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# *ECU Health Monitor Using CANUSB*

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***Abstract* — In automobile an OBD (On Board Diagnostics) facilitates the ECU (Electronic Control Unit) to identify the failures of vehicle systems and take essential corrective actions to preclude the accidents and hazards. Thus the diagnostics empower the driver and passenger safety. During ECU development phase most of the OEMs, Tier-1, and Tier-2 uses a Vector Tool "CANoe" for ECU diagnostics validation. The CANoe tool is very expensive. Its cost is ~ €10,000. The proposed system is a cost-effective tool that can be used to perform the similar functionality of ECU diagnostics validation during ECU development phase to monitor the ECU health. It uses CANUSB cable as hardware and application software developed in Microsoft C# language. It is the special tool, uses a single channel for transmitting and receiving various CAN messages to/from ECU. Using this tool, the diagnostic request messages and vehicle simulated messages can be sent and response messages can be validated. The tool would be having user-friendly GUI, manual as well as cyclic auto transmission of messages mode and message logging feature. The complete tool cost would be ~ ₹35,000.**

***Keywords— CAN, CANoe, CANUSB, Diagnostics, Diagnostics Trouble Code, ECU, OBD, OEMs, and UDS***

## I. INTRODUCTION

Prior day's vehicles were having a mechanical system for various features like Braking system, Steering systems, Windows, and Wiper Systems. Today, to meet market needs, vehicles are getting smarter with the aid of embedded systems. An Electronic Control Unit (ECU) is an electronic device which uses embedded systems having a microcontroller to control the various vehicle functions. The vehicles are becoming more advanced, autonomous, and connected. Vehicles are heavily regulated by law for consumer comfort & safety, to reduce emission and increase fuel efficiency. Since the 90s; the vehicles are built with ECUs having on-board diagnostic systems to monitor the health of the vehicle. The on-board diagnostic system uses OBD-II port and related subsequent standards. This port enables access to the vehicle to monitor the performance and function. As ECU has to control various time critical and safety functions, it involves complex algorithms. To offer more comfort and safety, the Original Equipment Manufacturers (OEMs) are focusing on to produce ISO 26262 Safety Standard compliant ECUs. To accomplish this compliance, one of the major areas is On-board Diagnostics using CAN. An OBD-II enables ECU to identify the failures of vehicle systems and take essential corrective actions to avoid the accidents and hazards. The proposed system is a cost-effective tool to perform ECU diagnostics validation to monitor the ECU health. Thus it empowers the driver and passenger safety.

## II. LITERATURE REVIEW

In the 80s, vehicles equipped with control systems which can alert the driver about a failure and allows the technician to retrieve Diagnostics Trouble Codes (DTC) that identify the failure in the vehicle. It helped to condense the emission and guide the technician to identify the fault. OBD system continuously monitors vehicle function behavior for correct functioning. The monitoring is of component monitoring and system monitoring. The Malfunction Indicator Lamp (MIL) is illuminated if any failure is detected. The fault is stored in ECU memory by saving the information about the failure in form of DTC and freeze frame. This information enables the technician take proper action to remove fault.

### A. Automotive Diagnostic Gateway using Diagnostic over Internet Protocol

Young Seo Lee et al proposed the diagnostic gateway that supports CAN, FlexRay and Ethernet protocols. The diagnostic gateway can be connected to the external diagnostic device through the Transmission Control Protocol (TCP) and provides the reliability and integrity of the diagnostic data through the TCP connection. The diagnostic services using CAN-based diagnostic protocols take too long because of the low bandwidth. In contrast, Ethernet-based DoIP provides high bandwidth and large data sizes for large-scale communication, and it can diagnose the vehicle in near real-time [1].

**B. On-Board Diagnostics (OBD) Scan Tool to Diagnose Emission Control System**
Prajakta Kulkarni et al described emission compliance requirement with a brief introduction of the OBD system along with scan tool to diagnose the system. The requirement of aftertreatment emission control system and its different types are discussed. A brief history of OBD has been presented. The main parameters like Diagnostic Trouble Codes, Malfunction Indicator Lamp, Freeze Frame and Parameters ID are discussed. The paper explains in detail the process of self-diagnosis technique for emission control system by using the scan tool. This paper helped to understand various diagnostics tool available for the ECU diagnostics [2].

**C. Design of an In-Vehicle Network (Using LIN, CAN and FlexRay), Gateway and its Diagnostics Using Vector CANoe**
Rishvanth et al described the design of In-vehicle network and Gateway using Vector tool CANoe. The simulated vehicle network provides an efficient method of communication between various ECUs. The papers discuss the communication protocols - Local Interconnect Network (LIN), Controller Area Network (CAN) and FlexRay. These communication protocols are used for low, medium and high-speed applications respectively. A gateway is a network node and acts as a bridge to transfer data from one communication protocol to another. Vector CANoe is OEM recommended a very powerful tool for the development, testing and analysis of entire ECU networks and individual ECUs. The paper explains in detail how to create 3 different networks (LIN, CAN, and FlexRay) and also how to design a gateway so that the messages can be transferred between different communication protocols [3].

**D. Diagnosis in Automotive Systems: A Survey**
Patrick E. Lanigan et al surveyed the technical literature for failure diagnosis approaches of a vehicle. This survey addresses both the online failure diagnosis approaches and offline failure diagnosis approaches. The online failure diagnosis is necessary to maintain the safe operation of the vehicle at operation/run time. The offline failure diagnosis is suitable for maintenance of the vehicle in a service facility. This survey gives a candid and critical look at the current state-of-the-art, highlighting where the field practices fall short of accomplishing the goals of safety-critical autonomous driving systems [4].

**F. Automotive Diagnostics Development Seminar** by Jeff Craig emphasized the evolution of automotive diagnostic technology, Diagnostic Standards, Transport Protocol, UDS (ISO 14229), running UDS on Different Buses (J1939, Ethernet) [5].

**G. Monitoring and Control System for Industrial Parameters Using CAN Bus**
Sarguna Priya.N et al described the system to monitor and control the various parameters such as pressure, temperature, and water level in the industry. The system uses PC, various sensors, and PIC microcontroller. The system provides an automatic control of various industrial parameters with the help of CAN bus application [6].

**H. Design and Development of a Vehicle Monitoring System Using CAN Protocol**
Mohammed Ismail et al described the prototype system to monitor real-time parameters of the vehicle using CAN protocol. It uses PIC microcontroller with its ADC module to gather data from analog sensors and converts it into to digital format. Then this information is displayed to vehicle driver through LCD display. It uses CAN bus as communication model which has efficient data transfer [7].

**I. Vehicle Health Monitoring System**
M.Jyothi Kiran et al described an in-vehicle embedded system which can generate Vehicle Health Report (VHR) as per user need. The data required for VHR can be obtained using OBD-II protocol. The system uses LabVIEW platform which has automotive diagnostics command set toolkit [8].

**J. Interfacing CAN Bus With PIC32 Microcontroller for Embedded Networking**
Umesh Goyal et al discussed on how to use the PIC32 microcontroller to develop CAN bus for embedded networking. It uses PIC32MX795F512L and IS01050 ICs to implement CAN bus. Also, the paper emphasizes the CAN protocol frame format and its working [9].

**K. Road vehicles — Unified diagnostic services (UDS) — Specification and requirements**
ISO 14229 Second Edition. This is an ISO standard 14229. It states the specification and requirements of Unified Diagnostics Services (UDS) protocol. It is must understand standard to get the knowledge of CAN diagnostics communication [10].

**L. Fault Diagnosis in Hybrid Electric Vehicle Regenerative Braking System**
Chaitanya Sankavaram et al described the fault diagnosis of regenerative braking systems (RBS) of Hybrid Electric Vehicle (HEV). It presents a systematic data-driven process to detect and diagnose faults in the regenerative braking. It uses wavelet-based feature extraction and MPLS-based data reduction to extract fault information, and subsequently, different diagnosis algorithms such as pattern recognition techniques, Euclidean distance criteria, and inference-based algorithms are used for classifying faults in the RBS simulation model [11].

**M. Incremental Classifiers for Data-Driven Fault Diagnosis Applied to Automotive Systems**
Chaitanya Sankavaram et al described the data-driven fault diagnosis. It employs statistical models, which can classify the data into nominal (healthy) and a fault class or distinguish among different fault classes. It explained the incremental learning techniques and validated the performance of an ensemble of classifiers on an automotive system. [12].

## III. DIAGNOSTICS TOOL SUMMARY

The Table1 shows the comparative summary of various hardware and software available for diagnostics tool.

Table 1: Diagnostics Tool Summary

| Parameters | CANoe with CANCase XL | PCAN | CANUSB |
|---|---|---|---|
| **Environment** | Hardware + Software | Hardware + Basic Software | Only Hardware. Application SW needs to be developed |
| **Protocol Supported** | CAN, LIN, XCP | CAN | CAN |
| **Max Speed** | 1 Mbps | 1 Mbps | 1 Mbps |
| **CAN Channel** | 2 | 2 | 1 |
| **Power** | USB | USB | USB |
| **Support ID** | 11/29 Bit | 11/29 Bit | 11/29 Bit |
| **PC Isolation** | Yes | Yes | Yes |
| **Tool SW Access** | No | Yes | Yes |
| **CAN Controller** | Phillips SJA 1000 | NXP SJA1000 | Philips SJA1000 |
| **CAN transceiver** | Piggybacks | NXP PCA82C25 1 | Philips 82C25 |
| **Operating Temperature** | -20 to 70 °C | -40 to 85 °C | -40 to 85 °C |
| **Cost** | ~ € 10,000 | ~ € 180 | ~ $ 120 |

## IV. PROPOSED SYSTEM BLOCK DIAGRAM

The proposed system contains following blocks explained hereunder in figure 1.

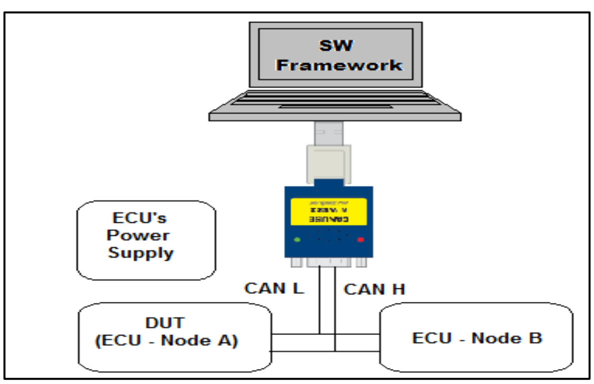



*Figure 1. Proposed System Block Diagram*

**Power Supply**: The power supply is used to power up the ECUs. It is required to keep the ECUs ON.

**DUT:** It is the Device Under Test. It is the ECU which we are using for diagnostics validation i.e. to monitor the health. It should support diagnostics over CAN protocol.

**CANUSB:** The system uses the CANUSB hardware as an interface between host PC and ECUs. CANUSB does not need the external power supply; it uses the power supply from host PC. The CANUSB supports both the 11bit as well as the 29bit CAN message ID format, RTR frames, built in FIFO queues and extended info/error information.

**SW Framework:** It is the application software developed using Microsoft C# language and DLL. It empowers the user to transmit and receive the CAN messages to/from DUT using CANUSB. Figure 2 shows the UI and Architecture of SW framework at a high level. It has GUI which enable the user to customize the CAN message to be sent. The middleware & event handling code handles all the working logic of the proposed system. The CANUSB device drivers take care of interaction between CAN bus and the middleware.

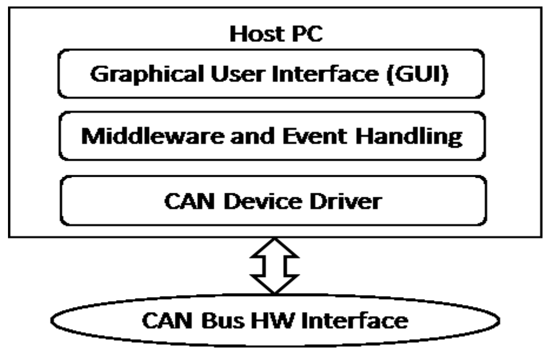



*Figure 2. UI and Architecture*

## V. PROPOSED SYSTEM WORKFLOW

The figure3 shows the flowchart of the proposed system.

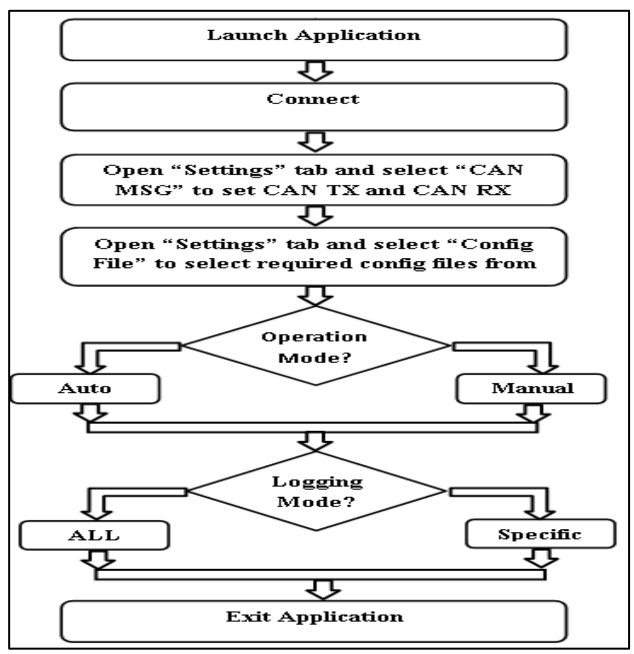



*Figure 3. Flow Chart*

## VI. RESULTS

The proposed system is developed as per the gathered requirements. Figure 4 shows the CAN Bus network. It uses ECU A and ECU B. It uses PIC microcontroller PIC18F458 for ECUs and MCP2551 CAN transceiver. It is a High-Performance, Enhanced Flash Microcontroller with CAN Module. The ECU A and ECU B form the CAN Bus network. The ECU A is the DUT.

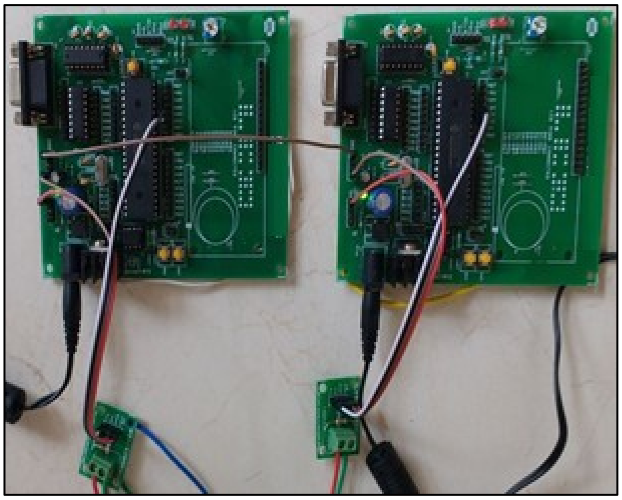


*Figure 4. CAN Bus Network ECU A and ECU B*

Figure 5 shows the ECU Health Monitor GUI. It has two operational modes; Manual operation mode and Auto operation mode. In manual mode, the user needs to fill-up all the fields of the message to be transmitted. The fields are 'DLC', 'MSG ID' and 'MSG Data bytes B0-B7'. Once all the fields are filled-up, the user needs to press 'Now' button to send the message. To send the message cyclically, the user needs to specify cycle time in 'Time' field and tick the checkbox present to the right side of the 'Now' button. In Auto Mode, the messages are transmitted automatically. For this, the user has to create a file by filling up all the fields of messages to be transmitted. The tool reads the messages from the file and sends these messages on bus automatically.

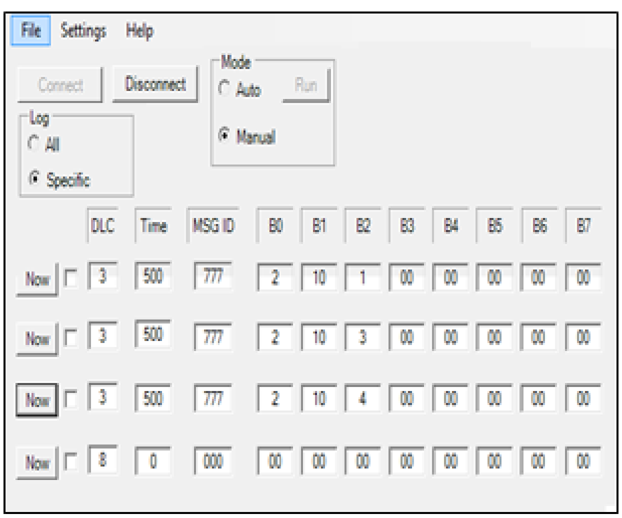
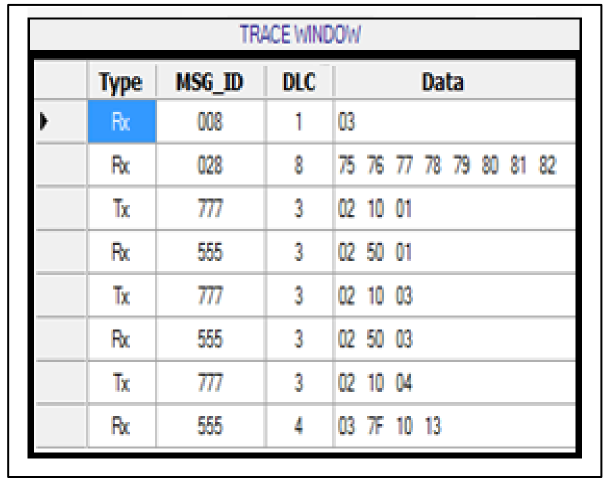



*Figure 5. ECU Health Monitor GUI*

Figure 6 shows the Trace Window of ECU Health Monitor. It has various fields of message like 'Type', 'MSG ID', 'DLC', and 'Data'.



TRACE WINDOW

| Type | MSG_ID | DLC | Data |
|---|---|---|---|
| Rx | 008 | 1 | 03 |
| Rx | 028 | 8 | 75 76 77 78 79 80 81 82 |
| Tx | 777 | 3 | 02 10 01 |
| Rx | 555 | 3 | 02 50 01 |
| Tx | 777 | 3 | 02 10 03 |
| Rx | 555 | 3 | 02 50 03 |
| Tx | 777 | 3 | 02 10 04 |
| Rx | 555 | 4 | 03 7F 10 13 |

*Figure 6. ECU Health Monitor Trace Window*

Using the Trace Window, the user can monitor the CAN communication happening on the CAN bus. The Trace Window helps to analyze the Diagnostics Request Response. Thus it enables to perform ECU diagnostics validation and monitor the ECU health.

The trace window is showing:

1. Communication Started

(0x008) – 01

(0x028) – 75 76 77 78 79 80 81 82

The 'ECU A' and 'ECU B' forms the CAN bus network. An 'ECU A' sends the message 0x008 and an 'ECU B' sends the message 0x028. The appearance of these messages on Trace Window indicates that the CAN communication is established between 'ECU A' and 'ECU B'.

2. Diagnostics Request (0x777) - Change Diagnostic Session to Default Session - 02 10 01

3. ECU Positive Response (0x555) - 02 50 01

The message 0x777 is a diagnostics request from 'ECU Health Monitor' tool to 'ECU A'. Hence the message's 'Type' is 'Tx' and it can be seen in trace window. In response to this request, an 'ECU A' sends a positive response 50. As this message is received by 'ECU Health Monitor' tool, the message's 'Type' is 'Rx' and it can be seen in Trace Window. This is a valid request from tool hence 'ECU A' changes the diagnostics session to Default session. The diagnostics session is indicated by message 0x008. The value 01 indicates that it is Default session. All these response logic is written in 'ECU A'.

4. Diagnostics Request (0x777) - Change Diagnostic Session to Extended Session - 02 10 03

5. ECU Positive Response (0x555) - 02 50 03

The message 0x777 is a diagnostics request from "ECU Health Monitor" tool to 'ECU A'. In response to this request, an 'ECU A' sends a positive response 50 and changes the diagnostics session to Extended. The diagnostics session is indicated by message 0x008. The value 03 indicates that it is Extended session. All these response logic is written in 'ECU A'.

6. Diagnostics Request (0x777) - Invalid Request - 02 10 04
7. ECU Negative Response (0x555) - 03 7F 10 13

The message 0x777 is a diagnostics request from 'ECU Health Monitor' tool to 'ECU A'. This is invalid request as per the logic is written in an 'ECU A'. So in response to this request, an 'ECU A' sends a negative response 7F.

## VII. CONCLUSION

The "ECU Health Monitor" tool is successfully designed and developed along with 'ECU A' and 'ECU B'. The ECUs are developed using PIC microcontroller PIC18F456 and CAN transceiver MCP2551. The 'ECU A' and 'ECUB' fulfill the need of CAN bus network. This paper gives an overview of various Diagnostics tools, methodologies used by diagnostics tools, and Evolution of Automotive Diagnostic Technology. The paper explains the workflow of the "ECU Health Monitor" tool and its principle of operation. Using "ECU Health Monitor" tool, an ECU diagnostics validation can be performed and ECU health can be monitored. Thus it helps to develop safety compliant robust ECUs, ultimately enables the driver and passenger safety. The "ECU Health Monitor" tool can be enhanced further to be used as 'Vehicle Health Monitoring System'.

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