Diagnostics & Trouble Shooting of Turbocharged Diesel Engine by OBD System

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Abstract

On-Board Diagnostics or OBD, is an automotive term referring to a vehicle's capability to diagnose and display faults and real -time sensor data. The objective of the thesis is to develop a low cost customized OBD prototype for a non OBD vehicle. In the case of any fault in a non OBD vehicle the driver just gets a warning through the glow of the Malfunction Indicator Lamp (MIL) but does not know the area of occurrence and nature of the fault. Most drivers are not aware of the significance of the MIL lamp. This leads to deterioration of vehicle health leading to unexpected breakdowns and obnoxious emissions. Toyota Innova's 2KD-FTV turbocharged diesel engine with intercooler is chosen for this experimental project. In this paper we propose a system that could detect and report the major engine faults of the Innova vehicle. The prototype also features data logging capability as well as provide repair guidance that is useful for drivers, engine tuners and mechanics. The proposed work is to analyze the following engine faults related to Fuel rail pressure sensor circuit, Intake Air Temperature Sensor Circuit(IAT), Manifold Absolute Pressure circuit (MAP) and Exhaust Gas Recirculation Flow Circuit (EGR). The Fault Thresholds, Detection Drive, Detection condition, Symptoms and Trouble areas are studied for Innova GX 2.5. Real time experimentation is done on the vehicle using Teach stream software and the waveforms for good and not good conditions are obtained. The prototype is developed using Arduino Uno with CAN as the communication protocol.

Keywords

OBD, 2KD-FTV, CAN Protocol, Arduino, Innova GX2.5

I. Introduction

The first onboard diagnostic computer system was introduced by Volkswagen in 1969 in their fuel-injected type 3 models. Car manufacturers look on to manufacture cars with reliable diagnostic systems that would alert the driver in the case of a fault occurrence and ensure that the faults are fixed before the car can actually breakdown. The amount of diagnostic information available via OBD has varied widely since the introduction of cars with OBD feature in the early 1980s.

The OBD II system helps to get various types of data from the Electronic Control Unit (ECU) of the car when the mechanics or car owners want to know the condition of their car. Different types of diagnostic data or parameters can be extracted from car using communication protocols. A review of the literature on the different parameters diagnosed and technologies incorporated in the OBD are discussed below.

Jerzy Merkiszt et al. [1] has worked on misfire fire detection methods in engines based on OBD data. Misfire Detection was done using Analysis of the Instantaneous Crankshaft Angular Velocity, Instantaneous Engine Exhaust Gas Pressure and Engine Torque. Jyong Lin et al. [2] have done a study on Remote On-Line Diagnostic System for Vehicles by Integrating the Technology of OBD, GPS, and 3G. Othman Nasri et al. [3] have developed a model-based decentralized solution and its application to the embedded diagnosis of the SDK system inside Renault-Volvo Truck with five control units connected via a CAN-bus using "Hardware in the Loop" (HIL) technique.LI Jun-wen et al. [4] have worked on maintenance way of electronic fuel pump control. Control areas analysed are fuel pump switch control, ECU control, and rotational speed control. X.L Zhou et al. [5] have studied on On-board diagnosis of the drive circuit of an electronically controlled injector. Through analysing the feedback current and voltage of the drive circuit under faulty and no-fault conditions and abstracting fault symptoms, this paper extends further the range of on-board diagnosis strategies, which can trigger an appropriate failure strategy to guarantee safety.

Richard J. Dumont et al.[6] have worked on Test and Control of Fuel Injector Deposits in Direct Injected Spark Ignition Vehicles by developing a short-duration fuel injector fouling test. Parameters studied were Long Term Fuel Trim and injector flow rate. Timothy H. Defries et al. [7] has worked on In-Use Fuel Economy and CO2 Emissions Measurement using OBD which is a cost effective method to collect in-use fuel consumption data using the on-board diagnostics (OBD) data stream in light-duty vehicles (LDVs).An analysis compared fuel rates calculated from OBD inputs, including mass air flow (MAF) sensor and narrow-band O2 sensors, against fuel rates determined through carbon balance measurements from dynamometer chassis testing.

Toyota's Innova is ranked the most selling car but it is a non-OBD vehicle. Our objective is to develop an OBD prototype that will improve the car's diagnostic feature in a low cost and reliable way using the latest Ardiuno electronic prototyping board and CAN protocol. While drivers want nothing more than dependable, economical transportation, many of us are looking to OBD for extra performance. A memory chip that can be interfaced with the Ardiuno can be used as a data logger. The service technician can just take the chip and insert it into his computer. Based on the pattern of the real time values recorded since the start of cranking of the vehicle he can diagnose the fault easily. This saves precious service time and more number of vehicles could be easily serviced.

II. 2KD-FTV Engine Specifications

Model	Toyota Innova GX 2.5
Engine Type	2KD-FTV
No. of Cylinders & Arrangement	4 cylinder, Inline
Valve mechanism	16-valve DOHC, Belt & Gear drive
Manifolds	Cross-flow
Combustion chamber	Direct injection type
Fuel system	Common-rail type
Displacement	2494 cm3 (152.2 cu.in)
Bore x Stroke	92.0 x 93.8mm
Compression ratio	18.5 : 1
Max.Output	75 kW @ 3600 rpm
Max.Torque	200 N-m @1400-3400 rpm
Firing order	1-3-4-2
Cetene rating	48 or higher
Emission Regulation	EURO III

III. Engine Fault Study & Experimental Analysis using Teachstream software

A. Fuel Rail Pressure Sensor Circuit Malfunction

1. Symptoms

- Black smoke
- Lack of power
- Poor drivability
- Lack of power due to accelerator restriction performed by Fail- safe function

2. Detection Drive Pattern

Ignition switch to ON for 1 second.

3. Detection Logic

1 trip detection logic

4. Fault Detection Condition

Fuel pressure sensor circuit low input- Fuel pressure sensor output 0.55V or less for 0.5 secs
Fuel pressure sensor circuit high input- Fuel pressure sensor output 4.9V or higher for 0.5 secs

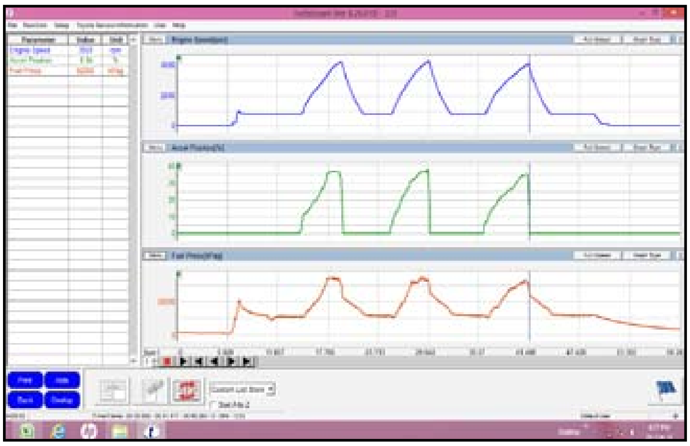


Fig. 1: Fuel Rail Pressure Sensor Circuit Good

Fig. 2: Fuel Rail Pressure Sensor Circuit Faulty

If the Rail pressure sensor circuit is good then as the engine throttle is increased and decreased the pressure also increases and decreases correspondingly as shown in Fig.3. If there is a fault in the fuel pressure circuit, despite the load variations the fuel pressure is a constant value, greater than 20000kPa as shown in Fig.4.

5. Trouble Area-

- Open/Short in FPS circuit
- Check Fuel pressure sensor
- Check ECM

B. Intake Air Temperature Sensor (IAT) circuit Malfunction-

1. Symptoms-

- Misfire
- Lack of power
- White smoke
- Combustion noise
- Black smoke

2. Detection logic

1 trip detection logic

3. Detection Drive Pattern

Ignition switch to ON for 1 second.

4. Detection condition

Open in IAT sensor-Temperature displayed in IAT sensor is -40° C (-40°F) for 0.5 secs
Short in IAT sensor-Temperature displayed in IAT sensor is 140° C(284°F or higher) for 0.5 secs

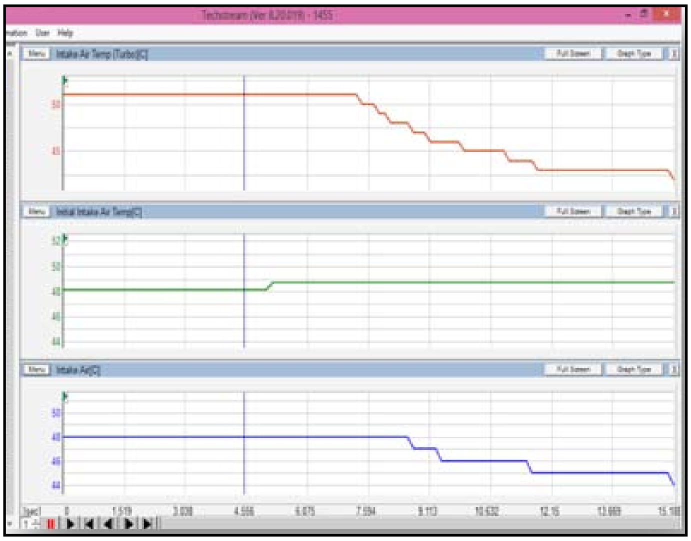


Fig. 3: IAT Sensor Circuit Good

If the Intake Air temperature sensor circuit is good then as the engine load is varied then the graph of the intake air temperature also shows variations as shown in Fig.3.

Fig. 4: IAT Sensor Circuit Faulty

If the IAT sensor circuit is in an open circuit condition then the waveform shows a standard value of -40°C, even though the load on the engine is varied as shown in Fig.4. Similarly for a short circuit fault the waveform remains constant throughout with a value of 140°C

5. Trouble Area-

- Open/Short in IAT circuit
- Check IAT sensor
- Check ECM

C. Manifold Absolute Pressure (MAP) Sensor Circuit Malfunction

1. Symptoms

- Black smoke
- White smoke
- Misfire

2. Detection Drive Pattern

3 secs after engine is started.

3. Detection Logic

1 trip detection logic

4. Detection Condition

MAP Circuit Low- MAP voltage is 0.2V or less with the engine speed at 4000rpm or less for 3 secs.
MAP circuit high-MAP meter voltage is 4.9V or high with the engine speed at 4000rpm or less for 3 secs.

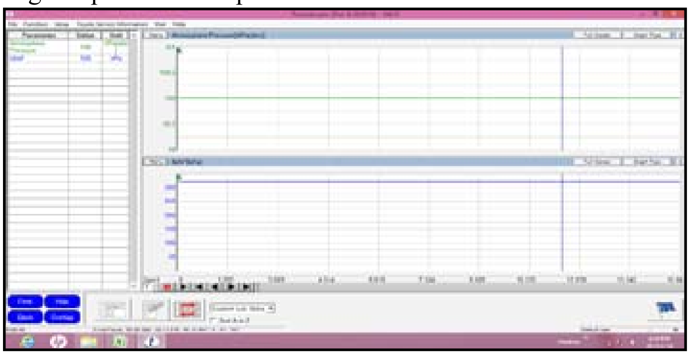


Fig. 5: MAP Sensor Circuit Good

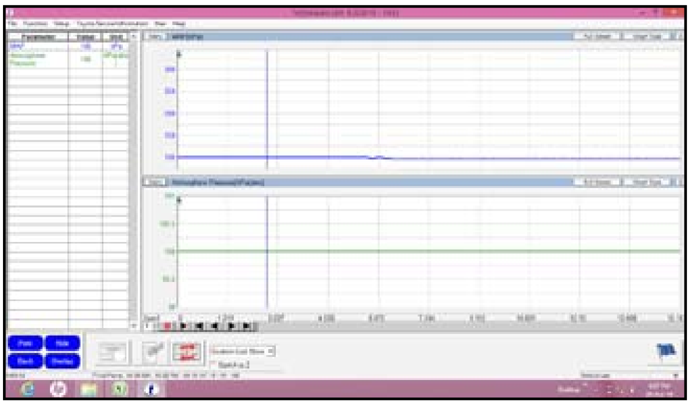


Fig. 6: MAP Sensor Circuit Faulty

If the MAP sensor circuit is good then as the engine load is varied then the graph of MAP sensor voltage level will be in the range of greater than 0.2 V but less than 4.9 V as shown in Fig. 5. If there is an open circuit then the waveform shows a pressure value with a corresponding voltage value that is less than 0.2V as shown in Fig. 6.Similarly if there is an open in the circuit a corresponding voltage level of MAP sensor output will be 4.9V or higher.

5. Trouble Area

- Open /short in MAP sensor circuit
- Check MAP sensor
- Check ECM

D. Exhaust Gas Recirculation Circuit(EGR) Malfunction

1. Symptoms

- Detonation
- Hard starting
- Misfire/ Rough Idling

2. Detection drive pattern

EGR valve is forcibly turned On after engine is started.

3. Detection logic

2 trip detection logic

4. Detection Condition

Mass Air Flow rate sensor voltage remains unchanged in spite turning On EGR assembly

Then the EGR valve is forcibly turned On using the Activate Data List in the Teachstream software. If the EGR circuit is good then MAF sensor output shows variations as in fig. 7. When there is a fault in the EGR circuit even though the EGR assembly is turned on the Mass Air Flow rate is not varied. MAF sensor ouput shows a constant value as in fig. 8

Fig. 7: EGR Flow Circuit Good

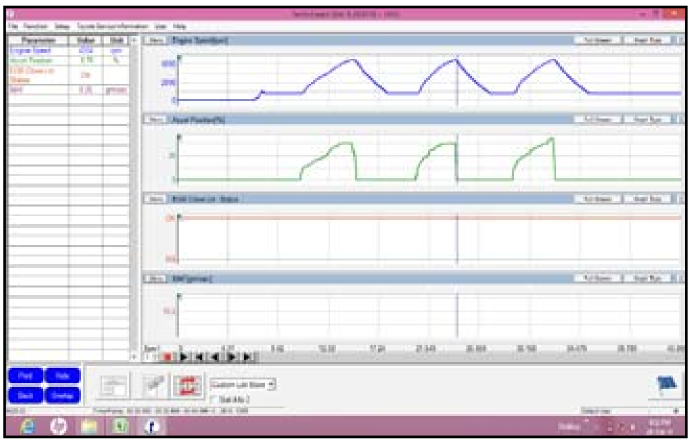


Fig. 8: EGR Flow Circuit Faulty

5. Trouble area-

- EGR valve assembly stuck
- Mass Air Flow meter
- EGR valve assembly does not move smoothly
- EGR blockage inline between exhaust manifold and intake manifold.
- Intake system leaks or blockages
- Exhaust system (Exhaust gas leaks)
- ECM

IV. Prototype Development

The heart of the OBD is the Arduino electronic platform containing the Atmega328 microcontroller. The blocks of the OBD prototype are Sensor Module, Display Module, CAN module and Data logger module. Arduino board operates at 12V Dc and has an inbuilt voltage regulator that gives 5V and 3.3V respectively which is used as input voltage for the prototype sensors. In the vehicle, the ECM gives a voltage of 0.5V to the sensors.The CAN module is constructed using Microchip MCP 2515 CAN Controller and MCP 2551 CAN Transceiver IC's. Twisted two wire copper wire is used as the medium. The transmission line is properly terminated to prevent reflection loss. The speed of data transmission by the CAN protocol was set to 500KBps. The memory chip interfaced with the Ardiuno board provides data logging of all the sensor data. It can be removed and connected to the PC for future diagnostics by the technician. The Transfer mode for data transfer was chosen to be SPI over its comparison with I2C and UART modes. Coding and compilation for Fault detection, LCD display, Datalogging and CAN communication was done using the Arduino Software and uploaded into the Arduino board.

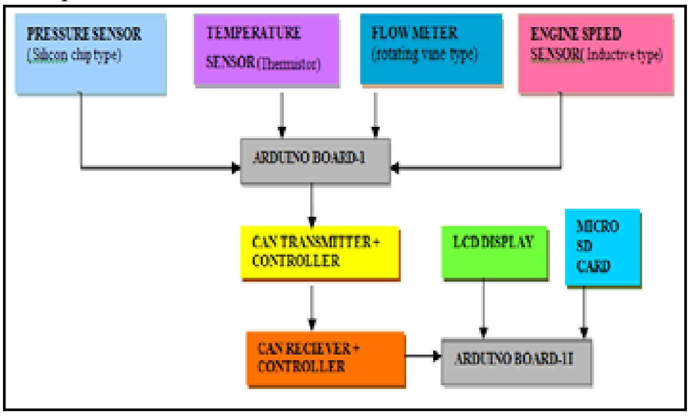


Fig. 9: Block Diagram of the OBD Prototype

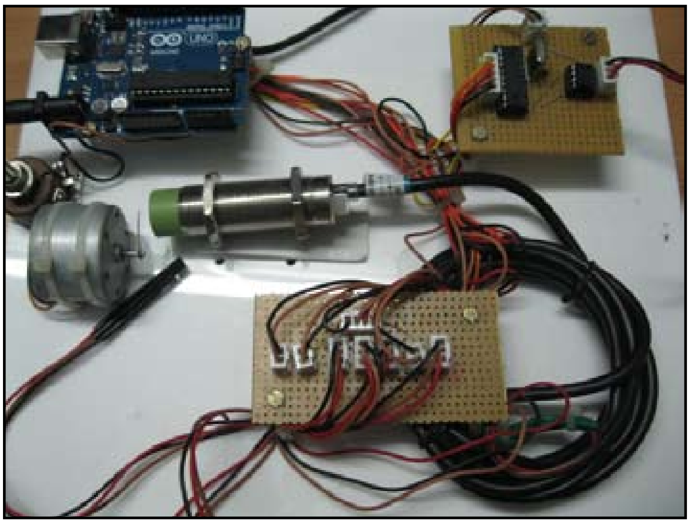


Fig. 10: Sensor Module

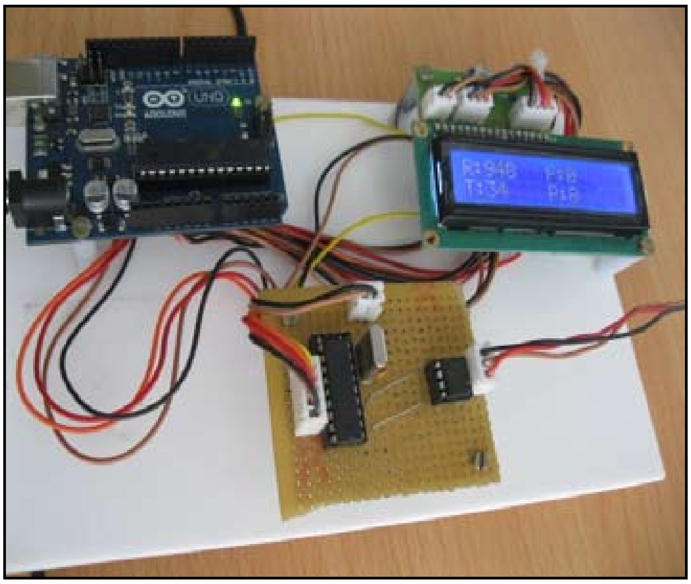


Fig. 11: Display Module

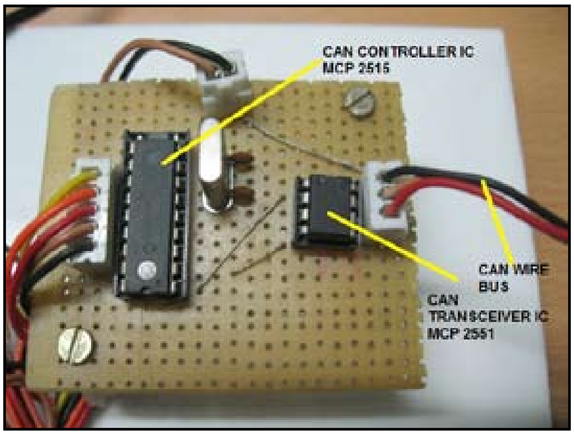


Fig. 12: CAN Module

V. Test-Bench Verification of Prototype

A Test bench module was constructed before the OBD was tested with the engine. As we cannot generate very high levels of temperature, pressure etc during testing, nominal values were chosen as thresholds to check the robustness of the device. The following sensors were used for the Test bench.

Fig. 13. LM34 Temperature

Fig. 14: Rotating Vane Flow Meter

Fig. 15: Silicon Chip Type Pressure Sensor

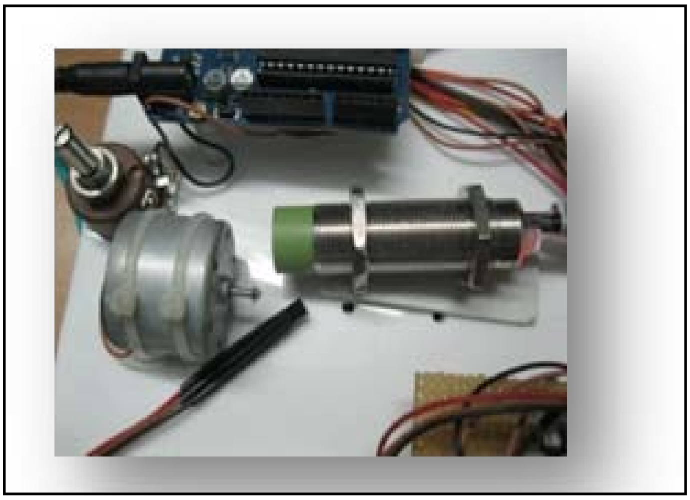


Fig. 16: Inductive Proximity Sensor

Parameter	Threshold set
Pressure	154 Pa
Temperature	105 degree Celsius
Flow	53 gm/sec

VI. Testing the Prototype with 2KD- FTV Engine Sensors

The following sensors were interfaced with the OBD prototype and tested by intentionally malfunctioning any one of their areas like for example making the sensor an open/short circuit.

Fig. 17: OBD Interfaced to Vehicle Sensors

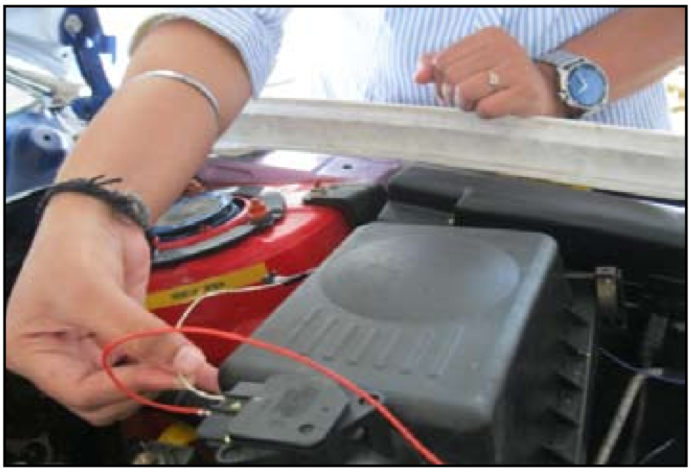


Fig. 18: MAP Sensor Interfacing

Fig. 19: IAT Sensor Interfacing

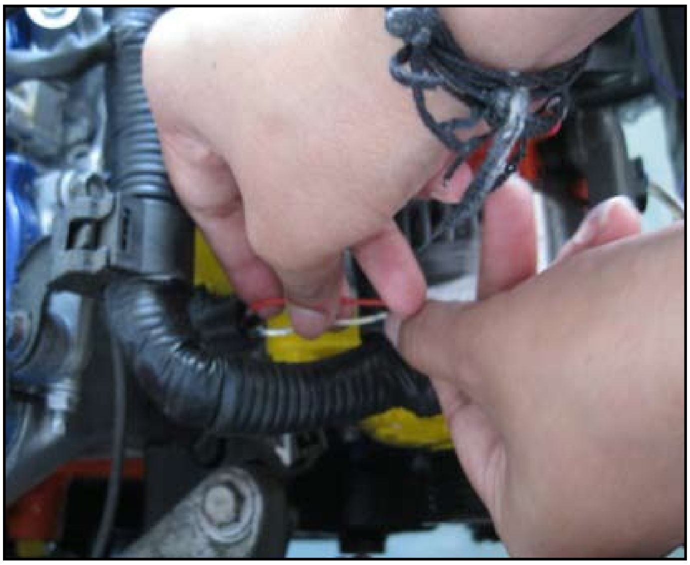


Fig. 19: Fuelrail Pressure Sensor Interfacing

Fig. 20: MAF Sensor Interfacing

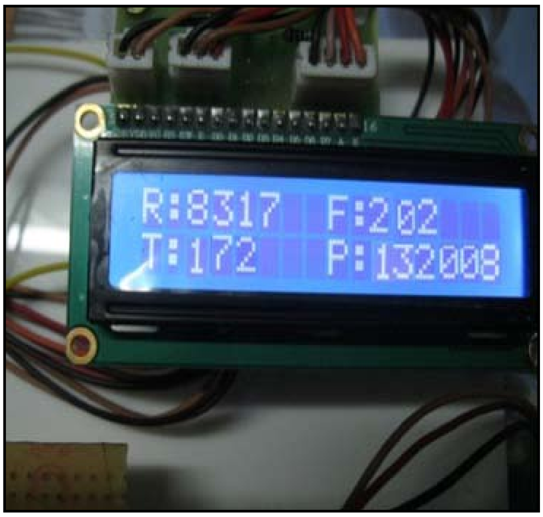
VII. Results & Conclusion

1. The OBD Prototype was able to successfully diagnose the faults in the circuits. It was able to detect the abrupt abnormal threshold levels. The threshold levels were set as below.

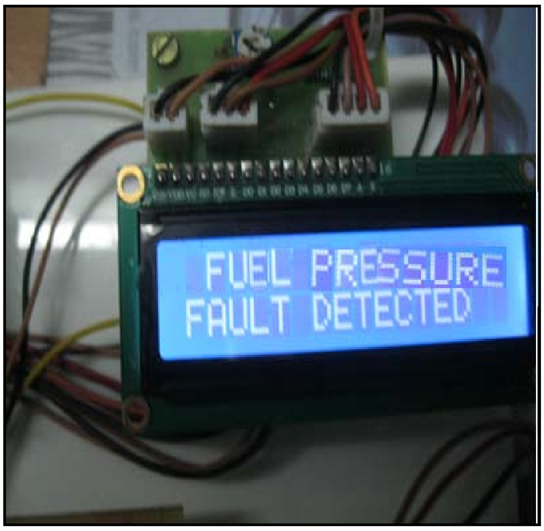
(Source : Innova Repair Manual)

Parameter	Threshold
Fuel Rail Pressure Sensor	0 KPa, 190000kPa
IAT Sensor	40 degree C, 140degree C
MAP Sensor	40 KPa, 320kPa
MAF Sensor	Should monitor MAF level for unchanging flow rate with EGR on

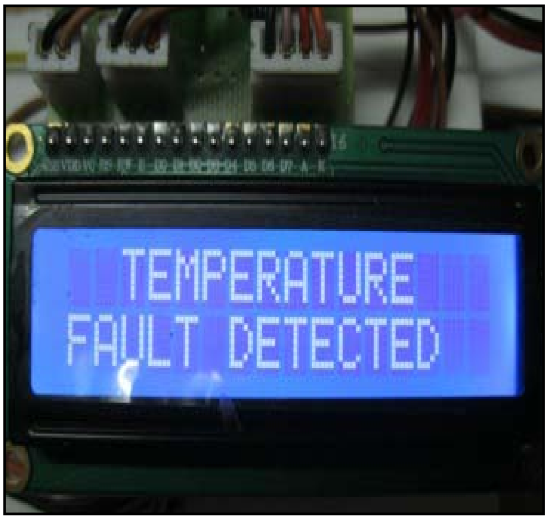
2. The OBD designed works robustly for diagnosing the faults of the 2KD-FTV engine using CAN bus at the speed of 500Kbps
3. Ability to detect multiple faults successfully.
4. Ability to Data log the faults at the speed of 8Mhz using SPI as the Transfer Protocol
5. The device is : Economical, Compact and lists out major engine circuit faults:
   - Fuel Rail Pressure Circuit Malfunction
   - Intake Air Temperature Circuit Malfunction
   - Manifold Absolute Pressure Circuit Malfunction
   - Exhaust gas Circuit Malfunction (Flow)
6. The Arduino UNO has provided a successful prototyping platform to design OBD for all versions of Innova model.



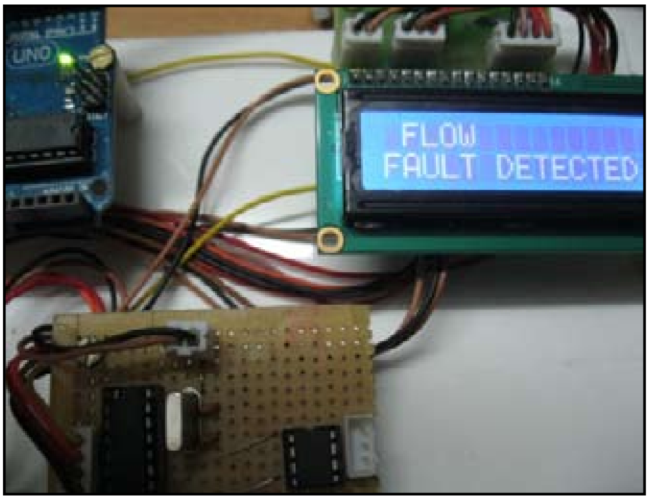
(a)



(b)



(c)



(d)

Fig. 20 (a, b, c, d) : Reading Real Time Sensor Values & Displaying Fault Area

VIII. Acknowledgement

I would like to thank Mr. Viswanathan D and Mr. Durai Raj. R of Lanson Toyota Pvt.Ltd., Chennai for their valuable support extended to complete this Industrial Internship Master's Thesis at their esteemed organization.

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