Hardware in Loop Simulation ECU Testing  
In Automotive

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Abstract: Hardware-in-the-loop (HIL) testing has become an essential verification step in the development of vehicle electronics and software systems. If the controller to be tested is implemented in the controller hardware, often denoted the electronic control unit (ECU), and the simulator has to run in real time. The aim of paper is to present set up HiL simulation environment which make functional testing and development of ECU’s possible, and realized hardware and software integrated with ECU’s.

Keywords: Hardware in the Loop simulation, Electronic Control Unit

I. INTRODUCTION

Hardware-in-the-Loop process has existed for no more than 15 to 20 years. Its roots are found in the Aviation industry. The reason the use of a HIL process is becoming more prevalent in all industries is driven by two major factors: time to market and complexity. Hardware-in-the-loop (HIL) simulation is a technique that is used in the development and test of complex process systems. HIL simulation provides an effective platform by adding the complexity of the plant under control to the test platform. The complexity of the plant under control is included in test and development by adding a mathematical representation of all related dynamic systems. These mathematical representations are referred to as the “plant simulation.” Another benefit of Hardware-In-the-Loop is that testing can be done without damaging equipment or endangering lives. For instance, potentially damaging conditions in an engine, such as over-temperature, can be simulated to test if the ECU can detect and report it.

II. HARDWARE IN LOOP SIMULATION SYSTEM

The Figure below shows that the plant is simulated and the ECU is real. The purpose of a Hardware-In-the-Loop system is to provide all of the electrical stimuli needed to fully exercise the ECU. In this way you “fool” the ECU into thinking that it is indeed connected to a real plant. The HIL simulation includes a mathematical model of the process and a hardware device/ECU you want to test, e.g. an industrial PID controller in our case.

a) HARDWARE SET UP

In hardware in loop simulation system consist of PXI and its modules and SCB cards and Electronic control unit and interface board.

b) NI PXI AND ITS CARDS

Accepts 3U PXI, PXI Express, Compact PCI and Compact PCI Express modules. The National Instruments PXIe-1065 18-slot chassis features a high bandwidth backplane to meet a wide range of high-performance test. NI PXIe-1065 provides a solution for high channel density systems.

SPECIFICATIONS:

1. AC Input Voltage range is 100 to 240 VAC
2. DC Output voltage range is Maximum combined +3.3 V, +5 V, and +12 V.
3. Maximum total power is 701.5 W.
4. The maximum power dissipated in the system should not exceed 140 W.
5. Pollution degree 2 For indoor use only.
6. Operating Environment is 0 to 55 °C
7. Storage Environment is -40 to 71 °C.
8. Relative humidity range is 5 to 95%.
III. NI PXI MODULES

a). SCB Cards

Serial control bus is used to connect the PXI and Electronic control unit

SPECIFICATIONS

1. Half-pitch DSUB 100-Pin / 0.050 series D-type connector
2. Suitable alternative to National Instruments SCB-100 connector block
3. Connector contains both latch blocks and #2-56 jack screws
4. Screw terminal for each data line plus 1 screw terminal for shield
5. Angled screw terminals provide compact, convenient wiring
6. Screw terminals accommodate wire sizes from 16AWG to 26AWG
7. Approximate dimensions: 3.75" x 4.5"
8. Rubber feet or DIN rail mount

b) INTERFACE BOARD

The 5-6K Interface Board provides a complete system development platform using evaluation modules from the Data Acquisition Products Group. This board passes signals from TMS320C5000™ and TMS320C6000™ DSK platforms featuring the 80-pin daughter card connectors defined in the TMS320Cross-Platform Daughter card Interface (SPRA711), to a variety of analog-to-digital and digital-to-analog converters. When combined with sensor or amplifier boards, it can provide a complete data acquisition system for a variety of applications.

c) ELECTRONIC CONTROL UNIT

An ECU is basically made up of hardware and software (firmware). The hardware is basically made up of various electronic components on a PCB. The most important of these components is a microcontroller chip along with an EPROM or a Flash memory chip. The software (firmware) is a set of lower-level codes that runs in the microcontroller.

The ECU is characterized by

1. many analog and digital I/O lines (low and high power)
2. Power device interface/control.
3. Different communication protocols (CAN, KWP-2000, etc.).
4. Large switching matrices for both low and high power signals.
5. high voltage tests
6. Intelligent communication interface adapters (standard or custom).
7. automatic fixture recognition and software sequence enable
8. Power device simulation.

IV. SOFTWARE SET UP

Developing a Hardware-in-the-Loop, High-Speed Simulation and Data Acquisition System for ECU Testing with the NI PXI Platform and NI LabVIEW Software.

SOFTWARE SYSTEM CONFIGURATION

1. Import CAN database files for testing.
2. Create and edit CAN channels easily.
**NI LAB View Software:**

3. FRONT PANEL

![Front Panel Image]

**V. BLOCKDIAGRAM**

1. LabVIEW is a graphical programming language that uses icons instead of lines of text to create applications.
2. NI LABVIEW program consist of front panel and block diagram.
3. Front panel consist of controls as inputs and indicators as outputs.
4. Block diagram consist logic of the program.

**MATLAB State flow model**

![State Flow Model Image]

1. MATLAB State Flow models are used for analysis of internal signal analysis.

**CANdb++:**

1. In Candb++ consist the CAN signals and LIN signals for testing.
2. CANdb++ files consist of vehicles nodes and messages and signal list.

![CANdb++ Image]

**VI. HILS TESTING AND SIMULATIONS**

2. Generation of Vector Canoe configuration file (.cfg) using CAN Database (.dbc).
3. GUI & Logic development for testing by using LabView Software.
4. Study of PXI and its modules for Hardware connection.
5. Test case generation and Verification.

**VII. SIMULATION & RESULTS**

![Flowchart Diagram]

**SPECIFICATION DOCUMENT AND DATABASE FILE AND MATLAB FILES**

- **GUI DESIGN**
- **PXI AND ITS MODULE STUDY**
- **TEST RESULTS VERIFICATION**

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VIII. CONCLUSION

After the ECU functions have been developed and implemented on the production ECU, they have to be tested thoroughly. With hardware-in-the-loop (HIL) simulation, you can easily cover all the different motor varieties and their ECUs. The ECU’s environment (interacting components or even a whole system), is simulated.

This has several advantages:
1. Function tests are possible at an early development stage, even before all parts are available in reality.
2. Laboratory tests reduce time and cost and take place under controlled conditions.
3. Failures, and the ECU’s behavior in what are normally dangerous situations, can be tested with no risk for the driver or the controlled machine.
4. The tests are reproducible and can be automated.

References


