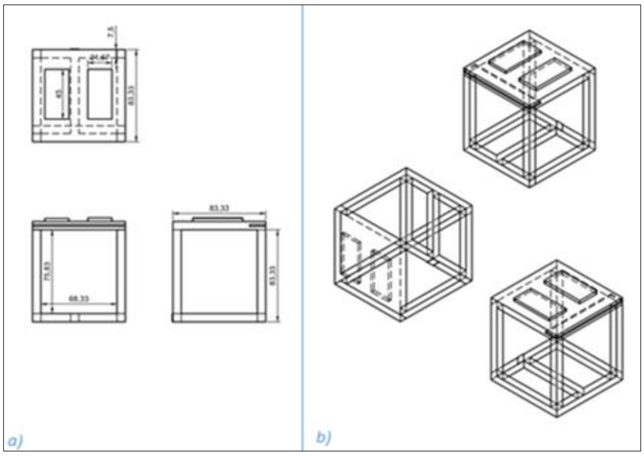

Figure12 a) and b) Orthogonal views in 1:6 scale

The figure above is the model of the physical structure of the load box represented in orthogonal views, showing the occupation area and the physical model designed to serve the connection between the BCM central office and the connection between the HIL simulators.

Figure 13 ECU and Simulator Connection in Platform.

5.6. Harness

The detailing considered here considers the internal part of the box and the harnesses that connect it to the BCM HIL. These, which connect the BCM to the Light Box. Regarding the accommodation of the wires in the ducts, taking care of the organization and robustness, the cables were conformed to avoid as little loss of length as possible, route by route.

5.7. Load Box Build

The construction of the structure was designed in the necessary measures and the profiles have cut and holes in the ends, the acrylic. This version of the light box is a model for testing in real loads, new development methodology, the idea of access to internal components and more space for allocation of components, the version still has challenges, but the project updates and new model of loads was necessary to increase the size of the structure and therefore opted for the use of structural profiles without any type of fixed connection.

Figure 14 Structure with connection lights

5.8. Loads Lights

Each Light Box project must be dimensioned by the amount and type of loads that will be used. This is the main parameter to be surveyed before starting the construction of the product.

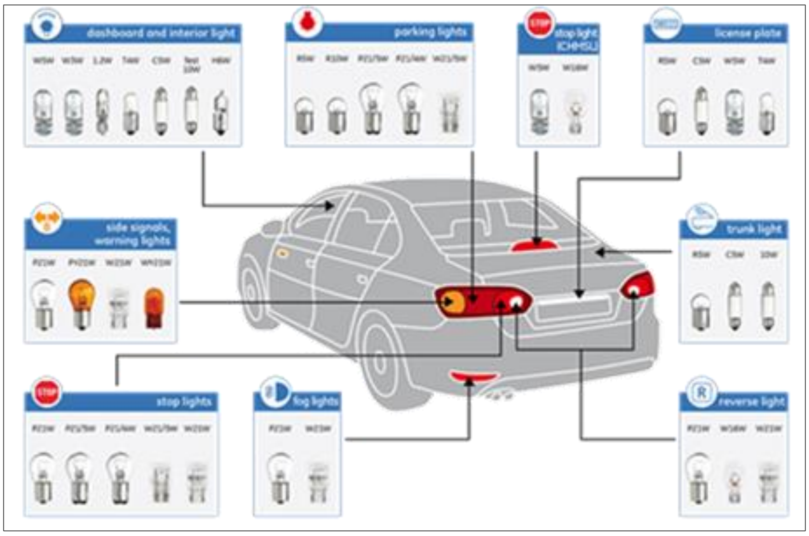

Figure 15 Structure with connection lights

6. Validation and verification report

Test quality is a subject that has been increasingly studied and sought solutions in the automotive industry[16].The consolidation of standards and their representativeness is extremely important so that it is possible to define the responsibilities of all those involved in the process of creating tests, from software vendors, manufacturers of simulators and hardware for testing , in addition to encouraging the correct use of the assignments is to charge the application of penalties for those who do not comply with these standards. On the one hand, for example, ISO has defined the quality of Verification and Validation by ISO 26262 as the loop test functions for electronic control units stress test case presented in this paper.

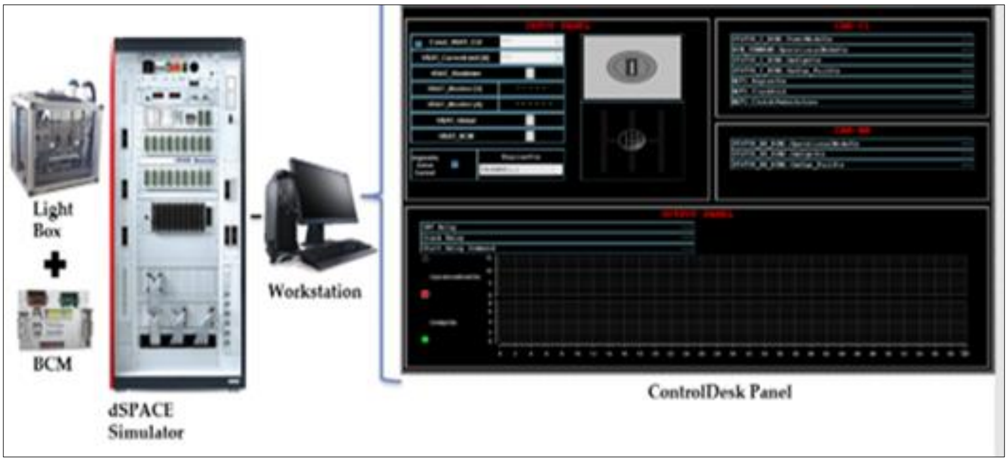

Figure 16 Complete BCM HIL Test System

The validation team uses the desktop with the software mentioned in this document to operate the HIL component simulator, performs the hardware configuration with its case tests, each application has a modeling and configuration file. This test was performed remotely due to the platform's ability to operate in different locations.

6.1. Test Performed to Analyze External lights

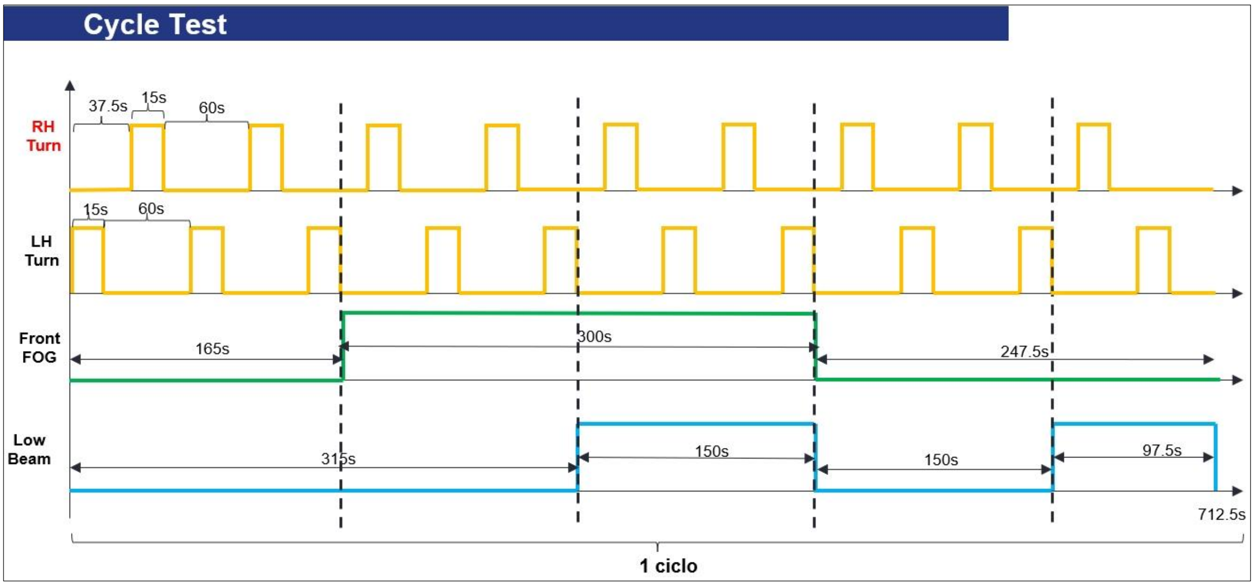

Figure 17 Validation Results Analyze

Performing stress testing on the Turn Light to check for any component failure or misbehavior with the BCM integration using the xIL platform The left Turn Light 'is a prototype part, so to avoid false diagnosis, the test was performed on the right Turn Light only.

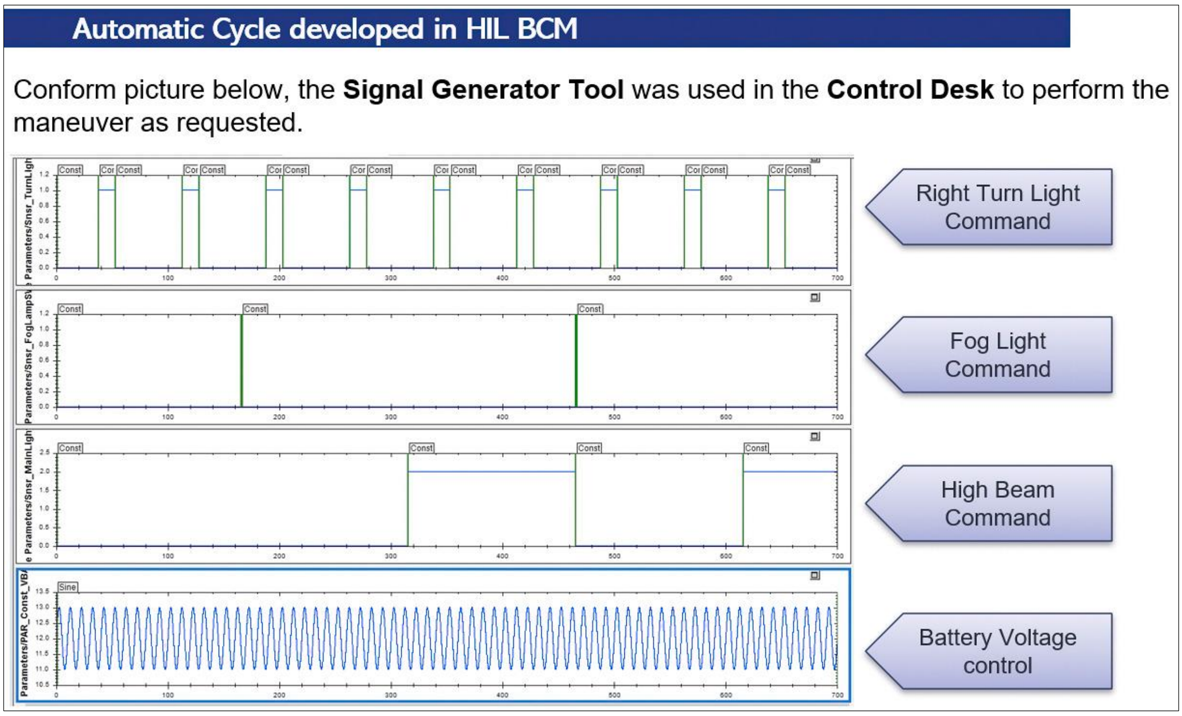

Figure 18 Validation Results Analyze

The test followed a procedure by the validation team to catch possible failures during operation.

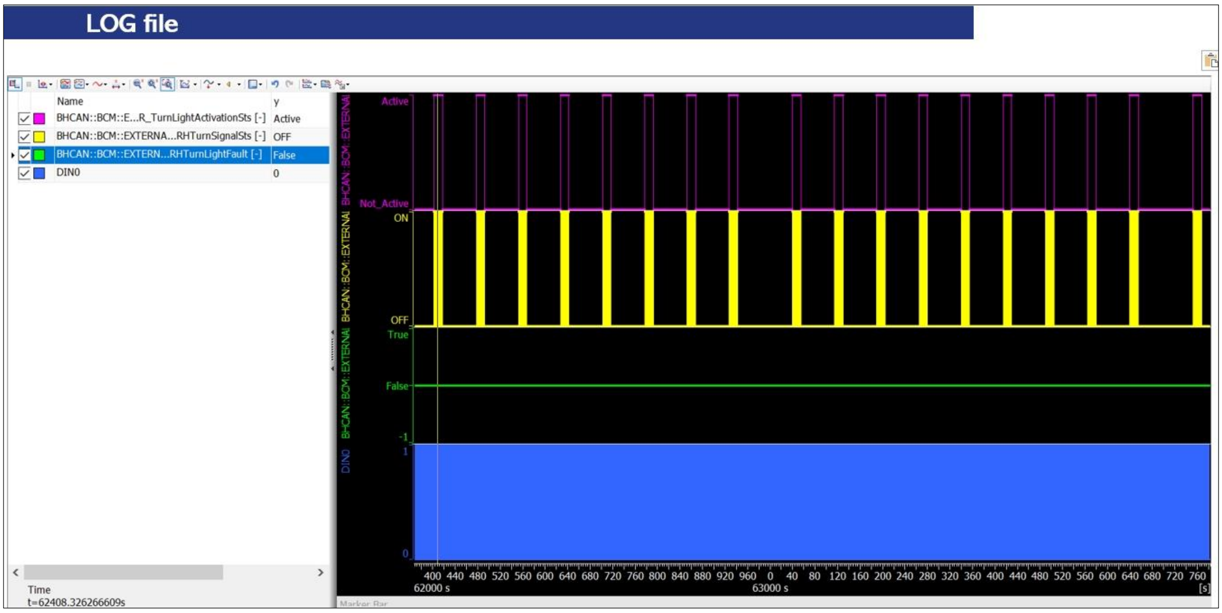

Figure 19 Validation Results Analyze

It is possible to check how it works and how its behavior is maintained during the test cycles.

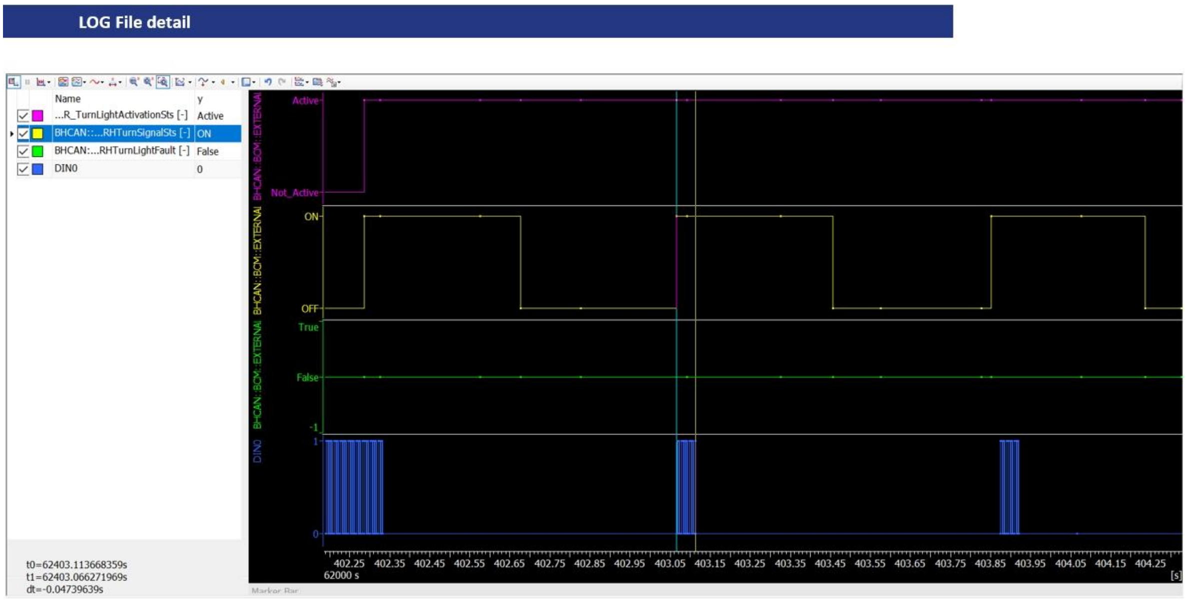

Figure 20 Validation Results Analyze

Analysis performed of the operation of the right lamp and making it possible to test its functions and integration with the updated central unit.

7. Conclusion

The digital age has affected the automotive market positively, raising customer expectations for safer and more technological vehicles. This has created challenges for the industry to produce the market need, encouraging the use of virtual testing, consequently xIL. As a result, the complexity of vehicle production has affected not only engineering teams, but all technological sectors. Therefore, changing testing methodology can provide innovations by increasing product quality and decreasing production time and cost.

In this context, this paper presented a case study to optimize the tests performed with the BCM central and internal/External light using HIL.

To share the methodology, the development of the load box was used as a case study defining each step of creation, structure, assembly, and validation.

Tests were performed for lamp actuation, fault insertion, integration with other power plants or functions. The comparison of test times using a systemic bench versus a component HIL showed the HIL to be more efficient, allowing the automation of tests and simulation of power plants not present on the test bench, on the other hand it was not possible to perform the same tests on the bench.

However, its development is a direct application to the BCM ECU and the vehicle light loads being only a part of all the tests that are performed in the validation of the vehicle throughout the development process.

Compliance with ethical standards

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Disclosure of conflict of interest

I declare that I am not subject to any kind of conflict of interest with the participants or with any other collaborator, direct or indirect, for the development of the Research Project entitled "Validation of Automotive Centrals using Hardware in the Loop - BCM and Lights", whose researchers involved are: "Marley Rosa Luciano e Rodney Rezende Saldanha".

I further state that my actions as a researcher are independent, autonomous, and committed to the primary interest of protecting the rights and safety of the research participant(s) in accordance with current law and other ethical guidelines for research involving human subjects

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