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Survey on "On Board Diagnostics - OBD"

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Abstract

The diagnosis of the problems faced in automotive present some challenging tasks to the car manufacturing companies. The cars must pose an easy to fix technique towards all of the issues picked up during its operation. The solution to this is the OBD. This paper will help the understanding of - OBD and its concepts. It will also help us to know how the malfunctions in the working of a car are detected by the OBD system, how are they identified using a scanning tool, how do Electronic Control Units(ECUs) communicate with each other using the protocols and how is the interface provided between the car and the PC for error analysis. Finally, the knowledge of software is provided which will help us know the use of OBD information for clever manipulations of performance results made by the car.

Keywords-*OBD (On Board Diagnostics), ECU (Electronic Control Unit)*

I. INTRODUCTION

Consider an automotive company that has released its product for customers. The car gets sold and some errors are expected to creep in as its use progresses. Thus, this calls for a need to have a customer service interface between a customer and the company. This interface is important for two reasons. Firstly, the market value of the car gets decided by the quality of customer support provided by the company. Superior is the service, better is the brand value of the car. Second reason is something that is exclusively applicable for automotives. Since automotives are one of the major reasons for air pollution, there is a need to regularly monitor the emissions made by the car. If there are a lot of toxic emissions, then there is a serious need for getting the emission system of the car back on track. It is for these reasons, especially the above mentioned second reason that a system such as OBD came into existence in cars.

II. EVENTS THAT LED TO THE BIRTH OF OBD

Basically OBD was introduced with a view of having a regulatory check over the emissions made by the car and keeping them within the safe limits. Today however, the idea of OBD is extended to monitor any electronic, mechanical or chemical component in a car. Following is a Table 2.1 of some of the noteworthy issues that have happened over the years. A look at the Figure 2.2 gives a better overview.

YEAR	EVENT
1960	California Motor vehicle Pollution Control Board (CMVOCB) was created in the U.S.A., to implement the air quality standards.
1966	California and the federal government used a driving cycle to certify 1966 vehicles and newer models which was referred to as either California Cycle or the Federal Test Procedure (FTP)
1970	The First major Clean Air Act was adopted by the Congress in 1970. Congress established the Environmental Protection Agency (EPA) with the overall responsibility of regulating motor vehicle pollution to the atmosphere. Congress also identified the Inspection and Maintenance (I/M) programs as an alternative for improving the air quality.
1975	All of the previous regulations led to the appearance of the charcoal canister, Exhaust Gas Recirculation (EGR) valves, and finally the catalytic converters
1977	Amendments to the Clean Air Act mandated inspection and maintenance for vehicles used in high pollution areas affected by high Hydro Carbon (HC) emissions.
1989	The California Code of Regulations (CCR) known as OBD II was adopted by the California Air Resources Board (CARB).

III. WHAT IS OBD

OBD [1] is an enhanced diagnostic monitor, built right into vehicle's Powertrain Control Module (PCM). It is designed to alert the driver when the emission levels of the car are greater than 1.5 times that of the standards set by EPA. Two generations of OBD systems have existed within the cars' PCMs. They are OBD II and OBD II. The OBD I was the standard used for the cars prior to the 90's and OBD II used for certifying the cars post 90's, 1995 onwards to be precise. There are a lot of differences between these two generations. Figure 3.1 shows a block diagram of essentials that the OBD system has in a car.

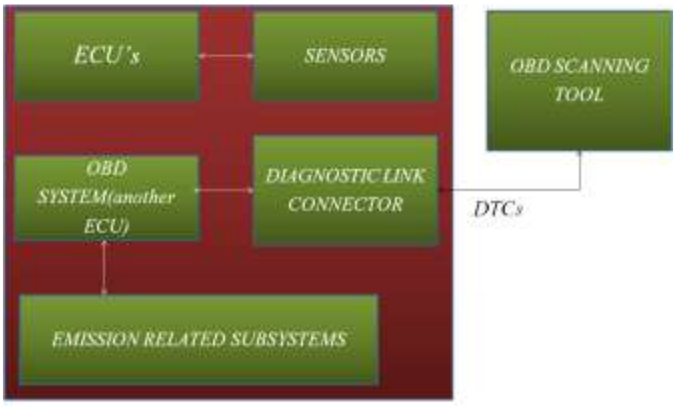

Figure 3.1: OBD Components

The OBD system is just another ECU in the Powertrain Control Module (PCM) of the car, which is monitoring the performance of various emission parameters. This is achieved by communication protocols (Refer section VII) between ECUs and the sensors that lie on the bus. The OBD system gets the data on a regular basis in every drive cycles (Refer section V) and takes several decisions as to whether to report an error or not? If error is seen then corresponding DTCs and Freeze frame data are stored in the memory and Malfunction Indicator light is being glown. Similar steps are followed in next drive cycles.

3.1 What are monitors?

Monitors are carefully planned experiments by the PCM to see if all the sensors in the engine subsystem are working together to produce acceptable emissions. Some of the monitors are

- Comprehensive component monitor
- Misfire detection monitor
- Fuel system monitor
- Catalyst efficiency monitor
- EGR system monitor
- Evaporative system monitor

These monitors are of two types

1. Continuous: The monitors that are always active during a drive cycle
2. Discontinuous: The monitors become active only if particular conditions for which they are serving get satisfied.

IV. CONCEPTS USED IN OBD AND THE FLOW OF OBD WORKING

The Figure 4.1 shows a flow of how OBD works in a car. Let us prepare an algorithm related to the same.

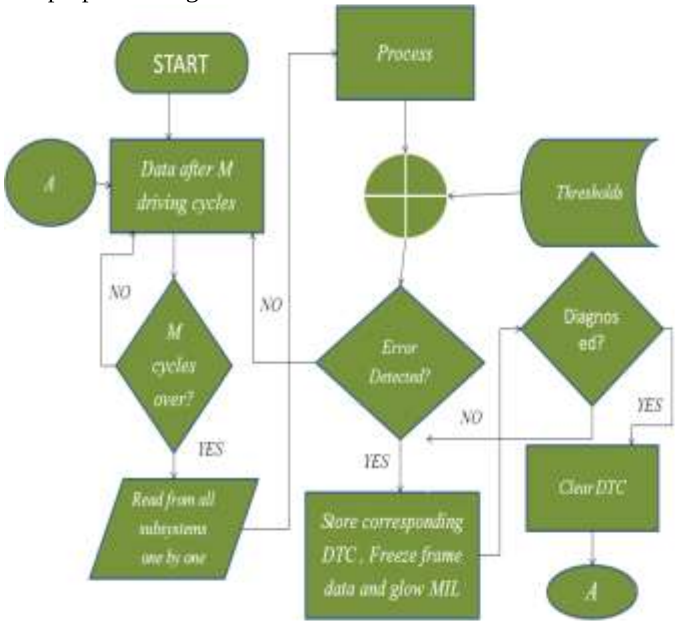

Figure 4.1: Flow of OBD process

Figure 4.2: OBD port in a car

Figure 4.3: Scan tool connected

Figure 4.4: PC connected to OBD system

Figure 4.4 shows connection of PC to the vehicle's OBD system. The PC must have appropriate software. The connection is established. The device connected to the com port is identified by device drivers. The car is taken for drive cycles. The drive cycle is as shown in Figure 4.5 below. This drive cycle is important as the OBD system monitors are performing at various stages.

1. Cold Start: In order to be classified as a cold start the engine coolant temperature must be below 50°C (122°F) and within 6°C (11°F) of the ambient air temperature during startup phase. The key must not be on prior to the cold start or the heated oxygen sensor diagnostic may not run.

2. Idle: The engine must be run for two and a half minutes with the air conditioner and the rear defroster should be kept on. The more electrical load applied the better it is. This tests the O2 heater, passive Air, Purge "No Flow", Misfire and Fuel Trim if closed loop is achieved.

3. Accelerate: Turn off the air conditioner and all the other loads and apply half throttle until 88km/hr is reached. Thus the Misfire, Fuel Trim, and Purge Flow diagnostics will be performed.

4. Hold Steady Speed: Hold a steady speed of 88km/hr (55mph) for about 3 minutes. Due to this the O2 response, air Intrusive, EGR diagnostics will be performed.

5. Decelerate: Take the pressure off the accelerator pedal. The clutch and brake should not be touched. The vehicle should coast along gradually slowing down to 32km/hr.

6. Accelerate: Accelerate at 3/4 throttle until 88-96 km/hr: This will perform the same diagnostics as in step 3.

7. Hold Steady Speed: Hold a steady speed of 88km/hr for five minutes. Due to this, along with the diagnostics executed in step 4, the catalyst monitor diagnostics will be performed.

8. Decelerate: This will perform the same diagnostics as seen in step 5. Do not press the clutch or brakes or shift gears.

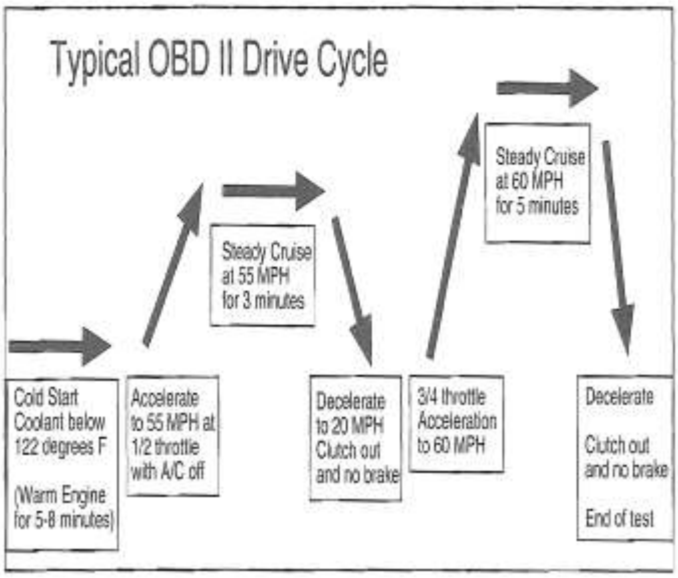

Figure 4.5: Typical OBD drive cycle

From above discussion we can make following list of concepts that are important to OBD.

- What are the subsystems monitored by OBD?
- What are the different protocols used in an OBD equipped car
- Diagnostic Link Connector(DLC)
- Diagnostic Trouble Codes(DTCs)
- OBD scanning tool
- OBD parameter IDs

V. OBD PROTOCOLS

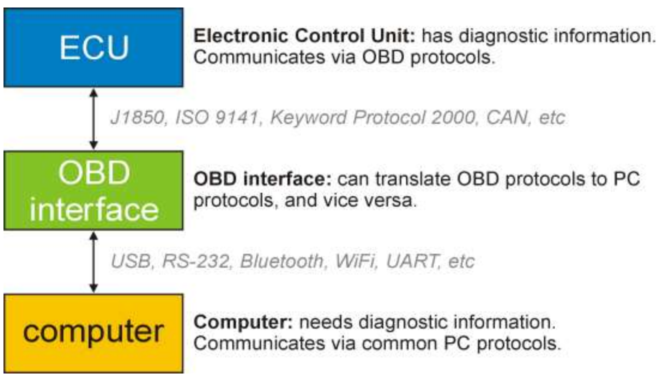

Figure 5.1: OBD and PC protocols

Figure 5.1 shows the OBD 2 protocols [4] and PC protocols. It also shows the need of OBD interface for proper conversion of voltage levels as applicable for a particular end terminal. An OBD2 compliant vehicle can use any of the five communication protocols:

1. SAE J1850 PWM(Pulse Width Modulation)
2. SAE J1850 VPW(Variable Pulse Width)
3. ISO9141-2
4. ISO14230-4 (KWP2000) (Keyword Protocol) and
5. Since 2003 also ISO 15765-4/SAE J2480 (CAN BUS).

a. ISO15765-4 (CAN-BUS):

The most modern protocol and is mandatory for all 2008+ vehicles. The pins 6 and 14 are used and communication could be of differential.

Four variants of ISO15765 are available. The only difference lies with the identifier length and bus speed:

- ISO 15765-4 CAN (11 bit ID,500 Kbaud)
- ISO 15765-4 CAN (29 bit ID,500 Kbaud)
- ISO 15765-4 CAN (11 bit ID,250 Kbaud)
- ISO 15765-4 CAN (29 bit ID,250 Kbaud)

b. ISO14230-4 (KWP2000):

This is a very common protocol for 2003+ vehicles that uses ISO9141 K-Line. Pin 7 is utilized. Two variants of ISO14230-4 are available. They differ only in method of communication initialization. All these variants use 10,400 bits per second.

- ISO 14230-4 KWP(Key Word Protocol)
- ISO 14230-4 KWP

c. ISO9141-2:

This is an older protocol used mostly on European vehicles between 2000 and 2004. It Uses pins 7 and 15 optionally. SAE J1850 VPW Diagnostic bus is used mostly on GM vehicles. Communication speed is 10.4 kB/sec

VI. DIAGNOSTIC LINK CONNECTOR

The following figure shows a DLC. It is a 16 pin female connector which is found on the dashboard at about 1.5 feet from driver's vehicle. Figure 6.1 also shows which pin is designated for a particular protocol. It may be noted that pins 16 (Car battery), 4(chassis ground), 5(signal ground) are common regardless of protocols being used

Figure 6.1: DLC pins of various protocols

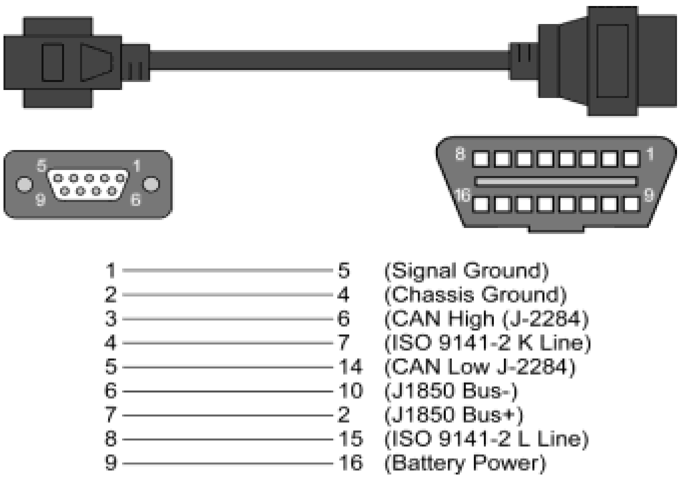

Figure 6.2: PC to DLC interface

The Figure 6.2 shows, the flow of signals between com port of PC and that of DLC. This is required for the interface of the 16 (Car battery), 4(chassis ground), 5(signal ground) are common regardless of protocols being used.

The Figure 6.2 shows, the flow of signals between com port of PC and that of DLC. This is required for the interface of the OBD system to that of PC. The cable is made available along with the scanning tool kit purchased from a particular vendor.

VII. DIAGNOSTIC TROUBLE CODES

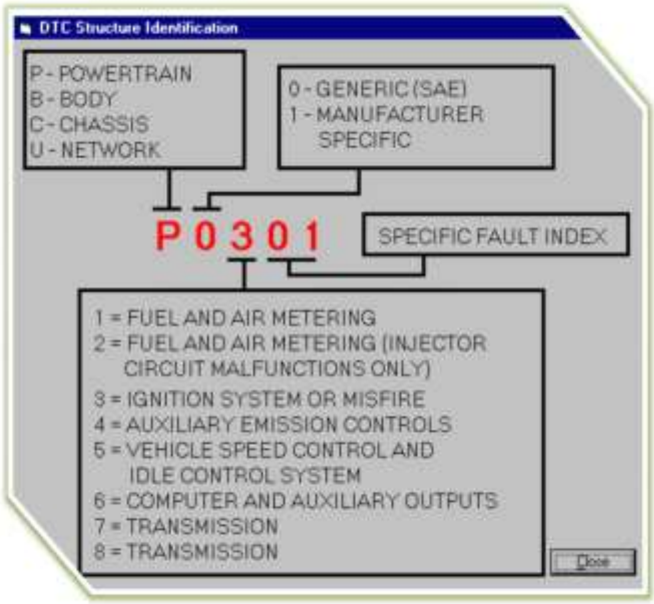

Figure 7.1: DTCs

The DTCs [5] stored in the vehicles' on board computer is a 5 digit format in case of OBD II systems. However in OBD I cars, blinking patterns of LEDs were used to detect a particular error in the emission system of the car. The DTCs of OBD I were not generic and were manufacture specific. The DTCs stored in this case were only for electrical and mechanical failures (at most) but never for chemical failures unlike OBD II.
OBD II DTC format is as shown in Figure 7.1. The format of the error codes is listed in the same figure. In the example shown, cylinder 3 has misfired. Also note that second digit indicates whether the fault codes are according to SAE standards or are manufacture specific.
Examples:

- Idle air control (IAC) valve (505-507) Idle control system diagnostics are performed for deterioration of idle air flow characteristics.
- In case of idle air control system malfunction fault code 505 is assigned.
- If the idle air control system is indicating lower than expected flow, fault code 506 is assigned and if the idle air control system is indicating higher than expected flow fault code 507 is assigned.

VIII. OBD SCANNING TOOLS

Figure 8.1 shows an OBD scanning tool according to SAE J1978 standard. The OBD scanning tool must be able to perform the following functions

Figure 8.1: Scan Tool

- Display DTC's.
- Display the Freeze Frame data.
- It must also have the ability to clear the previously diagnosed DTC and reset the freeze frame.

8.1 Freeze Frame Data

A freeze frame data is defined as a snapshot of various engine parameters that existed when a particular DTC was stored. If more than 1 DTC is stored at a time, then the freeze frame data corresponding to the latest DTC is stored and the previous freeze frame is erased or removed from the memory. The freeze frame assists the driver to simulate the conditions that caused an error to occur, thus helping in solving a problem in a much simplified way. The freeze frame data is regarding the following information

- Engine RPM
- Vehicle speed
- Air flow
- Engine load
- Fuel pressure
- Fuel trim value
- Engine coolant temperature
- Closed loop status

IX. OBD PARAMETER ID's

The OBD scanning tool that is used to retrieve the freeze frame data and the stored DTCs must be able to do a whole lot of functions than just that. These multiple functions are decided depending upon the mode of operation of the scanning tools. The modes are represented in hexadecimal number systems and are as shown Figure 9.1. Each mode of operation once selected has various sub modes of operation residing within them.

For example, if mode 1 and 16 is selected, then the OBD system responds by giving out 4 bytes of data (in this case only 2 bytes are enough). The 2 bytes correspond to oxygen sensor output voltage. The minimum reading would be 0 and maximum reading being 1.625 volt. The same mode of operation gives fuel trimming information, that tells the driver regarding leaner or exhaust rich fuel. In this way a particular mode will give a specific response as requested by the scanning tool operator.

MODE(HEX)	DESCRIPTION
01	Show current data
02	Show freeze frame data
03	Show stored Diagnostic Trouble Codes
04	Clear Diagnostic Trouble Codes and stored values
05	Test results, oxygen sensor monitoring (non CAN only)
06	Test results, other component/system monitoring (Test results, oxygen sensor monitoring for CAN only)
07	Show pending Diagnostic Trouble Codes
08	Control operation of on-board component/system
09	Request vehicle information
0A	Cleared DTCs

Figure 9.1: Parameter IDs

X. OBD SOFTWARE INSTALLED IN PC's

There is certain easy-to-use OBD-II diagnostic software [7], with which we can communicate with vehicle's On-Board Diagnostic system and turn the computer or mobile into a highly capable automotive scanner. OBD Auto Doctor and EASE scan tool are notable OBD software. The software is a must-have tool for everyone interested in getting to know their cars are performing better. Whether we want to monitor data in real-time or reset "check engine" light, OBD software is the requirement. With OBD software, we can perform some of the following functions

1. Find out why the check engine light or Malfunction Indicator Light (MIL) is on by reading the diagnostic trouble codes (DTCs). After reading the codes, you can reset the Check Engine Light
2. View engine sensor data in real-time in numeric and graphical form.
3. Monitor engine performance and functionality.
4. Make sure your car is ready for emissions tests.

The OBD software has helped in saving money on dealer visits. They help the drivers to learn driving more economically by monitoring fuel economy in real time and Saving the nature and cash at the same time. OBD-II systems provide access to the health information of a vehicle and access to numerous parameters and sensors from the Engine Control Unit (ECU). The OBD2 system offers valuable information such as diagnostic trouble codes, when troubleshooting problems. OBD diagnostic software interacts with the car and reads the diagnostic information from the car. For the communication, a small OBD adapter is needed in addition. The adapter is attached to a car's OBD (OBD I or OBD II) port. It acts as a bridge between your computer/mobile and the car. Using the adapter, OBD software can communicate with the car and present the diagnostic information in user friendly way. To start communicating with the car, we need to have ELM327-based adapter an OBDII compliant car. Just connect the OBDII adapter to the physical 16-pin OBD connector plug located near the dashboard (typically below the steering wheel), launch the software. The connection between the interface and the software can use Bluetooth, WI-Fi, serial port or USB connection depending on the type of hardware you have.

XI. EXAMPLES ILLUSTRATING MALFUNCTION DETECTION AND POTENTIAL METHODS OF CORRECTING THEM

11.1 FUEL LEVEL SENSOR

Let us first consider an example of fuel level sensor. The fuel level sensor has an actuator rod, that allows the float to be at the same level as that of the fuel in the tank. Connected to the actuator is a potentiometer. The value of the resistance changes as the level of fuel changes in the tank. Fuel level sensor of cars is as shown in figure 11.1. Following are the errors picked up by the OBD system and possible ways to correct them.

Figure 11.1: Fuel level sensor

Fuel level Sensor DTCs (460 464):

- Fuel level sensor circuit diagnostics are performed for deterioration of fuel level sensor characteristics.
- In case of fuel level sensor deterioration circuit malfunction fault code 460 is assigned.
- If the fuel level sensor circuit is indicating out of range/performance problem, fault code 461 is assigned.
- If the fuel level sensor circuit shows very low reading a fault code 462 is stored.
- If the fuel level sensor circuit is indicating very high reading fault code 463 is assigned.
- The expected value is estimated using flow parameters.
- If the fault fuel level sensor circuit is indicating intermittent faulty reading, fault code 464 is assigned.

11.2 CYLINDER MISFIRE DETECTION

Next we consider an example of cylinder misfire detection in the engine of the car. Figure 11.2 shows a read out of OBD scanning tool, indicating a misfire by 4th cylinder of the engine.

Figure 11.2: Scan tool read out

Following are some of the fault codes stored in the OBD system for various possible errors

Misfire Detector (DTCs300-312):

- Misfire sensor diagnostics are performed for reduction of cylinder torque due to lack of combustion.
- In case of detecting misfire in cylinder 1 fault code 300 is assigned.
- The fault codes for misfires in cylinder 2 to 12 are similarly assigned to 301 -312 respectively.

  The possible methods of correcting this particular problem are listed below

- The cause of misfire should be fairly easy to pinpoint if the problem is present all the time. A look at spark pug can point to problem.
- Signs of arcing on ignition coil (Figure 11.3), distributor caps (Figure 11.4) or rotor may point to a faulty component. Compression, timing and fuel pressure may also need to be checked.
- A faulty on-plug ignition coil is typically identified by swapping the coils between the cylinders and checking if the misfire moved with the coil or stayed at the same cylinder. A bad ignition coil may be replaced, and an idea to change all the spark plugs could work as well.
- The engine might need to be checked for vacuum leaks. The Short Term Fuel Trim (STFT) and Long Term Fuel Trim (LTFT) (Figure 11.5) need to be checked with a scan tool to see if the air/fuel mixture is too lean. A bad mass air flow sensor could cause the engine to run lean causing misfire.
- Some of the other possibilities of getting the bug fixed are 1) Pressure testing of the cooling system. 2) Valve adjustment may need to be checked. 3) The EGR valve and purge valve need to be checked. 4) Faulty mechanical valve train components like worn camshaft lobes or stretched timing chain. 5) A broken or damaged tooth at the crankshaft or camshaft sensor gear. 6) Checking the sensor signal with an oscilloscope can help if Crankshaft Position (CKP) sensor or Camshaft Position (CMP) sensor are suspected.

Figure 11.3: Ignition coil

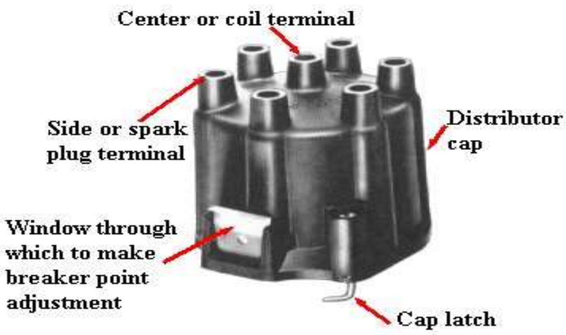

Figure 11.4: Distributor cap

Figure 11.5: Fuel trimming

CONCLUSION

This paper would like to first of all want to point out that with a technique such as OBDs, the drivers now don't have to wait and get frustrated in a long queue at a service station to get their car repaired. The driver now is being intimated continuously of the status of the emission system of the car. Most importantly, the environmental standards are obeyed and this ensures that the cars do not violate or degrade below these standards. The knowledge of OBD does not require a complete reset study of emission system of cars which is a major advantage. It just demands a conceptual study of the firm.

The idea of OBD can be used not only to monitor the emissions of the car, for which it is originally designed, but for all the systems in a car that the manufacturer desires for. The OBD is a prime especially in modern era of cars, where there are so many issues and problems associated with environment.

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