Hardware in Loop Test setup for Automated Testing of ECU

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Abstract - *Modern day automotive industries are facing severe challenges in terms of safety and comfort needs that are posed on the vehicle. To meet this demand, vehicles are increasing its dependency over the application of electronics. These electronics perform several control functions in the vehicle, and they are termed as Electronic control unit (ECU). An electronic control unit is a hardware that contains an embedded software to perform particular task. There are variety of ECUs available in the market that are designed for different functionality. Every ECUs undergoes several testings during its development cycle that includes software in loop test, Hardware in loop test and Model in loop test. In this paper, a Hardware in loop test setup is designed for simulating vehicle powernet components . The main aim of Test setup is to provide a vehicle environment by simulating different components of the powernet in the Lab and to trick the ECU that it is actually assembled in the car. To perform this test, a specialized hardware from Vector is used that enables the testing and control of test bench components manually as well as remotely through a specialized software called CANoe.*

Key Words*: *Electronic Control Unit*, *Hardware in Loop*, *Vector Tool.

1.INTRODUCTION

Due to the recent advancements in the automobile industry, the complexity of the system is getting higher to meet the safety and comfort demands posed on automobiles. For the past 30 years, both hardware and software are greatly involved in the automotive industries. These hardware and embedded software combination known as Electronic Control Unit (ECU) plays a vital role in the automobile control systems [1].

Modern automotive systems contain several electronic control units (ECUs) that coordinate with each other and each of them designed to handle functions like promising the optimal comfort of vehicles occupants like temperature control, to help drivers in handling vehicles power steering, to ensure the safety of passengers (e.g., antilocking systems) and protection of vehicle powernet. In recent days cars use more than 30 ECUs and their success majorly depends on the ECU software and underlying hardware, hence automotive industries are putting significant effort in ensuring the quality of ECU software and hardware [2].

In many situations, it is necessary to plan development and testing of controller when the end vehicle is not available or under development. In such a situation hardware in loop testing is used. In this process of testing such controllers emulates the external application environment and allows concurrent development of the electronic controllers. Even with the availability of end vehicles, when the end vehicle and design iterations are to be carried out using "in-vehicle" testing approach, then the same can be time-consuming. Using such an approach may lead to the hazard of the vehicle occupant during the failure of ECU operation [3].

Sometimes it is required to simulate wide range of use case scenarios under diverse environmental conditions. For example, for a power-train related application various road conditions, road-grades, frictional coefficients will have to be simulated. Hence based on the application and ECU requirement the HIL test bench components, design and controller used varies. Hence the test engineer needs to have a clear understanding of the ECU functionality and requirement before designing the test bench.[5]

To test some of the functionality of ECU that is connected to the powernet a Hardware in loop test bench design approach is proposed which has the capability to simulate the power net components like Alternator, battery, electronic power steering and wiring harness in the Lab environment. After the design of this HIL set-up, it allows us to automate the various test cases and perform testing in the lab atmosphere

1.1 Hardware in loop Test Environment

Hardware in Loop test is a technique where real signals from an ECU are connected to a test setup that simulates reality, tricking the ECU into thinking it is in the assembled product. Test and design iteration takes place as though the real-world system is being used. This makes test engineers easily execute hundreds of possible scenarios to test the ECU without the cost and time associated with actual physical tests.

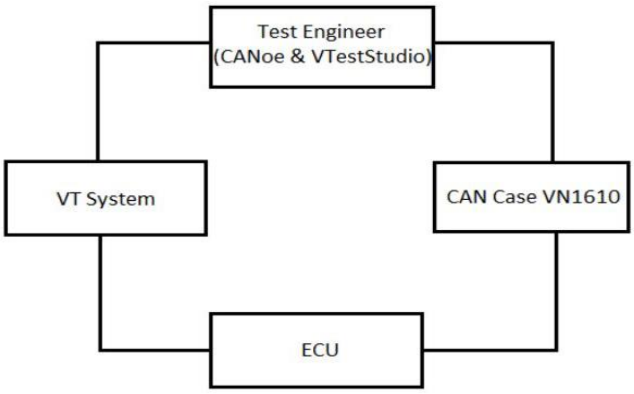

Fig -1: Block Diagram of HIL Test Environment

The entire system design involving Device under test (ECU), VT system and Test PC in a loop forms hardware in loop and the system is shown in the Fig 1. All the pins of the ECU are connected to the components of the Test setup like programmable power supply, programmable load, and CAN Case VN1610 for CAN communication. The Test bench uses DC contactors for switching on/off the power supply and programmable loads. Also, to sense the current and voltage across the pins of ECU current transducer with VT modules like VT2816 and VT2820 for DC contactor control are used. All the VT modules are configured in CANoe tool.

1.2 VT system

The VT System is a modular hardware tool for testing. It can access ECU's I/O for testing purposes. Another benefit when using the VT System and CANoe tool is that it allows control of some of the testbench components like contactors, power supply and DC electronic loads. All the VT modules connected in the VT System are added to CANoe. All the modules are configured as per requirements.

The VT System is connected to ECU's particular pins instead of the real loads such as LED channels in the headlamp. The loads and sensors are simulated by the VT System modules. However, these modules can also be connected to the original actuators and sensors. All equipment required for testing the connected ECU inputs or outputs are integrated into the VT System modules [4].

1.3 CANcase VN1640A

The VN1600 interface set is an advanced version of CANcaseXL, which is a flexible and cost-efficient solution for CAN applications. The VN1600 interface set provides multi-application functionality that supports simultaneous operation of several different applications on one single channel, Example: CANape and CANoe. Tasks accomplished by CAN case range from simple bus analysis to complex bus simulations with calibration, diagnostic, and reprogramming tasks. CAN trace window in CANoe software will display all the messages and diagnostics that is being transmitted between several ECUs over the CAN bus with the help of the connected CAN case VN1610.

1.4 CANoe and VtestStudio

CANoe is a robust software tool for ECU and bus simulation, bus analysis, and test automation. In CANoe the overall system is shown graphically with the CAN bus and all network nodes. CANoe is attached with CAN database containing all messages and .cdd file containing all diagnostic services. Start the measurement and CANoe will immediately begin to transmit the message cyclically configured in the generator block.

The VtestStudio software tool is an adaptable and integrated work environment for developing test cases for embedded systems. It is accomplished with four kinds of editor for writing test cases. The one being used here is the Vtest Table editor. Vtest Table editor is used as it is easy to use and can compress several lines of codes written in CAPL. It is a command-based editor. One more advantage of Vtest Table is that CAPL code can also be attached in this editor. It need not require any programming expertise as well.

2. Design of Test bench

Design and development of test bench involves number of components. The expected outcome and desired performance are achieved only if all the components are interfaced and synchronized in the desired fashion. The process of selecting and designing the components as per the required specifications plays an important role. This section deals with the design and selection of various components needed for the operation

2.1 VT 7001 power supply module

A VT 7001 is a power supply module that comes up with an internal power supply. The VT 7001 module has additional control option up to 2 external power supplies that can carry maximum of 70A per channel. The module provides additional features like input and output voltage measurement, serial interface for driving external power supply, relays for producing short circuit between output lines.

2.2 Test bench power supply

Sometimes HIL bench needs to be operated at high current for certain applications, during that time it is necessary to use an external power supply to meet the requirement.

Selection of power supply for a particular application is quite easy, the right power supply is selected based on Voltage and current requirements. But for complex requirements such as test bench application, additional feature needs to be taken care. Hence, the external power supply used for HIL testing is done based on the following features

- **Power requirements**: ECU operates at different voltage ranges and current ranges, hence initial basic criteria that the power supply selected should match the power requirements.
- **Ripple and Noise**: Ideally the power supply should be free from any variations in the voltages, but in practice there are some periodic variations called ripple and random variations called noise. Hence keeping in mind, the above two parameters (Voltage ripple and current ripple) from the power supply should be as minimum as possible (< 0.05%) for the application.
- **Programming accuracy:** It is a measure of how close the output based on the set point value. This can be even seen from the built-in voltmeter and ammeter to measure its output.
- **Output response:** It is a measure of how fast the power supply operates for a particular application. When the power supply setpoint changes, it takes some time for the output to reach that value. The specifications are typically for voltage from 10 to 90% of its rated output.
- **Computer interface** option enables power supply to control manually as well as using computer. This is achieved with the help of GPIB, LAN and USB hardware interfaces.

2.1 DC Electronic load

The Test bench requires DC electronic load that simulates different vehicle loads like Electric power steering and battery profiles of powernet. The DC electronic loads used for the test bench is also programmable that can draw required amount of current directly from the power supply. The DC electronic load is capable to operate at constant current mode, constant voltage mode and constant power mode.

2.3 Current sensor

For high current measurement sometimes current transducers are required along with some of the VT measurement modules to bring it down to measurable range. Many current sensors available in the market are designed for the measurement of AC, DC and pulsed current in automotive applications. These provides the galvanic isolation between high-power primary and electronic secondary circuit. These are designed for high frequency applications and works on the principle of Hall effect.

Hall effect is caused by the Lorentz force which acts on the mobile electric charge carriers in the conductor when they exposed to magnetic field perpendicular to the conductor. Fig 2 shows the Equivalent circuit of current transducer.

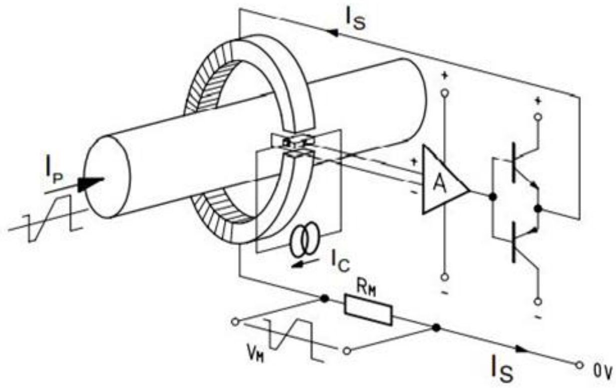

Fig -2: Equivalent circuit of Current sensor

The selection of current transducer is the result of economical tradeoff between the transducer and the associated subsystems. Particularly attention was taken for electrical power supply requirement and peak current measurement range. Also, mechanical considerations like aperture size for the proper passage of wiring harness were taken into consideration.

In addition to the current sensor for measurement through CANoe software and for calculating effective value of the sensed current, VT2816 measurement module can be used. These modules contain 12 channels for Voltage and current measurement, Out of 12 channels in the VT2816, first 8 channels are used for multi-purpose hence both voltage and current can be measured. But from channel 9 to 12 only voltages are measured.

2.4 DC contactor

A contactor is essentially an electromechanical switch or relay that will close in order to make the connection and allows the current flow or opens to stop the flow of current. DC contactors are available with different connection types like SPST and SPDT. Normally HIL test bench uses SPST type DC contactors to connect power supplies or to disconnect the loads in the test bench at suitable points as per the test requirement when it is required to use additional component along with power supply SPDT type of switches can be used. The DC contactor used for the test bench is shown in the Fig 3

Fig -3: DC contactor

DC contactor used for test bench power supply and load connections are done based on following selection criteria

- **Rated Voltage**: Normally the rated operating voltage of the DC contactor should not be less than 1.25 times its operating circuit voltage. The rated operating voltage of contactor selected for test bench is 12 to 900Vdc.
- **Rated Current:** when rated current flows through the contacts the temperature rise should be within permissible limits, normally contactors rated current is selected for 1.25 times the rated current of the working circuit.
- **Make and break power switching capacity**: The contactor should be able to make or break normal or overload currents safely. This is normally mentioned in the electrical switching cycles of the contactors.
- **Coil operating voltage and current**: The DC contactor coil operating voltage is normally in the range of 9 to 36V dc, and coil operating current be up to 3A.

In the test bench the contactor coil voltage is controlled by VT2820 general purpose. The VT 2820 General purpose relay module have 20 channels for switching signal paths in the test system and it is also equipped with a 7A resettable fuse, the specified current can flow only for certain time after which the fuse interrupts the current flow.

2.5 Wiring Harness for Components connection

In order to connect the test bench components current carrying capacity (ampacity) of the conductor and voltage drop are the two main criteria used to select conductor size for any given circuit. Voltage drop is determined from the conductor resistance at desired design temperature and load current. Since the conductor length depends on the length of circuit path, hence the distance must be known. In united states conductor size is normally given in American wire gauge (AWG) or circular mils (CM). Fig 4 shows the ampacity chart for DC applications.

Circular mils are a measure of cross-sectional area of a conductor. For DC application normally voltage drop should be less than 3% of supply voltage considering this voltage drop, the cross-sectional area of wiring harness is calculated as

AWG	Diameter (inches)	Diameter (mm)	Cross Sectional Area (kcmil)	Cross Sectional Area (mm^2)	Resistance (Ohms per 1000m)	Resistance (Ohms per 1000m)
0000	0.46	11.684	211.6	107.22	0.049	0.1608
000	0.4096	10.405	167.81	85.029	0.0618	0.2028
00	0.3648	9.266	133.08	67.431	0.0779	0.2557
0	0.3249	8.251	105.53	53.475	0.0983	0.3224
1	0.2893	7.348	83.693	42.408	0.1239	0.4066
2	0.2576	6.544	66.371	33.631	0.1563	0.5127
3	0.2294	5.827	52.635	26.67	0.197	0.6464
4	0.2043	5.189	41.741	21.151	0.2485	0.8152
5	0.1819	4.621	33.102	16.773	0.3133	1.028
6	0.162	4.115	26.251	13.302	0.3951	1.296
7	0.1443	3.665	20.818	10.549	0.4982	1.634
8	0.1285	3.264	16.51	8.366	0.6282	2.061
9	0.1144	2.906	13.093	6.634	0.7921	2.599
10	0.1019	2.588	10.383	5.261	0.9988	3.277

Fig -4: Ampacity chart.

Circular mils (CM)= $\frac{Fvd*Iload*Lloop}{Vdrop}$

Where,

Fvd= Copper wire resistivity at desired temperature in CM/feet.
I_{load}=Load current.
L_{loop}=Conductor loop length feed+return.
V_{drop}= Voltage drop in volt.

3. Configuration of Test bench power supply and DC electronic load

Test bench power supply and DC electronic load for the HIL application comes up with Vector CAN database(*.dbc) and is intended to be used with Vector company softwares like CANalyzer and CANoe. This database defines the most important commands available for a particular device like power supply and loads. Due to the structure of database not all the available commands can be addressed to signals. However the CAN interface hardware includes some of the register lists which list all available commands for certain device series. The remaining commands can be implemented into the database via CAPL scripts.

In order to implement all the above said features, it requires a CAN hardware interface, a dedicated database, Vector software or compatible software and CAN controller hardware. In order to setup the power supply and loads in the test PC, it is required to adjust CAN base ID of that particular device. When using multiple devices on the same bus, the CAN base ID of every unit has to be different. In the database editor, CAN IDs of the basic messages so they

match the device IDs. Every device gets 3 IDs. The default IDs in the database is thus 0,1 and 2.
Query_object = Base ID+1
Read_object= Base ID+2
Send_object=Base ID.

4. Conclusions

Hardware in loop test setup for automated testing of ECU was proposed. The test setup was mainly aimed for the ECUs that are connected to vehicle powernet and to provide a suitable vehicle environment and simulate the different components of the vehicle powernet. The components of the test bench are selected based on the test requirement and sizing of the current sensor for measurement of current at different paths, wiring harness sizing for connecting different electrical components, DC contactors for connection and disconnection of power supply and loads are done suitably based on the requirement. Specialized hardware for the automation and software control is achieved using VT system modules. The testbench components are capable of control using CANoe tool after configuration of the hardware components in the tool.

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