Low Cost Hardware In The Loop (HIL)

Test Tool

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*Abstract*—Test and Validation teams across several automotive companies use COTS (Commercial Off-the-Shelf) technology for the design and development of Automated Test Equipment (ATE). During System Validation and Verification (V&V) phases, automotive R&D programs budget high costs for professional development tool licenses like Vector CANoe/CANalyzer, Vehicle Spy from Intrepid Control Systems or similar to execute test cases to a vehicle Electronic Control Unit (ECU) under test. While these tools are excellent to design and develop large simulations and tests scenarios, once the design is finished, sometimes they are no longer needed. This project uses a low-cost microcontroller platform that can execute specific test cases to an ECU using CAN protocol commanded by an instruction received by a TCP client.

Keywords—Hardware-in-the-loop, Automated Test, Ethernet, CAN.

# Introduction

Commercial of the Shelf Technology (COTS) offer several solutions out of the box for automotive communications. Companies like Vector Informatik or Intrepid Control Systems have specialized hardware and software tools to simulate complete Electronic Control Units (ECUs). Some of these commercial tools have become a standard in the automotive industry.

In R&D disciplines, most of System Validation and Verification teams rely on these types of tools to design and develop Automated Test Equipment (ATE) to communicate and execute test cases. Some of the benefits they offer are tool standardization, database homogenization, system model reuse from software development teams among others.

These tools are excellent to design and develop large vehicle simulations and tests scenarios but once the test modes have been designed, users of these tools still need to have expensive Runtime licenses to execute their developed models. Sometimes these models are for Proof of Concepts purposes, test demos or small implementations that make it difficult to justify the purchase of a high-cost development or Runtime tool license.

The purpose of this Hardware-in-the-loop (HIL) test tool is to allow test developers to implement and execute their already developed test scripts without the need of Runtime licenses.

This project uses the Nucleo-H723ZG development platform from ST Microelectronics which has a low cost but highly capable MCU (Arm® Cortex®-M7-based STM32H7). This MCU can communicate with any ECU via CAN and execute user defined test scenarios. The user communication to the HIL Test Tool is via Ethernet, the HIL Test Tool acts as TCP server so any TCP client can communicate with it and send command instructions to the Device Under Test (DUT).

This project was designed and built using the waterfall process methodology. A requirements phase, design phase, implementation phase and test phase were implemented and will be discussed in the following sections.

# Concept

The general purpose of this project is to emulate the functionality of an Automated Test Equipment (ATE) capable of running pre-defined test scenarios via CAN communication to any type of ECU that has CAN communication available. For this project, a basic vehicle CAN network consisting of 3 ECUs is simulated using Vector CANoe to demonstrate the functions of the HIL Test Tool.

The HIL Test Tool uses FreeRTOS as operative system to handle the different tasks to interact with the DUTs implemented in the simulated vehicle network in CANoe. The yellow box in *Figure 1* represents the CAN interface to allow physical devices to interact with the simulated network. Any TCP client can interact with the HIL Test Tool but for this project a custom TCP client was developed using NI LabVIEW to have a better interaction with the Test Tool.

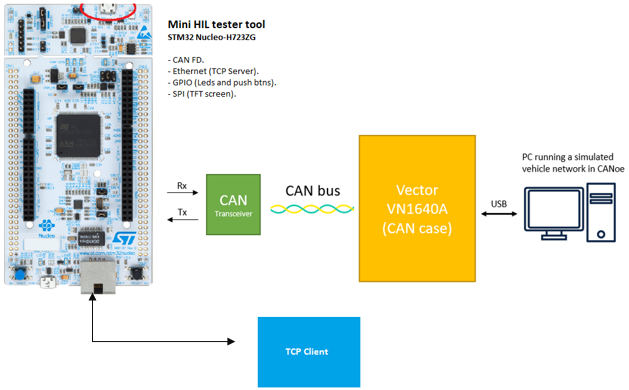
*Figure 1* shows the overall concept of the project and the main project elements.

Figure 1. Project Elements

The next section will describe the different requirements for the main project components.

# REQUIREMENTS

Requirements for this project are divided in 3 groups: HIL Test Tool, Simulated CAN Network and TCP client.

## HIL Test Tool Hardware Requirements

| ID | HIL Test Tool Hardware Requirements | | |
| --- | --- | --- | --- |
| Name | Type | Description |
| HW-001 | Dev. Board | Functional | Board has 3 CAN HS/FD controllers. |
| HW-002 | CAN Transceiver | Functional | NXP TJA1441AT is used as Tx. |
| HW-003 | Ethernet Comm. | Functional | Board has Ethernet connection. |
| HW-004 | CAN termination | Functional | 120Ohm resistor used as termination. |
| HW-005 | Ethernet cable | Functional | CAT6 cable is used. |
| HW-006 | CAN Connector | Functional | A DB9 connector is used for PINs 2 & 7. |
| HW-007 | CAN cable | Functional | A twisted pair cable is used for comm. |
| HW-008 | LCD screen | Functional | ST7735 1.8” display from Adafruit was used. |

Table 1. HIL Test Tool Hardware Requirements.

| ID | HIL Test Tool Software Requirements | | |
| --- | --- | --- | --- |
| Name | Type | Description |
| SW-001 | RTOS | Functional | FreeRTOS is used |
| SW-002 | CAN bus speed | Functional | 500kbaud is configured |
| SW-003 | Serial COM | Functional | UART1 enabled |
| SW-004 | RT response | Functional |  |
| SW-005 | TCP Comm. | Functional | Board has a TCP server. |
| SW-006 | Software Arch. | Functional | Modular & scalable. |
| SW-007 | Test Scripts | Functional | Modular & scalable. |

Table 2. HIL Test Tool Software Requirements.

| ID | Simulated CAN Network Requirements | | |
| --- | --- | --- | --- |
| Name | Type | Description |
| SM-001 | CAN network | Functional | CAN network with at least 1 ECU. |
| SM-002 | ECU1: Engine | Functional | Read/write Speed signal |
| SM-003 | ECU2: Lights | Functional | Read/write Light & hazard signal |
| SM-004 | ECU3: Display | Functional | Read/write panel values. |
| HW-009 | CAN Interface | Functional | Vector VN case 1640 |

Table 3. Simulated CAN network Requirements.

| ID | TCP Client Requirements | | |
| --- | --- | --- | --- |
| Name | Type | Description |
| TC-001 |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

Table 4. TCP Client Requirements

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*a**b* 

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