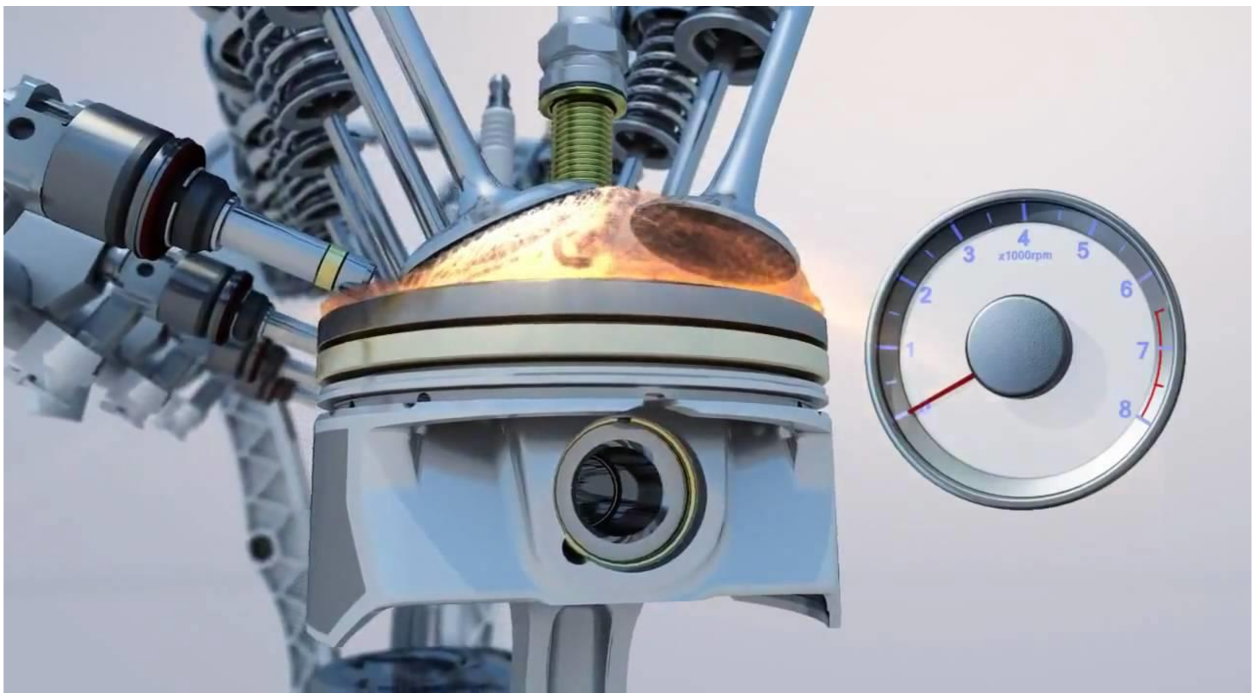
Automotive Mechanics

Level IV

Based on October 2023, Curriculum Version II



Module Title: Diagnosing Engine Management Systems

Module code: EIS AUM4 M02 1023

Nominal duration: 70 Hours

Prepared by: Ministry of Labor and Skill

October, 2023

Addis Ababa, Ethiopia

Table of Contents

Acronyms

ABS	Antilock brake system
ADC	Analog Digital Convertor
CID	Cylinder Identification
CKP	Crankshaft Position Sensor
CTSs	Coolant Temperature Sensors
DIS	Distributor Less Ignition System
DTC	Data Trouble Code
ECM	Electronic Control Module
ECU	Electronic Control Unit
EECS	Evaporative Emission Control System
EGO	Exhaust Gas Oxygen Sensor'
EGR	Exhaust Gas Recirculation
EMS	Engine Management System
GDI	Gasoline direct injection
I/O	Input Output
iATN	International Automotive Technician's Network
ISCV	Idle Speed Control Valve
LED	Light-Emitting Diode
MAF	Mass Air Flow
NTC	Negative Temperature Sensor
PDA	Personal Digital Assistant
PFI	Port fuel injection
RCA	Root Cause Analysis
ROM	Read Only Memory
RPM	Revolution per minute
SCV	Suction Control Valve
TBI	Throttle Body Injection
TDC	Top Dead Centre
VIN	Vehicle Identification Number

Introduction to Module

In Modern Automotive Application, Engine Management System (EMS) is one of a critical aspects to improve the diesel and gasoline engine efficiency.

This module is designed to meet the industry requirement under the Automotive Mechanics level IV Occupational standard, particularly for the unit of competency: Diagnosis Engine Management System (EMS)

This module covers the units:

- Basics of Engine Management System
- Gasoline and Diesel Engines Control System
- Sensor Diagnostics
- Actuators Diagnostics

Learning Objective of the Module

- Understand the Engine Management System basics
- Cognize Gasoline and Diesel Engines Control
- Perform Sensor Diagnostics
- Perform Actuators Diagnostics

Module Instruction

For effective use these modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit.
2. Accomplish the Self-checks at the end of each unit.
3. Perform Operation Sheets which were provided at the end of units.
4. Do the "LAP test" giver at the end of each unit and
5. Read the identified reference book for Examples and exercise.

Unit One: Basics of Engine Management System

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Essentiality of Engine Management System
- Diagnostic Techniques
- Diagnostic Processes
- Engine Systems Diagnostics
- Engine Performance Measurement Tools

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Understand Essentiality of Engine Management System
- Grasp Diagnostic Techniques
- Follow Diagnostic Processes
- Perform Engine Systems Diagnostics
- Identify Engine Performance Measurement Tools

1.1 Introduction to EMS

Engine Management System (EMS) comprises of Electronic Control Unit (ECU), sensors, actuators and control algorithms that determine the performance of the Engine as a whole and as part of the vehicle.

The Electronic Control Unit consist of a 32-bit microprocessor with peripheral devices like ignition driver, ADCs device and I/O drivers. Microprocessor controls the injection parameters as well as some of the vehicle related outputs such as Fan, AC drivability in gears, variable turbine turbocharger, EGR etc. The ECU receives input from various sensors located on the engine and the vehicle, and decides the injection quantity, injection timing, number of injections best suited for the engine to work with maximum efficiency and safety. It is the 'Brain' of the Engine Management System.

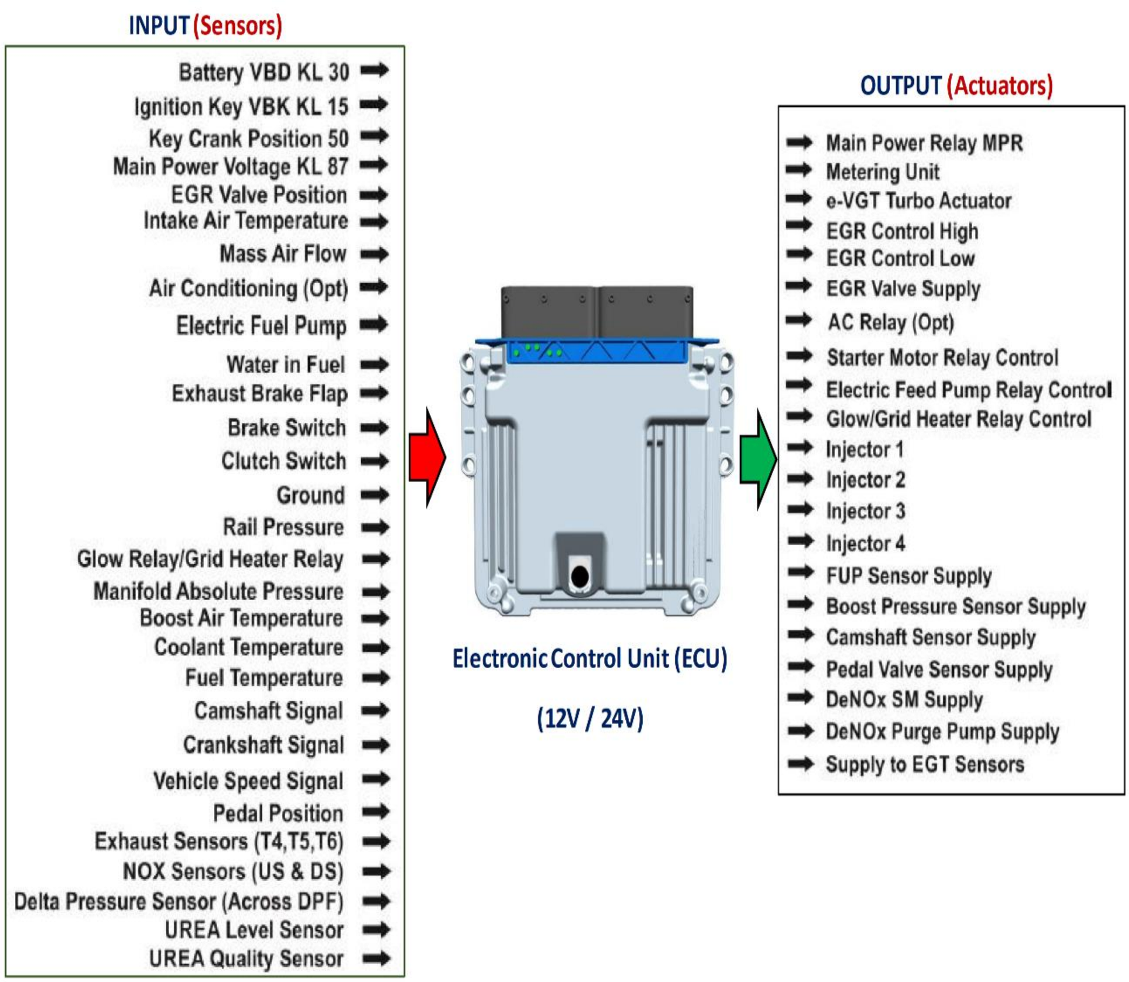


Figure 1: 1 EMS System Layout

1.2 Essentiality of Engine Management System

The engine management system ensures that the driver request is implemented. For example, it converts the acceleration/deceleration requests into a corresponding engine output. During its evolution electronic engine control progressively increases the number of engine sub systems it manages and kind of tasks it performs. This development is necessary to provide the needed accuracy and adaptability in order

I. Exhaust Emissions

The engine exhaust consists of products from the combustion of the air and fuel mixture. Under perfect combustion conditions the hydrocarbons (HC) would combine in a thermal reaction with oxygen in the air to form carbon dioxide (CO_2) and water (H_2O). Unfortunately perfect combustion does not occur. It might be created.

- Carbon monoxide (CO)
- Oxides of nitrogen (NO_X) and
- Hydrocarbon (HC)

II. Fuel Consumption

A lot of different factors are working in partnership to make of central importance fuel economy:

- The need of a better and more rational use of energetic resources to reach a sustainable growth The fuel price always under increment
- The electronic engine control system provides the fuel metering and ignition timing precision required to minimize fuel consumption.

III. Drivability

Another requirement of the electronic engine control system is to provide acceptable drivability under all operating conditions.

- No stalls, hesitations or other objectionable roughness should occur under vehicle operation.
- Drivability is influenced by almost every operation of the control system and, unlike exhaust emissions or fuel economy, is not easily measured.

IV. Evaporative Emissions (Gasoline engine only)

Hydrocarbon (HC) emissions in the form of fuel vapours escaping from the vehicle are closely regulated. The prime source of these emissions is the fuel tank. Due to ambient heating of the fuel and the return of unused hot fuel from the engine, fuel vapours are generated in the tank. The evaporative emission control system (EECS) is used to control the evaporative HC emissions. The fuel vapours are rotated to the intake manifold via the EECS and they are burned in the combustion process.

V. System Diagnostics

The purpose of system diagnostics is to provide a warning to the driver when the control system determines a malfunction of a component or a system and to assist the service technician in identify and correct the failure. The ECU determines a malfunction has occurred when a sensor signal, received during normal engine operation or during a system test, indicates there is a problem.

Engine Management System (EMS) comprises of Electronic Control Unit (ECU), sensors, actuators and control algorithms that determine the performance of the Engine as a whole and as part of the vehicle.

1.3 Diagnostic Techniques

Diagnostics or fault-finding is a fundamental part of an automotive technician's work. The subject of diagnostics does not relate to individual areas of the vehicle. If your knowledge of a vehicle system is at a suitable level, then you will use the same logical process for diagnosing the fault, whatever the system.

This information is vital and will ensure that you find the fault – particularly if you have developed the diagnostic skills to go with it. The general type of information available is as follows:

- Engine diagnostics, testing and tuning;
- Servicing, repairs and times;
- Fuel and ignition systems;
- Auto electrics data;
- Component location;
- Body repairs, tracking and tires.

This is one of the most difficult skills to learn. It is also one of the most important. The secret is twofold:

- Know your own limitations – it is not possible to be good at everything;
- Leave systems alone where you could cause more damage or even injury – for example, airbag circuits.

Often with the best of intentions, a person new to diagnostics will not only fail to find the fault but also introduce more faults into the system in the process. I would suggest you learn your own strengths and weaknesses; you may be confident and good at dealing with mechanical system problems but less so when electronics is involved. Of course you may be just the opposite of this. Remember that diagnostic skill is in two parts – the knowledge of the system and the ability to apply diagnostics. If you do not yet fully understand a system, leave it alone until you do.

The Art of Diagnostics

The knowledge needed for accurate diagnostics is in two parts:

- Understanding of the system in which the problem exists;
- Having the ability to apply a logical diagnostic routine.

The knowledge requirement and use of diagnostic skills can be illustrated with a very simple example:

After connecting a hosepipe and turning on the tap, no water comes out of the end. Your knowledge of this system tells you that water should come out providing the tap is on, because the pressure from a tap pushes water through the pipe, and so on. This is where your diagnostic skills become essential. The following stages are now required:

1. Confirm that no water is coming out by looking down the end of the pipe.
2. Check if water comes out of the other taps, or did it come out of this tap before you connected the hose?
3. Consider what this information tells you; for example, if the answer is 'Yes' the hose must be blocked or kinked.
4. Walk the length of the pipe looking for a kink.
5. Straighten out the hose.
6. Check that water now comes out and that no other problems have been created.

Much simplified I accept, but the procedure you have just followed made the hose work and it is also guaranteed to find a fault in any system. It is easy to see how it works in connection with a hosepipe and I'm sure anybody could have found that fault (well most people anyway).

For Example see the following Case

Let us assume that the reported fault with the vehicle is overheating. As is quite common in many workshop situations that's all the information we have to start with. Now work through the six stages:

Stage 1 – Take a quick look to check for obvious problems such as leaks, broken drive belts or lack of coolant. Run the vehicle and confirm that the fault exists. It could be the temperature gauge, for example.

Stage 2 – Is the driver available to give more information? For example, does the engine overheat all the time or just when working hard? Check records, if available, of previous work done to the vehicle.

Stage 3 – Consider what you now know. Does this allow you to narrow down what the cause of the fault could be? For example, if the vehicle overheats all the time and it had recently had a new cylinder head gasket fitted, would you be suspicious about this? Do not let two and two make five, but do let it act as a pointer. Remember that in the science of logical diagnostics, two and two always makes four. However, until you know this for certain then play the best odds to narrow down the fault.

Stage 4 – The further tests carried out would now be directed by your thinking at stage 3. You do not yet know if the fault is a leaking head gasket, the thermostat stuck closed or some other problem.

Playing the odds, a cooling system pressure test would probably be the next test. If the pressure increases when the engine is running, then it is likely to be a head gasket or similar problem. If no pressure increase is noted, then move on to the next test and so on. After each test go back to stage 3 and evaluate what you know, not what you don't know.

Stage 5 – Let us assume the problem was a thermostat stuck closed – replace it and top up the coolant, etc.

Stage 6 – Check that the system is now working. Also check that you have not caused any further problems such as leaks or loose wires.

1.4 Diagnostic Processes

A. Six-Step Troubleshooting Plan

It is a way to organize your efforts, keeping you on-track while you are troubleshooting the problem. The Six- steps of Troubleshooting plan can be explained in either of the following manner. However, both steps have equivalent logical approach to conduct diagnostic process.

I. Verify the complaint

This is a method for gathering information stated by the customer (driver). Sometimes you will be able to discover other things that the driver does not realize. Therefore, you should attempt to understand what the customer complaint is and pay attention to the vehicle's operation at driving conditions. Because gathering information will simplify your task. This is the first step in any diagnostic process. When you are handed a repair order with a customer's complaint on it, there are three things that you must do:

- You must be able to identify the problem the customer noted
- You must determine if it is a problem or not
- If there is a problem, determine if it is intermittent or continuous

II. Define the problem

Now that you have verified that there is a problem, you need to examine the problem symptoms more thoroughly. The related symptoms check is an operational check
The major goal of this check is to determine:

- How much of the system is affected.
- Find clues to the location of the problem by operating other systems related or connected to the problem area

If any part of the failed system works, it is extremely important to determine exactly which parts are working and which parts are not. This step will save you from making unnecessary checks to parts of the system that are OK. In this step, you can define the problem and know what happens and when it happens.

III. Analyse the Symptoms

At this point, you need to stop, and put all of this information together to define:

- Exactly which components/circuits are affected (both the customer's complaint and any related symptoms)

- What kind of problem you need to look for (open, short-to-ground, high resistance, if it is electrical problem)
- When it occurs (what operating conditions: key ON, driver's door open, etc.)
- In this step the problem system will be isolated which involves knowing which system can cause the problem.

IV. Isolate the system

This is a kind of test to determine the exact problem. To do this:

- First identify the possible causes for the problem
- Find possible problem areas and determine where to begin making tests
- Then conduct test to pinpoint the problem
- Before identifying the exact problem (pinpoint) each suspected system is tested.
- If a fault is obtained in the system, detailed tests should be conducted to determine the exact problem.
- If no faults are found in the suspected parts (systems), others should be tested. At this point, you need to stop, and put all of this information together to define:

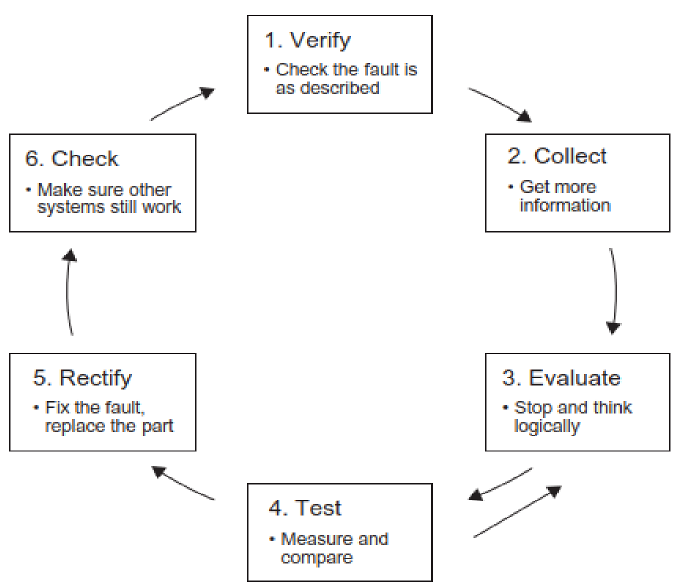
V. Correct the trouble

Correcting the trouble is probably the most straightforward step in the diagnostic process. Once the problems have been identified, they must be corrected. Here you have to follow the proper procedure when replacing any component and when making an adjustment.

VI. Verify the repair

After making the repair, you must always verify that the problem was actually fixed.

With the repairs and adjustments made, for example run the engine and bring it to the same condition that the problem occurred in before.



B. Black Box Technique

The technique outlined here is known as 'black box fault-finding'. This is an excellent technique and can be applied to many vehicle systems from engine management and ABS to cruise control and instrumentation. As most systems now revolve around an ECU, the ECU is considered to be a 'black box'; in other words, we know what it should do but the exact details of how it does it are less important.

A block diagram that could be used to represent any number of automobile electrical or electronic systems. In reality the arrows from the 'inputs' to the ECU and from the ECU to the 'outputs' are wires. Treating the ECU as a 'black box' allows us to ignore its complexity. The theory is that if all the sensors and associated wiring to the 'black box' are OK, all the output actuators and their wiring are OK and the supply/earth (ground) connections are OK, then the fault must be the 'black box'. Most ECUs are very reliable however, and it is far more likely that the fault will be found in the inputs or outputs.

Normal fault-finding or testing techniques can be applied to the sensors and actuators. For example, if an ABS system uses four inductive type wheel speed sensors, then an easy test is to measure their resistance.

Even if the correct value were not known, it would be very unlikely for all four to be wrong at the same time so a comparison can be made. If the same resistance reading is obtained on the end of the sensor wires at the ECU then almost all of the 'inputs' have been tested with just a few ohmmeter readings.

The same technique will often work with 'outputs'. If the resistance of all the operating windings in say a hydraulic modulator were the same, then it would be reasonable to

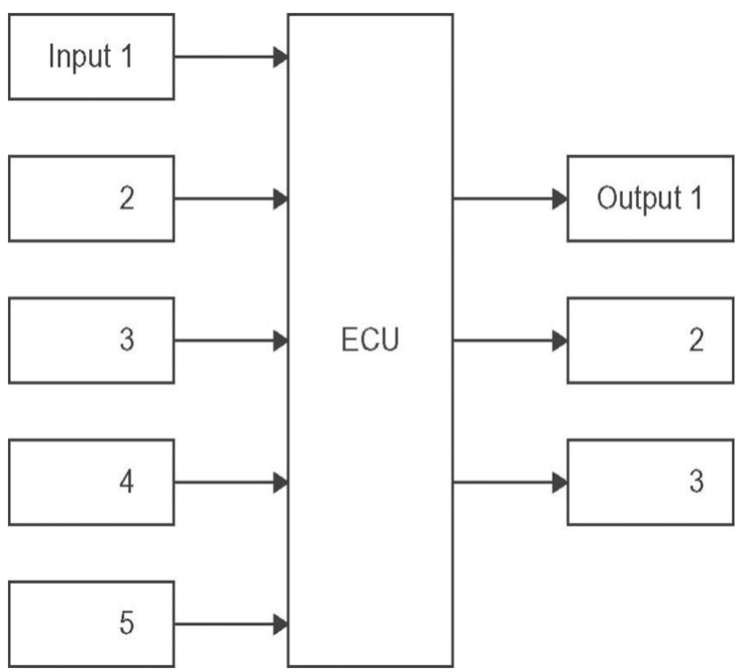


Figure 1: 2 Six-Stage Diagnostics Process

assume the figure was correct.

Figure 1: 3 Black Box Technique

C. Root Cause Analysis

The phrase 'Root Cause Analysis' (RCA) is used to describe a range of problem-solving methods aimed at identifying the root causes of problems or events. I have included this short section because it helps to reinforce the importance of keeping an open mind when diag-nosing faults, and again, stresses the need to work in a logical and structured way. The root cause of a problem is not always obvious; an example will help to illustrate this:

Let us assume the symptom was that one rear light on a car did not work. Using the six stage process, a connector block was replaced as it had an open circuit fault. The light now works OK but what was missed was that a small leak from the rear screen washer pipe dripped on the connector when the washer was operated. This was the root cause.

The practice of RCA is based, quite rightly, on the belief that problems are best solved by attempting to address, correct or eliminate the root causes, as opposed to just addressing the faults causing observable symptoms. By dealing with root causes, it is more likely that problems will not reoccur. RCA is best considered to be an iterative process because complete prevention of recurrence by one corrective action is not always realistic.

The following list is a much simplified representation of a failure-based RCA process. Note that the key steps are numbers 3 and 4. This is because they direct the corrective action at the true root cause of the problem.

1. Define the problem.
2. Gather data and evidence.
3. Identify the causes and root causes.
4. Identify corrective action(s).
5. Implement the root cause correction(s).
6. Ensure effectiveness.

   As an observant reader, you will also note that these steps

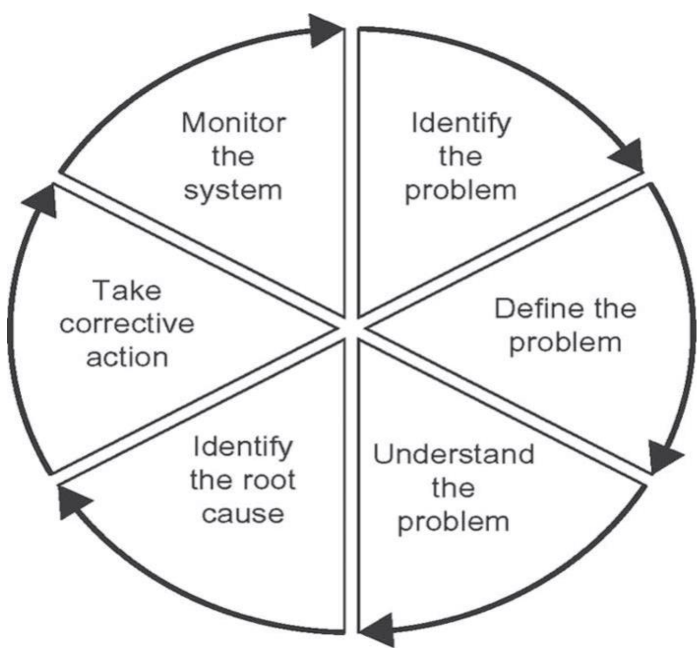


Figure 1: 4 Root Cause Analysis

are very similar to our six-stage fault-finding process.

1.3 Vehicle and Engine Identification Number

1.4.1 Vehicle Identification Number

Before any service is done to a vehicle, it is important for you to know exactly what type of vehicle you are working on. The best way to do this is to refer to the vehicle's identification number (VIN). The VIN is given on a plate behind the lower corner of the driver's side of the windshield as well as other locations on the vehicle. The VIN is made up of seventeen characters and contains all pertinent information about the vehicle. The use of the seventeen numbers and letter code became mandatory beginning with 1981 vehicles and is used by all manufacturers of vehicles both domestic and foreign. Most new vehicles have a scan code below the VIN.

Figure 1: 5 Sample VIN Number

Each character of a VIN has a particular purpose.

- **Digits 1 through 3 combined is the WMI, (World Manufacturer Identifier**).

➢ The first digit of the VIN number is the country of origin or final processing plant. For example, numbers, 1, 4 and 5 represent the U.S. 2 is Canada and the number 3 represents Mexico. The Society of Automotive Engineers are the ones who assign WMI's to countries and manufacturers.

➢ Next is the digit that represents the manufacturer, for example, 'G' is for General Motors, 'C' can be Chrysler and 'B' for BMW.

- ➢ The third digit combined with the first two may identify the type of vehicle, such as whether it is a truck, SUV or car. For example, a Chevrolet truck VIN would start as '1GC'. 1 for the US as the country of origin, G for General Motors and C for Truck.

- **Vehicle Descriptor**
- ➢ Digits 4 through 8 represent the vehicle descriptor section. This is information such as model type, restraint types, body type, engine, and transmission.
- **Check Digit**
- ➢ Digit 9 is a check digit. The 9th digit is like a security code, called a check digit. It is a code number/letter the manufacturer generates to verify authenticity of the whole number.
- **Vehicle Identification Section (VIS)**
- ➢ The 10th digit is the model year. This table below is a good quick guide to years. So if the 10th digit is a 'D' this means the vehicle is a 2013 model.

A	**1980**	L	**1990**	Y	**2000**	A	**2010**
B	1981	M	1991	1	2001	B	2011
C	1982	N	1992	2	2002	C	2012
D	1983	P	1993	3	2003	D	2013
E	1984	R	1994	4	2004	E	2014
F	1985	S	1995	5	2005	F	2015
G	1986	T	1996	6	2006	G	2016
H	1987	V	1997	7	2007	H	2017
J	1988	W	1998	8	2008	J	2018
K	1989	X	1999	9	2009	K	2019

Figure 1: 6 Model's Year

Plant Code

- ➢ The 11th digit is the manufacturer's plant code. Vehicle manufacturers all have their own unique codes for which plant the car, truck, or SUV's are built.

Production Number

- Digits 12 through 17 digits are numbers the vehicle gets as it rolls through the production line. These numbers are usually sequential. For example, the very first of that vehicle might end in 000001.

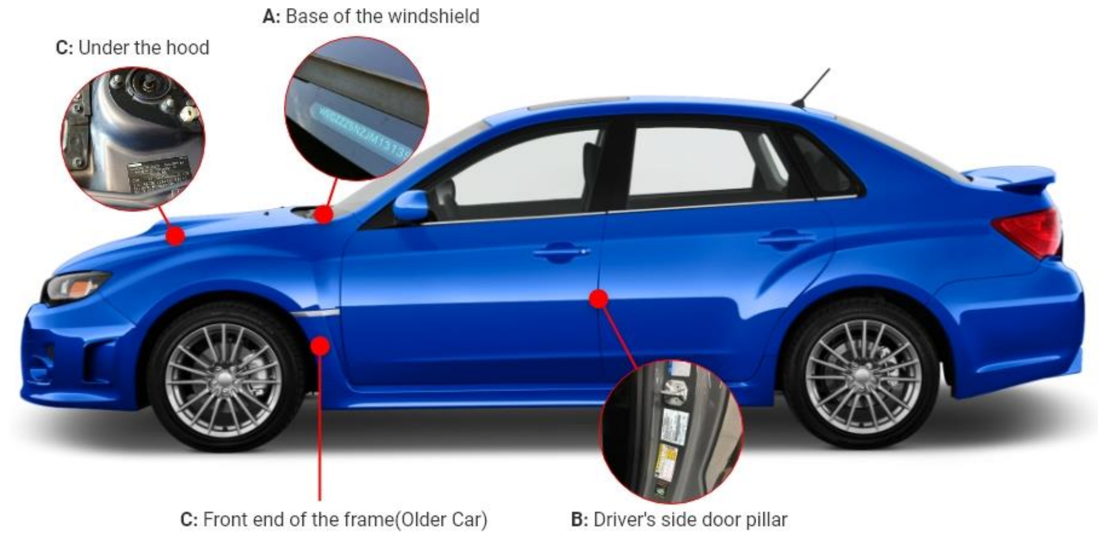
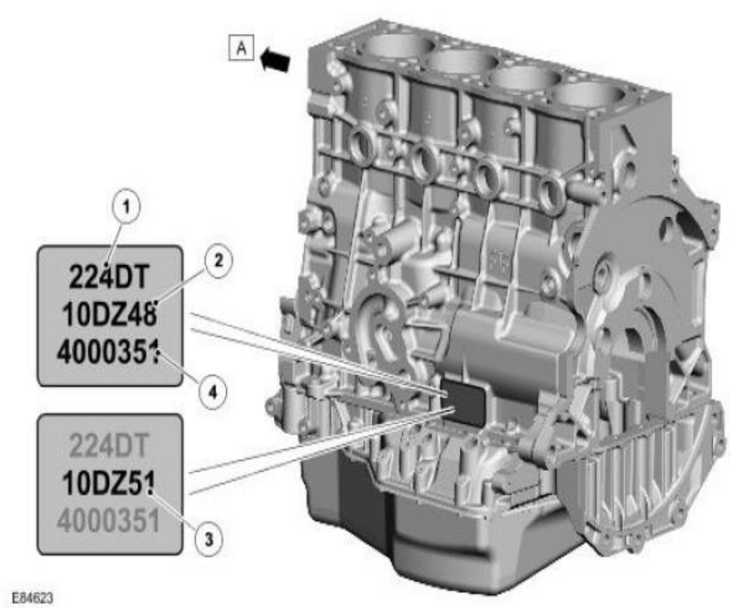


Figure 1:7 VIN Locations

1.4.2 Engine Identification Number

By referring to the VIN, much information about the vehicle can be determined. Identification numbers are also found on the engine. Some manufacturers use tags or stickers attached at various places, such as the valve cover or oil pan. Blocks often have a serial number stamped into them.

Service manuals typically give the location of the code for a particular engine. The engine code is generally found beside



Item	Part Number	Description
A		Front of engine
1		Engine type
2		Engine variant (manual transmission)
3		Engine variant (automatic transmission)
4		Engine serial number

Figure 1: 8 Engine Identification Number

the serial number. The engine code will help you determine the correct specifications for that particular engine.

1.4 Service Information

Service information includes written instructions and technical illustrations to help you properly repair a damaged vehicle. Service information is published by vehicle manufacturers (Jaguar, Chrysler, General Motors, Toyota, and soon) and aftermarket publishers (Mitchell Manuals, Motor Manuals, and Chilton Manuals, for example).

1.4.1 Auto Manufacturers' Service Information

The primary source for repair and specification information for any car, van, or truck is the manufacturer. The manufacturer publishes appropriate service each year, for every vehicle built. The information may be divided into sections such as chassis, suspension, steering, emission control, fuel systems, brakes, basic maintenance, engine, transmission, body, and so on.

Each major section is divided into subsystems, these cover all repairs, adjustments, specifications, diagnostic procedures, and any required special tools. Since many technical changes occur on specific vehicles each year, manufacturers' service manuals need to be constantly updated. Updates are published as service bulletins that show the changes in specifications and repair procedures during the model year. These changes do not appear in the service manual until the next year. The car manufacturer provides these bulletins to dealers and repair facilities on a regular basis. Automotive manufacturers also publish a series of technician reference books. The publications provide general instructions about the service and repair of the

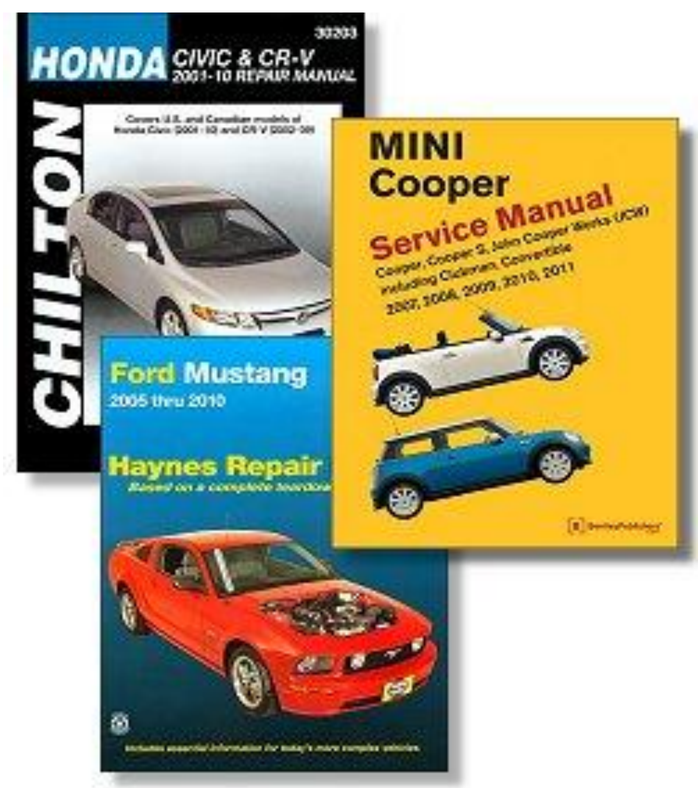


Figure 1: 9 Auto Manufacturers' Service Information

manufacturers' vehicles and also indicate their recommended techniques.

1.4.2 General and Specialty Repair Manuals

Service manuals are also published by independent companies rather than the manufacturers. However, they pay for and get most of their information from the car makers. The manuals contain component information, diagnostic steps, repair procedures, and specifications for several makes of automobiles in one book. Information is usually condensed and is more general than the manufacturers' manuals. The condensed format allows for more coverage in less space and, therefore, is not always specific. They may also contain several years of models as well as several makes in one book.

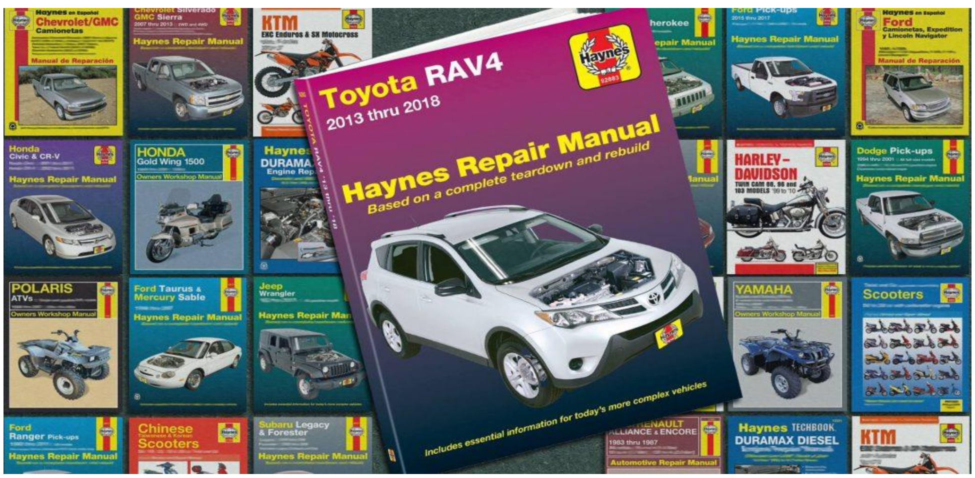


Figure 1: 10 Repair Manual

Finding Information in Service Manuals

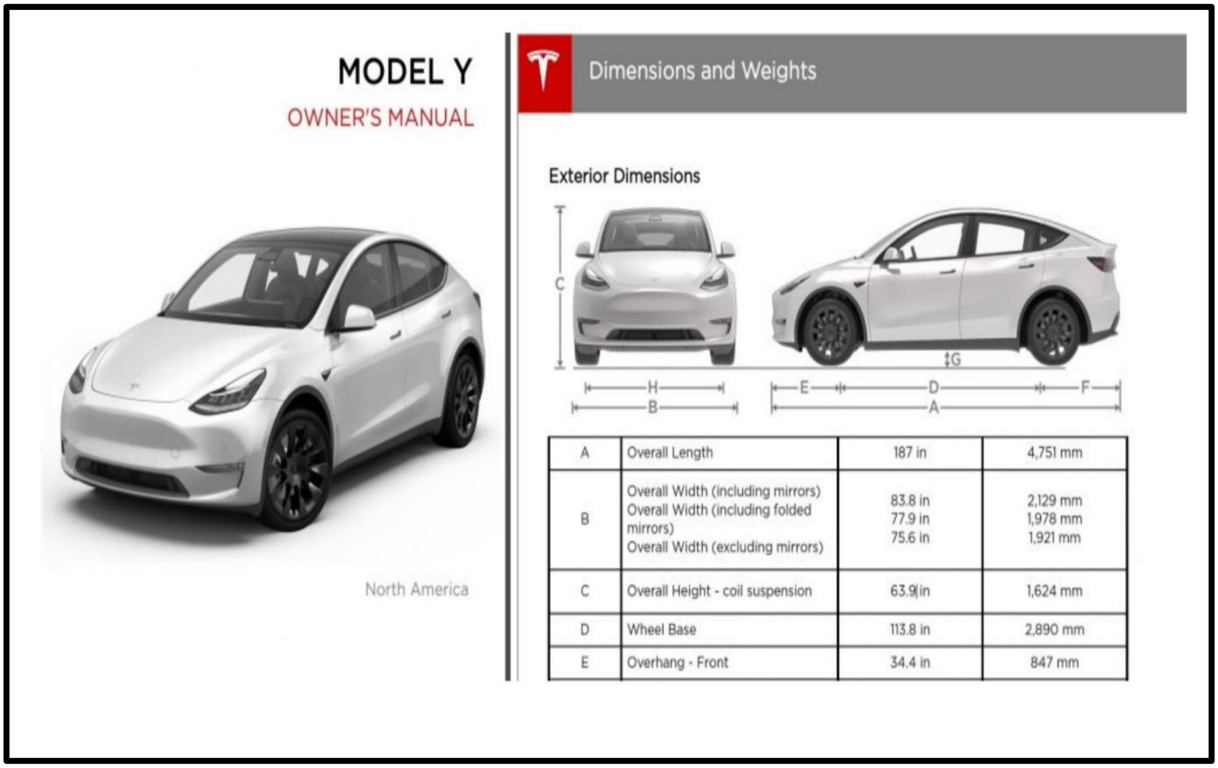
To obtain the correct system specifications and other information, you must first identify the exact system you are working on. The best source for vehicle identification is the VIN. The code can be interpreted through information given in the service manual. The manual may also help you identify the system through identification of key components or other identification numbers and/or markings. To use a service manual:

1. Select the appropriate manual for the vehicle being serviced.
2. Use the table of contents to locate the section that applies to the work being done.
3. Use the index at the front of that section to locate the required information.
4. Carefully read the information and study the applicable illustrations and diagrams.
5. Follow all of the required steps and procedures given for that service operation.

6. Adhere to all of the given specifications and perform all measurement and adjustment procedures with accuracy and precision.

1.4.3 Owner's Manuals

An owner's manual comes with the vehicle when it is new. It contains operating instructions for the vehicle and its accessories. It also contains valuable information about checking and adding fluids, safety precautions, a complete list of capacities, and the specifications for the various fluids and lubricants for the vehicle.



A	Overall Length	187 in	4,751 mm
B	Overall Width (including mirrors) Overall Width (including folded mirrors) Overall Width (excluding mirrors)	83.8 in 77.9 in 75.6 in	2,129 mm 1,978 mm 1,921 mm
C	Overall Height - coil suspension	63.9 in	1,624 mm
D	Wheel Base	113.8 in	2,890 mm
E	Overhang - Front	34.4 in	847 mm

Figure 1: 11 Sample Owner's Manuals

1.4.4 Hotline Services

Hotline services provide answers to service concerns by telephone. Manufacturers provide help by telephone for technicians in their dealerships. There are subscription services for independents to be able to get repair information by phone. Some manufacturers also have a phone modem system that can transmit computer information from the car to another location. The vehicle's diagnostic link is connected to the modem.

The technician in the service bay runs a test sequence on the vehicle. The system downloads the latest updated repair information on that particular model of car. If that does not repair the problem, a technical specialist at the manufacturer's location will review the data and propose a repair.

1.4.5 iATN

The International Automotive Technician's Network (iATN) is comprised of a group of thousands of professional automotive technicians from around the world. The technicians in this group exchange technical knowledge and information with other members. The Web address for this group is www .iatn.net.

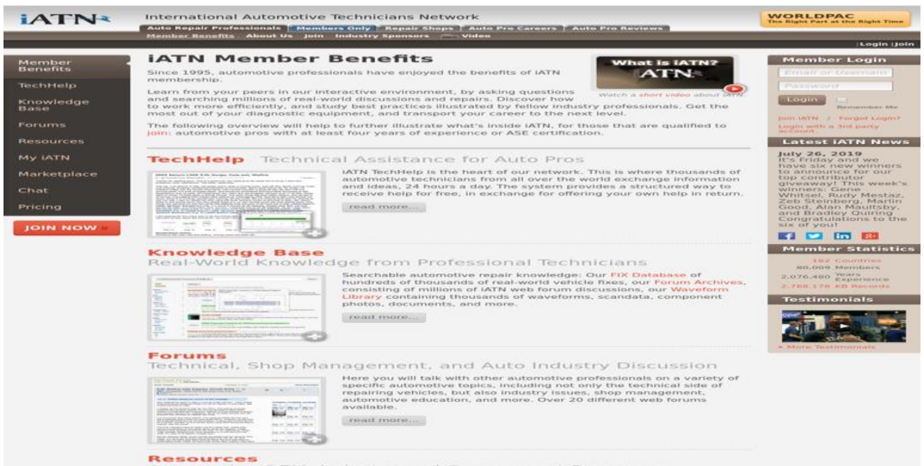


Figure 1: 12 International Automotive Technician's Network Features

1.4.6 The Internet

The Internet has had a major impact on automotive repair. Both do-it-yourselves and professional technicians have access to a seemingly endless supply of information. This can be good and bad. With the ability to find diagnostic and repair information online, many consumers take on repairing their cars and trucks on their own. When using the Internet to help solve a problem or make a repair, you will need to learn how to determine what is good information and what is not. This judgment call often comes down to experience and understanding what you are working on.

Figure 1: 14 Web based mechanic

1.5 Engine Systems Diagnostics

1.5.1 Engine Fault Symptoms

The engine management light is a general indication of a problem, rather than a specific warning, and there are a number of issues that can cause it to make an appearance. These faults can range in severity, with anything from a faulty sensor right through to an engine misfire among the potential causes of the engine management light illuminating. Some issues can also be less obvious than others. Let’s discuss some of them

- **Hard start/long crank (**due to failure in starting, fuel, Ignition, intake air, exhaust , PCV (Positive crankcase ventilation) , EVAP (Evaporative emissions purge actuator) systems; MAF (Mass air flow) Sensor and computer; fuel contamination, flow restriction, low pressure, leakage)
- **No Crank:** (due to failure in anti-theft devices, base engine components and starting system)
- **No Start (Engine cranks):** (due to failure in anti-theft devices, fuel, ignition, intake air, exhaust system, computer and base engine)
- **Slow Return to Idle:** (due to failure in vacuum leaks, throttle Body and intake air system Leaks)
- **Fast Idle or Runs On:** (due to failure in base engine, fuel, ignition, intake air and electronic control systems)
- **Low/Slow Idle or Stalls/Quits During Deceleration:** (due to failure in base engine, , fuel, ignition, intake air, electronic control and automatic transmission systems)
- **Backfires:** (due to failure in base engine, secondary ignition, fuel delivery and exhaust systems)
- **Lack or Loss of Power:** (due to failure in base engine, , fuel, ignition, intake air, exhaust , brake electronic control and automatic transmission, supercharger/ turbo charger System)
- **Spark knock :** (due to failure in base engine, , fuel, ignition, intake air, electronic control System)

- **Poor Fuel Economy:** (due to failure in base engine, , fuel, ignition, intake air, exhaust , brake electronic control and automatic transmission, steering and suspension System)

1.5.2 Mechanical Diagnostics

A. Check the Obvious First

Start all hands-on diagnostic routines with ‘hand and eye checks’. In other words, look over the vehicle for obvious faults. For example, if automatic transmission fluid is leaking on to the floor then put this right before carrying out complicated stall tests. Here are some further suggestions that will at some point save you a lot of time.

- If the engine is blowing blue smoke out of the exhaust – consider the worth of tracing the cause of a tapping noise in the engine.
- When an engine will not start – check that there is fuel in the tank.

B. Noise, Vibration and Harshness

Noise, vibration and harshness (NVH) concerns have become more important as drivers have become more sensitive to these issues. Drivers have higher expectations of comfort levels. NVH issues are more noticeable due to reduced engine noise and better insulation in general. The main areas of the vehicle that produce NVH are:

- Tires
- Engine accessories
- Suspension
- Driveline

It is necessary to isolate the NVH into its specific area(s) to allow more detailed diagnosis. A road test, as outlined later, is often the best method. The five most common sources of non-axle noise are exhaust, tires, roof racks, trim and mouldings, and transmission. Ensure that none of the following conditions is the cause of the noise before proceeding with a driveline strip down and diagnosis.

1. In certain conditions, the pitch of the exhaust may sound like gear noise or under other conditions like a wheel bearing rumble.
2. Tires can produce a high-pitched tread whine or roar, similar to gear noise. This is particularly the case for non-standard tires.
3. Trim and mouldings can cause whistling or whining noises.

4. Clunk may occur when the throttle is applied or released due to backlash somewhere in the driveline.
5. Bearing rumble sounds like marbles being tumbled.

C. Engine Noise

Noise is very difficult to describe. However, the following are useful terms and are accompanied by suggestions as to when they are most likely to occur.

- Gear noise is typically a howling or whining due to gear damage or incorrect bearing preload. It can occur at various speeds and driving conditions or it can be continuous.
- 'Chuckle' is a rattling noise that sounds like a stick held against the spokes of a spinning bicycle wheel. It usually occurs while decelerating.
- Knock is very similar to chuckle though it may be louder and occurs on acceleration or deceleration.

How do you tell a constant tapping from a rattle? Worse still, how do you describe a noise in a book? I'll do my best. Try the following table as a non-definitive guide to the source or cause of engine or engine ancillary noises.

Sources of engine noise	Possible cause	Required action
Misfiring/backfiring	Fuel in tank has wrong octane/cetane number, or is wrong type of fuel Ignition system faulty Engine temperature too high Carbon deposits in the combustion chamber start to glow and cause misfiring Timing incorrect, which causes misfiring in the intake/ exhaust system	Determine which type of fuel was last put in the tank Check the ignition system Check the engine cooling system Remove the carbon deposits by using fuel additives and driving the vehicle carefully Check the timing
Valve train faulty	Valve clearance too large due to faulty bucket tappets or incorrect adjustment of valve clearance Valve timing incorrectly adjusted valves and pistons are touching Timing belt broken or damaged	Adjust valve clearance if possible and renew faulty bucket tappets – check cam condition Check the valve timing and adjust if necessary Check timing belt and check pistons and valves for damage – renew any faulty parts
Engine components faulty	Pistons Piston rings Cylinder head gasket Big-end and/or main bearing journals	Disassemble the engine and check components
Ancillary components	Engine components or ancillary components loose or broken	Check that all components are secure, tighten/ adjust as required. Renew if broken

Figure 1: 13 1 Source of Engine Noise

The above table is a further guide to engine noise. Possible causes are listed together with the necessary repair or further diagnosis action as appropriate.

1.5.3 Electrical Diagnostics

A. Check the Obvious First

Start all hands-on diagnostic routines with 'hand and eye checks'. In other words, look over the vehicle for obvious faults. For example, if the battery terminals are loose or corroded then put this right before carrying out complicated voltage readings. Here are some further suggestions that will at some point save you a lot of time.

- A misfire may be caused by a loose plug lead – it is easier to look for this than interpret the ignition waveforms on a scope.
- If the ABS warning light stays on – look to see if the wheel speed sensor(s) are covered in mud or oil.

B. Test Lights and Analogue Meters – Warning

A test lamp is ideal for tracing faults in say a lighting circuit because it will cause a current to flow, which tests out high-resistance connections. However, it is this same property that will damage delicate electronic circuits – so don't use it for any circuit that contains an electronic control unit (ECU).

C. Volt Drop Testing

Volt drop is a term used to describe the difference between two points in a circuit. In this way we can talk about a voltage drop across a battery (normally about 12.6 V) or the voltage drop across a closed switch (ideally 0 V but may be 0.1 or 0.2 V).

The first secret to volt drop testing is to remember a basic rule about a series electrical circuit:

'The sum of all volt drops around a circuit always add up to the supply'.

The second secret is to ensure the circuit is switched on and operating – or at least the circuit should be 'trying to operate'. If the circuit is operating correctly, V1 + V2 + V3 = Vs. When electrical testing therefore, and if the battery voltage is measured as say 12 V, a reading of less than 12 V at V2 would indi-cate a volt drop between the terminals of V1 and/or V3. Likewise the correct operation of the switch, that is, it closes and makes a good connection, would be con-firmed by a very low reading on V1. What is often described as a ‘bad earth’ (when what is meant is a high resistance to earth) could equally be determined by the reading on V3. To further narrow the cause of a volt drop down, simply measure across a smaller area. The voltmeter V4, for example, would only assess the condition of the switch contacts.

D. Generic Electrical Testing Procedure

The following procedure is very generic but with little adaptation can be applied to any electrical system.

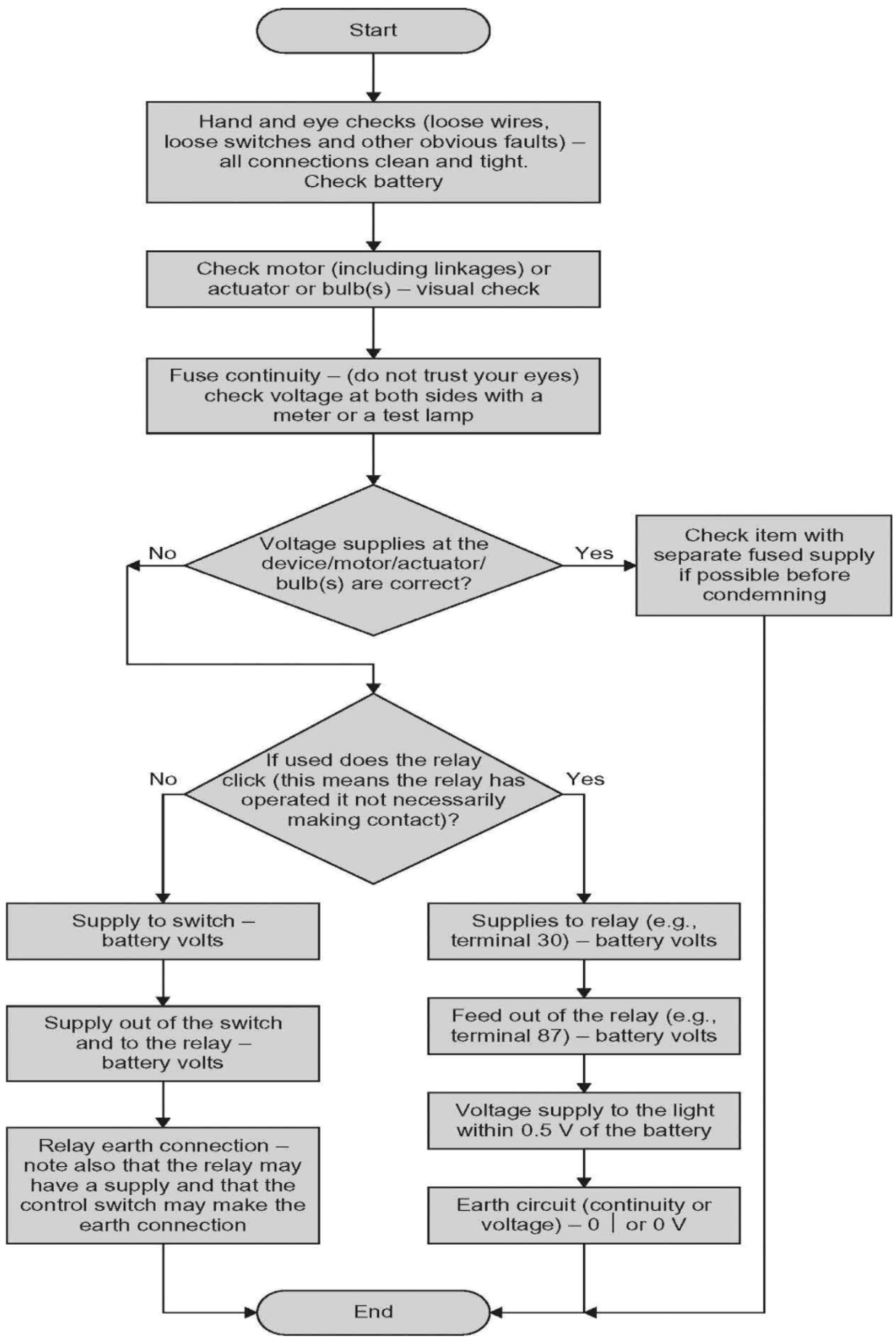


Figure 1: 14 Generic Electrical Testing Procedure

1.6 Engine Performance Measurement Tools

1.6.1 Scan Tools

A scan tool is a microprocessor designed to communicate with the vehicle's computer. Connected to the computer through diagnostic connectors, a scan tool can access diagnostic trouble codes (DTCs), run tests to check system operations, and monitor the activity of the system. Trouble codes and test results are displayed on a screen or printed out on the scanner printer.

The scan tool is connected to specific diagnostic connectors on the vehicle. It must be programmed for the model year, make of vehicle, and type of engine. With OBD-II, the diagnostic connectors (commonly called Data Link Connector or DLCs) are located in the same place on all vehicles. Most OBD-II scan tools have the ability to store, or "freeze," data during a road test and then play back this data when the vehicle is returned to the shop. Scan

Figure 1: 15 Scan Tools

Tool may have the following capabilities:

- Retrieve DTCs.
- Monitor system operational data.
- Reprogram the vehicle's electronic control modules.
- Perform systems diagnostic tests.
- Display appropriate service information, including electrical diagrams.
- Display TSBs.
- Display troubleshooting instructions.
- Perform easy tool updating through a personal computer (PC).

Some scan tools work directly with a PC through un-cabled communication links, such as Bluetooth. Others use a Personal Digital Assistant (PDA). These are small hand-held units that allow you to read DTCs, monitor the activity of sensors, and view inspection/maintenance system test results to quickly determine what service the vehicle requires. Most of these scan tools also have the ability to:

- Perform system and component tests.
- Report test results of monitored systems.
- Exchange files between a PC and a PDA.
- View and print files on a PC.
- Print DTC/freeze frame.
- Generate emissions reports.
- Display relative TSBs.
- Display full diagnostic code descriptions.
- Observe live sensor data.
- Update the scan tool as a manufacturer's interfaces change.

Figure 1: 16 Scan Tools Package

1.6.2 Oscilloscope

An oscilloscope or lab scope is a visual voltmeter. A lab scope converts electrical signals to a visual image representing voltage changes over a period of time. This information is displayed in the form of a continuous voltage line called a waveform or trace. A scope displays any change in voltage as it occurs. An upward movement of the trace on an oscilloscope indicates an increase in voltage, and a downward movement represents a decrease in voltage.

Figure 1:17 Oscilloscope

1.6.3 Engine Analysers

When performing a complete engine performance analysis, an engine analyzer is used. An engine analyzer houses all of the necessary test equipment. With an engine analyzer, you can perform tests on the battery, starting system, charging system, primary and secondary ignition circuits, electronic control systems, fuel system, emissions system, and engine assembly. The analyzer is connected to these systems by a variety of leads, inductive clamps, probes, and connectors. The data received from these connections is processed by several computers within the analyzer.

Figure 1: 18 Engine Analysers

1.6.4 Fuel Pressure Gauge

A fuel pressure gauge is essential for diagnosing fuel injection systems. A fuel pressure gauge is used to check the discharge pressure of fuel pumps, the regulated pressure of fuel injection systems, and injector pressure drop. This test can identify faulty pumps, regulators, or injectors and can identify restrictions present in the fuel delivery system. Restrictions are typically caused by a dirty fuel filter, collapsed hoses, or damaged fuel lines.

Figure 1: 19 Fuel Pressure Gauge

1.6.5 Injector Balance Tester

The injector balance tester is used to test the injectors in a port fuel injected engine for proper operation. A fuel pressure gauge is also used during the injector balance test. The injector balance tester contains a timing circuit, and some injector balance testers have an off-on switch.

A pair of leads on the tester must be connected to the battery with the correct polarity. The injector terminals are disconnected, and a second double lead on the tester is attached to the injector terminals.

Figure 1:20 Injector Balance Tester

1.6.6 Injector Circuit Test light

A special test light called a noid light can be used to determine if a fuel injector is receiving its proper voltage pulse from the computer. The wiring harness connector is disconnected from the injector and the noid light is plugged into the connector.

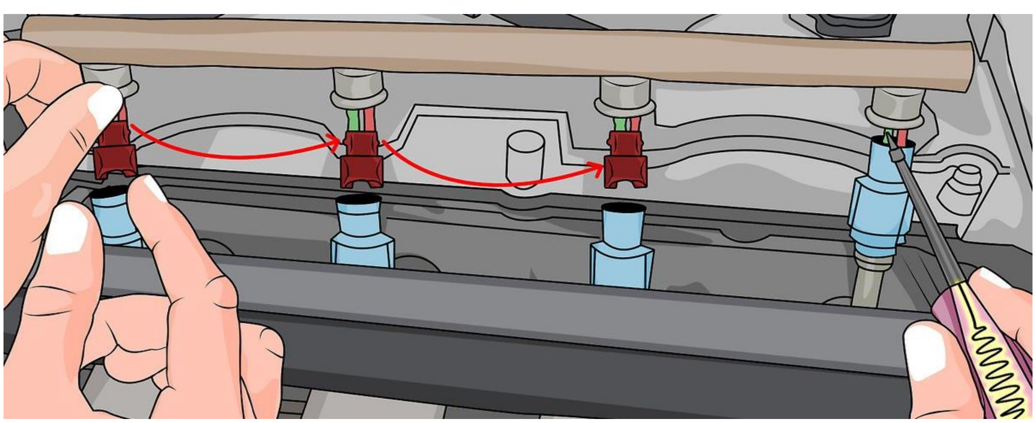


Figure 1:21 10 Injector Circuit Test light

After disabling the ignition to prevent starting, the engine is turned over by the starter motor. The noid light will flash rapidly if the voltage signal is present. No flash usually indicates an open in the power feed or ground circuit to the injector.

1.6.7 Vacuum Gauge

Measuring intake manifold vacuum is another way to diagnose the condition of an engine. Manifold vacuum is tested with a vacuum gauge. Vacuum is formed on a piston's intake stroke. As the piston moves down, it lowers the pressure of the air in the cylinder—if the cylinder is sealed.

Figure 1: 22 Vacuum Gauge

This lower cylinder pressure is called engine vacuum. If there is a leak, atmospheric pressure will force air into the cylinder and the resultant pressure will not be as low. The reason atmospheric pressure enters is simply that whenever there is a low and high pressure, the high pressure always moves toward the low pressure. Vacuum is measured in inches of mercury (in. Hg) and in kilopascals (kPa).

1.6.8 Vacuum Pump

There are many vacuum-operated devices and vacuum switches on cars. These devices use engine vacuum to cause a mechanical action or to switch something on or off. The tool used to test vacuum actuated components is the vacuum pump. There are two types of vacuum pumps: an electrical operated pump and a hand-held pump. The handheld pump is most often used for diagnostics. A hand-held vacuum pump consists of a hand

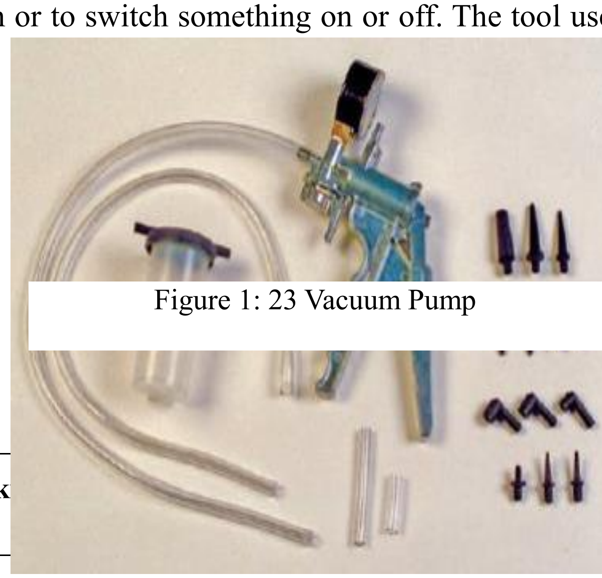


Figure 1: 23 Vacuum Pump

pump, a vacuum gauge, and a length of rubber hose used to attach the pump to the component being tested. Tests with the vacuum pump can usually be performed without removing the component from the vehicle.

1.6.9 Tachometer

A tachometer is used to measure engine speed. Like other meters, tachometers are available in analog and digital types. Digital meters are the most common. Tachometers are connected to the ignition system to monitor ignition pulses, which are then converted to engine speed by the meter. Several types of inductive pickup tachometers that simplify rpm testing are available. An inductive tachometer simply clamps over the number 1 spark plug wire. The digital display gives the engine rpm, based on the magnetic pulses created by the secondary voltage in the wire. This type of tachometer is suitable for distributor less ignition systems.

Figure 1: 24 Tachometer

1.6.10 Timing Light

A timing light is used to check ignition timing. The timing light is connected to the battery terminals and has an inductive cl amp that fits over the number 1 spark plug wire. While the engine is running, the timing light emits a beam of light each time the spark plug fires. Many timing lights have a timing advance knob that may be used to check

Figure 1: 25 Timing Light

spark advance. Some timing lights electronically measure timing advance as the engine rpm is increased and displays it on an LED display.

1.6.11 Spark Tester

A spark tester is a fake spark plug. The tester is constructed like a spark plug but does not have a ground electrode. In place of the electrode there is a grounding clamp.

Figure 1: 26 Spark Tester

Using test spark plugs is an easy way to determine if the ignition problem is caused by something in the primary or secondary circuit. The spark tester is inserted in the spark plug end of an ignition cable. When the engine is cranked, a spark should be seen from the tester to a ground. Experience with these testers will also help you determine the intensity of the spark.

1.6.12 Exhaust Analysers

Most states require an annual emissions inspection to meet that goal. Many shops have an exhaust analyzer for inspection purposes. Exhaust analyzers are also very valuable diagnostic tools. By looking at the quality of an engine's exhaust, a technician is able to look at the engine's combustion process and the efficiency of the vehicle's emission controls.

Any defect will cause emission levels to increase.

The amount and type of change is considered during diagnostics. Exhaust analyzers measure the amount of HC and CO in the exhaust. HC is measured in parts per million (ppm) or grams per mile (g/mi) and

Figure 1: 27 Exhaust Analysers

CO is measured as a percent of the total exhaust. In addition to measuring HC and CO levels, an exhaust analyzer also monitors CO2 and O2 levels.

Self-check 1

Directions: Answer all the questions listed below.

Part I: Say True or False

1. The VIN is given on a plate behind the lower corner of the driver's side of the windshield
2. The first digit of the VIN number is the country of origin or final processing plant
3. The 7th digit is like a security code, called a check digit.
4. A lab scope is a visual voltmeter that shows voltage over a period of time
5. A fuel pressure gauge is not an essential for diagnosing fuel injection systems.

Part II: Fill in the Blank Space

1. _______________is comprised of a group of thousands of professional automotive technicians from around the world
2. _______________is used to measure engine speed
3. ________________contains operating instructions for the vehicle and its accessories.
4. _________________made up of seventeen characters and contains all pertinent information about the vehicle.
5. The ___________ digit is the model year

Part-III: Answer the following questions accordingly.

1. Discuss the Engine Performance Measurement Tools
2. What are the common Engine Faults
3. Describe about the essentiality of Engine Management System
4. Discuss the Six-Step Troubleshooting Plan
5. Describe the Diagnostic Procedure
6. Why does the customer concern need to verify?

Operation Sheet 1

Operation Title: Operate a Scan Tool

Instruction:

- Keep safe your working area
- Refer to your vehicle's service manual to obtain the manufacturer's specifications

Purpose: To operate Scan tool

Required Tools and Equipment: Scan Tool

Precautions: Before making a test make sure engine safe conditions

Quality Criteria: - Check properly the engine performance

Procedures:

P24-1 *Be sure the engine is at normal operating temperature and the ignition switch is off.*

P24-2 *Install the proper module for the vehicle and system into the scan tool.*

P24-3 *Connect the scan tool power leads to the battery or cigar lighter (depending on the design of the scan tool).*

P24-4 *Enter the vehicle's model year and VIN code into the scan tool.*

P24-5 *Select the proper scan tool adapter for the vehicle's DLC.*

P24-6 *Connect the scan tool to the DLC.*

P24-7 *Retrieve the DTCs with the scan tool. Interpret the codes by using the service manual.*

P24-8 *Start the engine and obtain the input sensor and output actuator data on the scan tool. If a printer for the tool is available, print out the data report.*

P24-9 *Compare the input sensor and actuator data to the specifications given in the service manual. Mark all data that are not within specifications.*

Unit Two: Gasoline and Diesel Engines Control System

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Layout and Working of EMS
- Gasoline Engine Management System
- Diesel Ignition Engine Management System

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Understand Layout and Working of EMS
- Familiarization with Gasoline Engine Management System
- Familiarization with Diesel Ignition Engine Management System

2.1 Layout and Working of EMS

The objectives of a control system are the quantitative measures of the tasks to be performed by the system or desired values. It regulates the values of the outputs in a prescribed manner by the (operator determined) inputs through the elements (or components) of the control system. The results/outputs are controlled variables. A control system should; perform its function accurately, Respond quickly, be stable and respond only to valid inputs (noise immunity) a control system consisting of interconnected components is designed to achieve a desired purpose.

The relationship between the controller input and the desired plant output is called the control law for the system and the desired value for the plant output is often called the set point. A device that converts the electrical signal to the desired mechanical action is called an actuator.

Control systems may be categorized by the strategy they employ into one, or a combination of, the following types:

2.1.1 Open Loop Control

The components of an open-loop controller include the electronic controller, which has an output to an actuator. The actuator, in turn, regulates the plant being controlled in accordance with the desired relationship between the reference input and the value of the controlled variable in the plant.

Many examples of open-loop control are encountered in automotive electronic systems, such as fuel control in certain operating modes. In the open-loop control system of Figure A below, the command input is sent to a system block, which performs a control operation on the input to generate an intermediate signal that drives the plant. This type of control is called open loop control because the output of the system is never compared with the command input to see if they match.

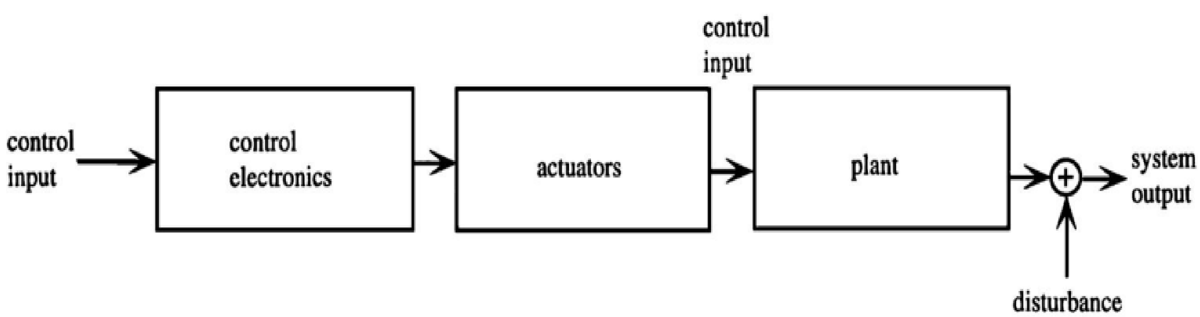


Figure 1: 28 Open Loop Process

The control electronics generates the electrical signal for the actuator in response to the control input and in accordance with the desired relationship between the control input and the system output. The operation of the plant is directly regulated by the actuator (which might simply be an electric motor).

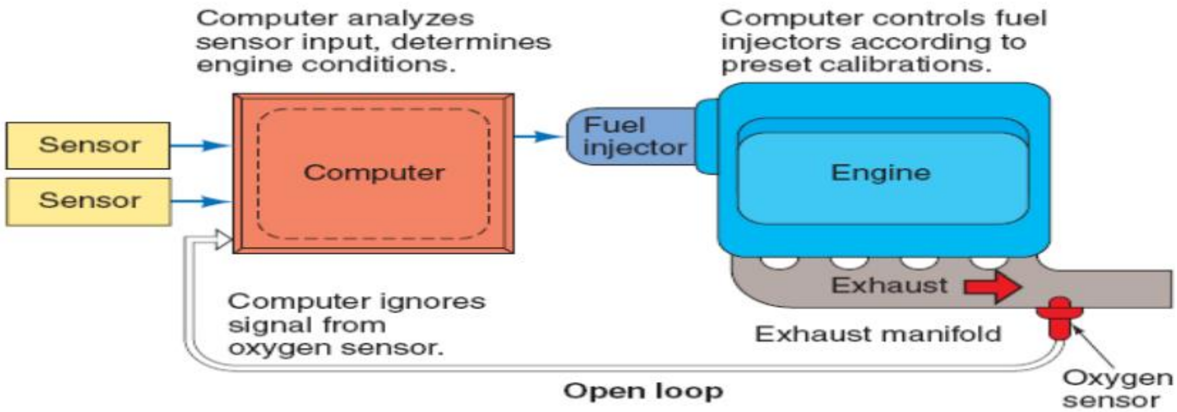


Figure 1: 29 Open Loop Application

The system output may also be affected by external disturbances that are not an inherent part of the plant but are the result of the operating environment. One of the principal drawbacks to the open-loop controller is its inability to compensate for changes that might occur in the controller or the plant or for any disturbances.

This defect is eliminated in a closed-loop control system, in which the actual system output is compared to the desired output value in accordance with the input. Of course, a measurement must be made of the plant output in such a system, and this requires measurement instrumentation.

During engine cranking the mixture is set rich by an amount depending on the engine temperature (measured via the engine coolant sensor). Once the engine starts and until a specific set of conditions is satisfied, the engine control operates in the open-loop mode. In this mode the mass air flow is measured (via MAF sensor).

The correct fuel amount is computed in the electronic controller as a function of engine temperature. The correct actuating signal is then computed and sent to the fuel metering actuator. In essentially all modern engines, fuel metering is accomplished by a set of fuel injectors. After combustion the exhaust gases flow past the EGO sensor, through the TWC, and out the tailpipe. Once the EGO sensor has reached its operating temperature (typically a few seconds to about 2 min), the EGO sensor signal is read by the controller and the system begins closed-loop operation.

2.1.2 Feed Forward Control

Fig below shows feed forward control system in which the input demand is modified by the output from a disturbance measurement system to correct for the effects of the disturbance. In the example of ignition timing, engine load is estimated indirectly by measurement of inlet manifold vacuum. The optimal relationship between ignition timing and load for a particular engine speed is not linear. So one ways to modify ignition timing with load for a defined speed range is to use a look-up table with input variables of engine speed and inlet manifold pressure.

Rather more sophisticated compensation algorithms are present within Electronic Spark Advance systems to counter the effects of engine warm-up, overheating, and idling performance and knock control, but the underlying weakness remains of lack of feedback of engine performance measures to alter timing.

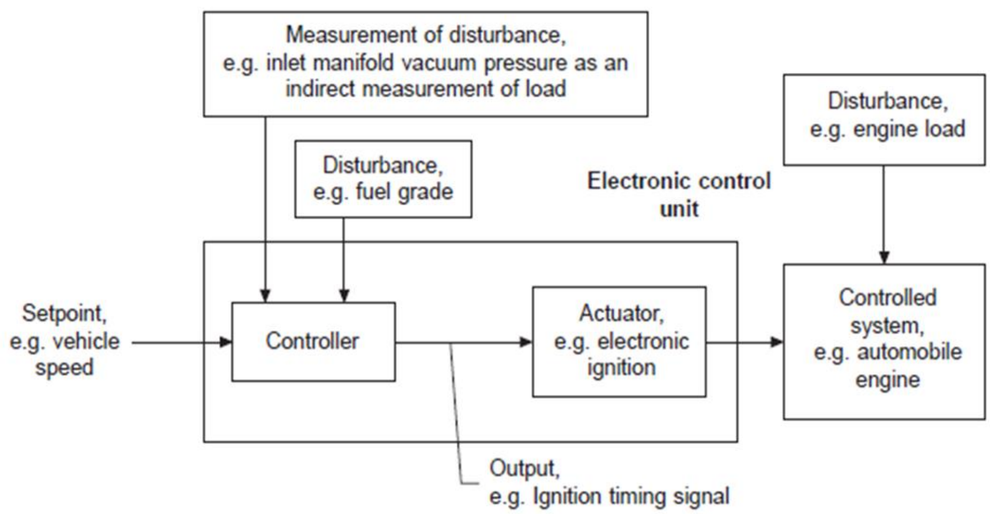


Figure 1:30 Feed Forward Control System Showing Compensation Offset

2.1.3 Closed Loop Control

In a closed-loop control system a measurement of the output variable being controlled is obtained via a sensor and fed back to the controller. The measured value of the controlled variable is compared with the desired value for that variable based on the reference input. An error signal based on the difference between desired and actual values of the output signal is created, and the controller generates an actuating signal that tends to reduce the error to zero. In addition to reducing this error to zero, feedback has other potential benefits in a control system. It can affect control system performance by improving system stability and suppressing the effects of disturbances in the system. For any given set of operating conditions, the fuel metering actuator provides fuel flow to produce an air/fuel ratio set by the controller output. This mixture is burned in the cylinder and the combustion products leave the engine through the exhaust pipe.

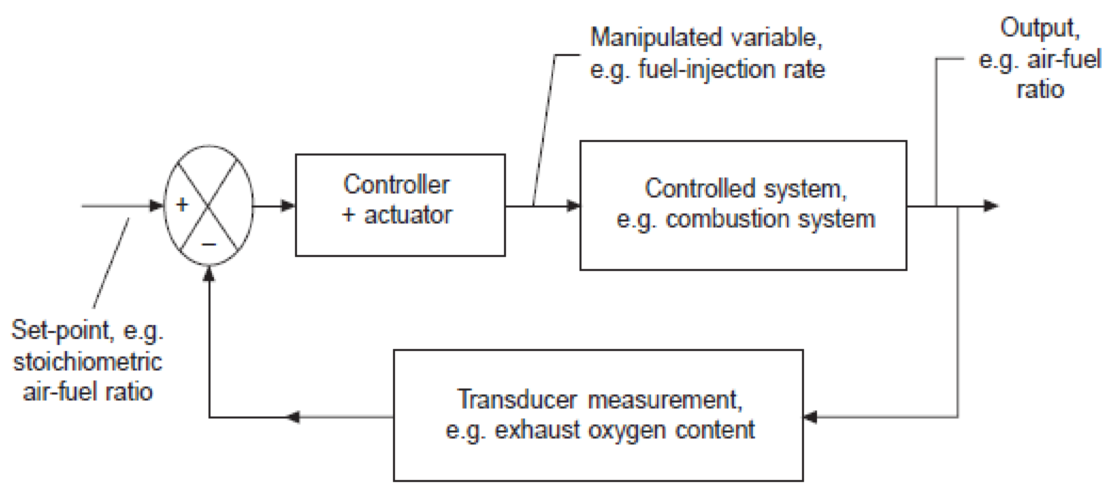


Figure 1: 31 Closed Loop Process

The EGO sensor generates a feedback signal for the controller input that depends on the air/fuel ratio. This signal tells the controller to adjust the fuel flow rate for the required air/fuel ratio, thus completing the loop.

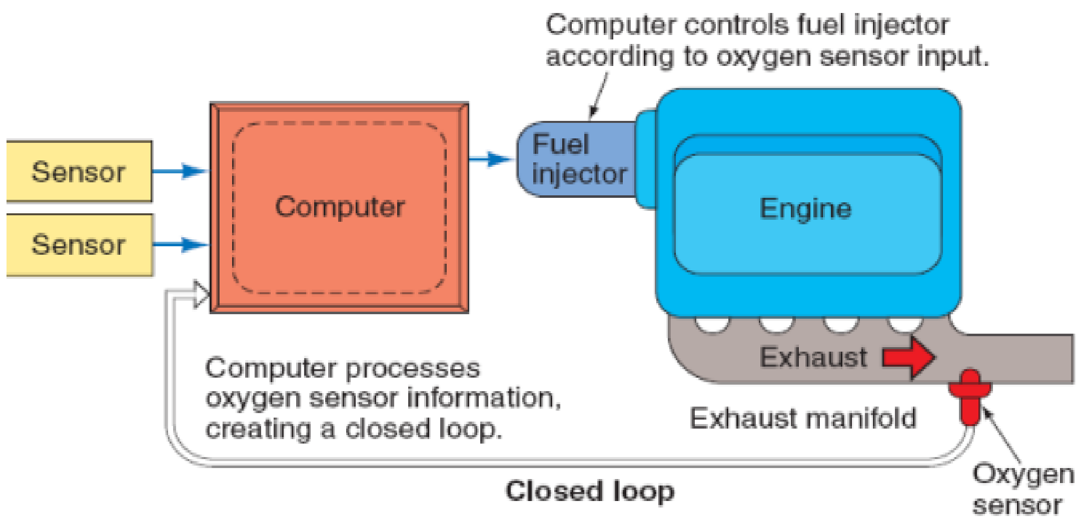


Figure 1: 32 Closed Loop Application

2.1.4 Sequential Control

Sequential control is present in a number of control systems within automobiles. Sequences of events which may be open, feed-forward or closed-loop in structure are found in examples of manufacturer's electronics park advance and electronic fuel injection systems.

For instance, during cranking of the engine on start-up, ECU controlling fuel injection

Injection Period = Basic Cranking Injection Duration + Temperature Correction +Battery Voltage Correction

produces an injection duration using the formula

During initial phase an appropriate cranking duration related to cranking speed is modified by the intake air and coolant temperature sensors the algorithm belongs to the feed forward where the disturbance effect is measured and an allowance made for its effect. A correction may also be made for battery voltage variations since the injector speed of response is a function of battery voltage. Engine speed feedback, after successful starting, enables the ECU to progressively reduce the injection duration; the ECU producing a large enrichment of the fuel supplied during the initial phase. Following the start-up phase, the ECU moves into an engine warm-up enrichment phase which, as the coolant temperature rises, reduces the injector duration.

In the final stage of the sequence, normal or steady-state operation is reached at the end of the warm-up phase and stoichiometric control or control of the air-fuel mixture to a ratio of 14.7:1 ($\lambda = 1$) is produced by use of closed-loop control application to the injection duration. This is formed by using information from an exhaust gas oxygen concentration sensor and modifying the injection duration by a correction coefficient constrained to a range of between 0.8 and 1.2.

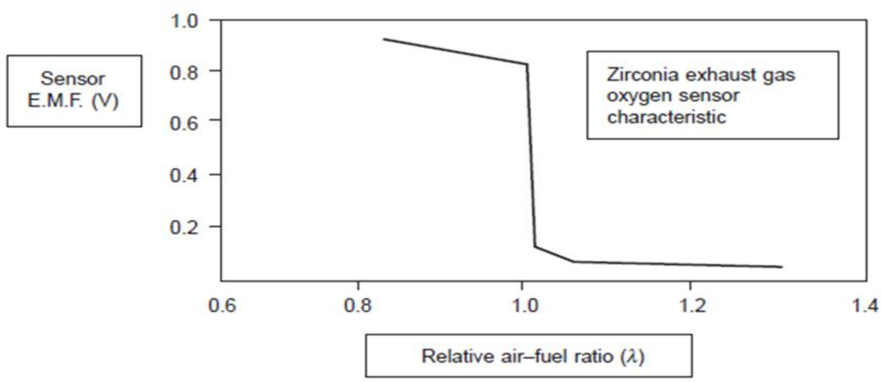


Figure 1: 33 Output characteristic of a zirconia exhaust gas oxygen sensor

2.2 Gasoline Engine Management System

2.2.1 Injection Types

A. Throttle Body Injection

The throttle body injection is also known as single point injection. This system can be used in single cylinder engines and multi-cylinder engines. This system replaces a carburettor with one or two fuel injectors which are placed upstream (above) of the throttle valve. Hence named as throttle body injection. The throttle controls the amount of charge inducted into cylinder. The fuel injector injects the fuel in throttle body. The injected fuel mixes with air and passes to intake manifold.

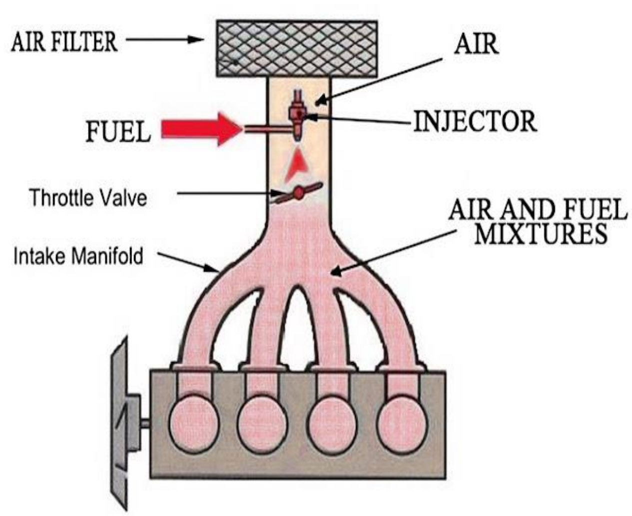


Figure 1: 34 TBI Outline

As mentioned earlier, TBI is a single point fuel injection, but in case of V-engines (having 8 to 16 cylinders), two such TBI systems would be used because V-engines have two intake manifolds. There are two injection strategies viz. *Continuous injection* and T*imed or Sequential Injection.*

B. Multi-Point Fuel Injection (MPFI)

The MPFI injection system is also known as port fuel injection (PFI). This injection system is widely used in multi-cylinder petrol engines.

In this, the each cylinder is provided with individual injector which is located over intake valve as shown in Fig. below. The fuel can be supplied to each injector by a common accumulator or separate branching of pipes.

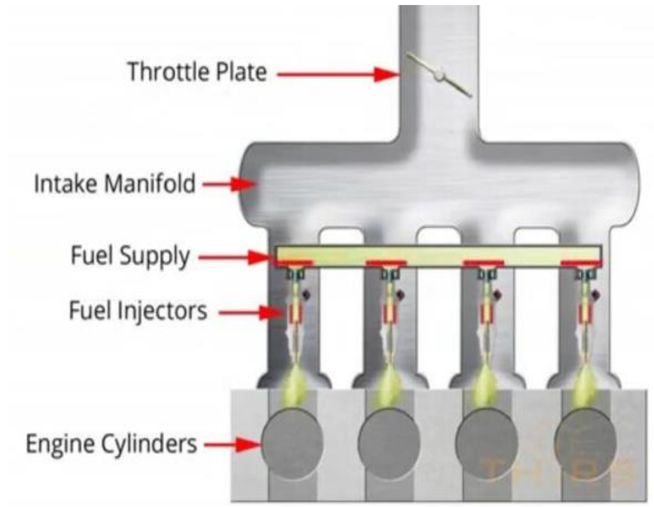


Figure 1: 35 Multi-Point Fuel Injection

This system allows, more uniform fuel distribution to each cylinder. Hence, it helps to smooth running of engine. The amount of fuel injected is dependent on the engine speed and load. Various sensors are such as speed sensor, throttle position sensor, mass air flow sensor etc. are used to control the quantity of fuel injected.

The heat conducted from the engine cylinder assists the fuel evaporation, which improves the homogeneity of the mixture. There are two types of MPFI systems, these are listed below. The MPFI systems, they are known by the trade name Jetronic like L-Jetronic, K-Jetronic, and KE-Jetronic etc.

I. D- MPFI System

In this, D stands for “Druck”. It is a German word meaning “Pressure”. It is also known as manifold pressure control system. The Fig. below shows the block diagram of D- MPFI system. The quantity of fuel injected depends of the intake manifold pressure. The intake manifold vacuum is sensed by the pressure sensor and it sends the signal to ECU (Electronic Control Unit). The ECU decides the quantity of fuel injection, time of injection depending on the look-up table data.

The signal from ECU actuates the fuel injection. The solenoid (Electromagnetic) fuel injectors are used for fuel injection. It also employs other sensors like engine rpm sensor, air temperature sensor etc. for accurate metering of fuel. The exhaust gas oxygen (EGO) sensor detects the amount of oxygen retained in exhaust gas. This is because the 3 way catalytic converter gives better conversion efficiency at stoichiometric air-fuel ratio.

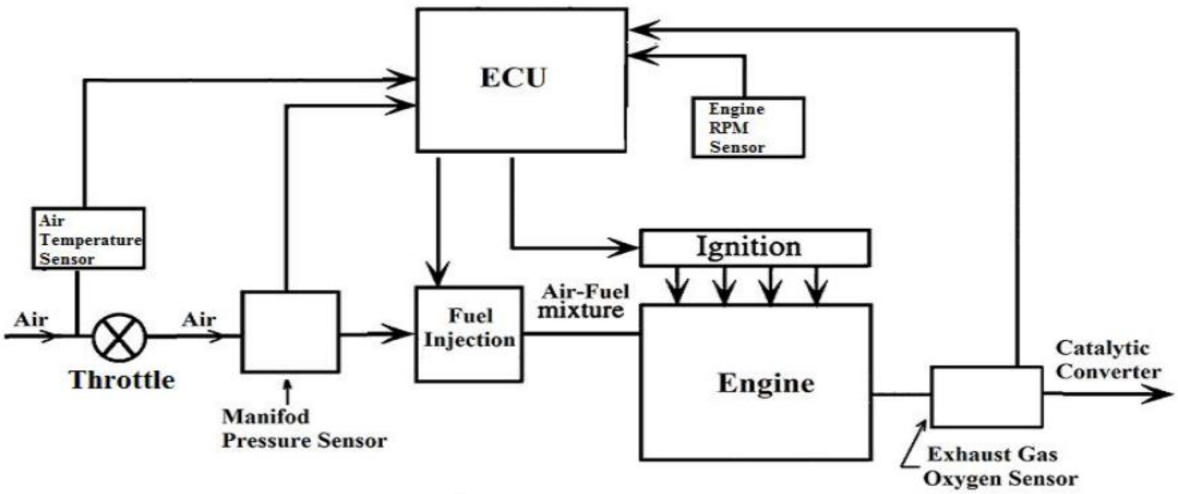


Figure 1: 36 D- MPFI System

II. L- MPFI System

In this, L stands for "Luft". It is a German word meaning "Air". It is similar to D-MPFI system, the only difference being use of intake air flow sensor which replaces the pressure sensor. The air flow sensor measures the amount of air inducted into cylinder and sends the signal to the ECU as shown in Fig. below.

Also, the ECU also receives the information from engine rpm sensor, inlet air temperature sensor and decides the quantity of fuel injection. The exhaust gas oxygen (EGO) sensor (also known as lambda sensor) detects the amount of oxygen retained in exhaust gas.

The modern automotive engine is also equipped with sensors like, coolant temperature sensor, Throttle position sensor, manifold absolute pressure sensor, crankshaft position sensor, camshaft position sensor etc. These sensor helps for close control of engine which in turn gives good performance, better economy and reduced emissions. It also improves the life cycle of engine. But, use of sensors increases cost of automobile, increases maintenance and requires a special equipment's for servicing them.

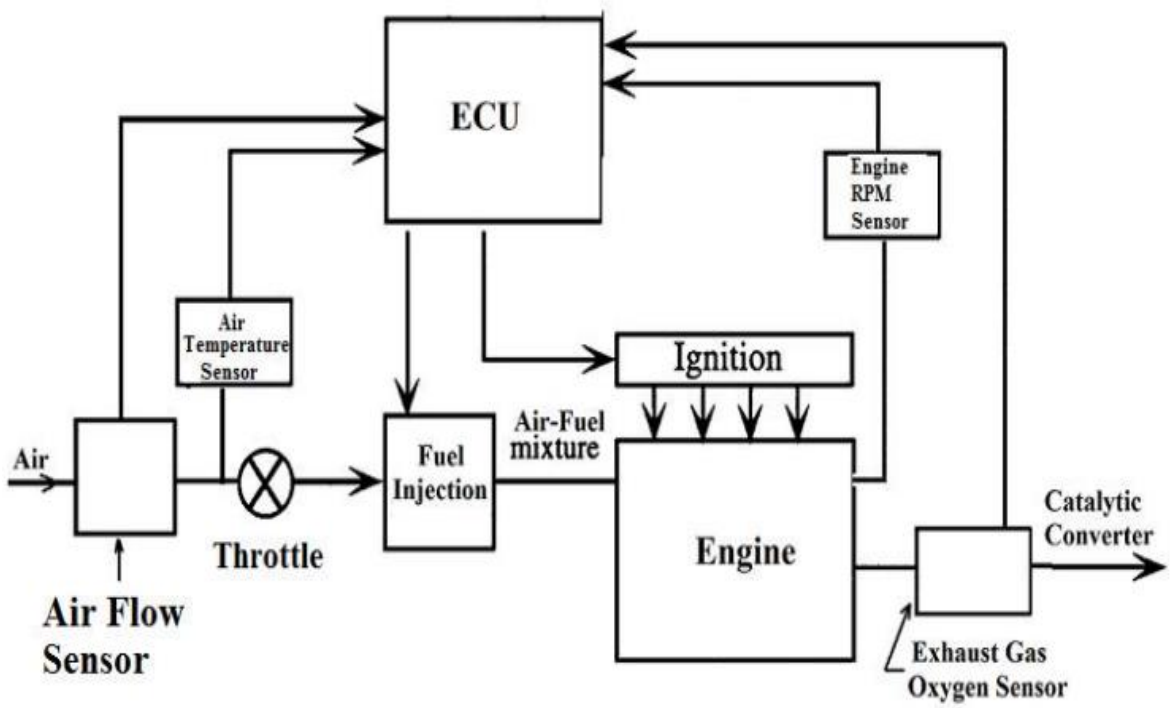


Figure 1: 37 L- MPFI System

III. Gasoline Direct Injection

Gasoline direct injection (GDI) is a type of fuel injection that delivers highly pressurized fuel directly into the engine cylinders. Traditional port or throttle body injection systems deliver fuel into the intake port above the intake valve. In port or throttle body engines, air mixes with the fuel in the intake port and the mixture enters the cylinder via the intake valve.

Direct injection engines can run with much less fuel than traditional fuel injection, reducing emissions and increasing fuel economy. The engine control module (ECM) selects the ratio of fuel to air for the engines to run efficiently in all situations.

Figure 1: 38 Gasoline Direct Injection Engine

Although direct injection diesel

engines are common, the technology is relatively new in gasoline engines. In addition to improved fuel efficiency, direct injection allows the use of higher than normal compression ratios, which increases power.

Direct injection engines use two fuel pumps, a low-pressure pump and a high-pressure pump. The low-pressure pump sends fuel from the tank, through the fuel filter and into the high-pressure pump.

The engine's camshaft drives the high-pressure pump, allowing fuel pressure as high as 2,500 pounds of force per square inch (PSI). This highly pressurized fuel travels through fuel rails and directly into the engine cylinders via specifically designed fuel injectors. During normal engine operation, cylinder pressure is quite high. The high-pressure fuel pump overcomes cylinder pressure, allowing finely atomized fuel to enter. Direct injection engines are physically different from port or throttle body injected engines. An additional access point to the cylinder exists to allow for the fuel injector. GDI engines also utilize a high-pressure fuel rail and high-pressure fuel pump — as well as corresponding high-pressure relief valves in case of a malfunction.

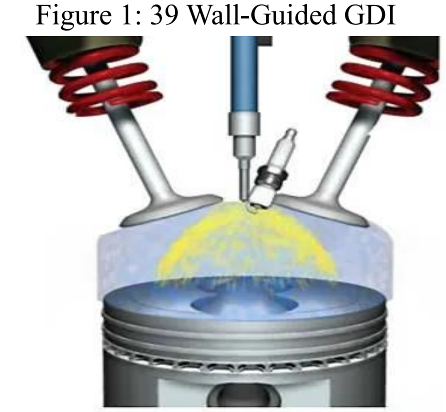
a) Direct Injection Modes

There are a few primary techniques used for creating a distribution of fuel around the combustion chambers in a direct injection engine. These GDI modes are:

- **Wall-Guided:** A wall-guided system positions the injector at an angle between the inlet valves and has a distinctive piston shape that directs fuel toward the spark plug. When injected, a specially shaped piston dome deflects the fuel mix up toward the spark plug. The piston then helps further push the combustible mixture toward the spark plug.

Figure 1: 39 Wall-Guided GDI

Spray-Guided: This system positions the injector centrally in the top of the combustion chamber



next to the spark plug and sprays fuel directly down and across the spark plug. This design is generally more efficient than wall-guided systems because the fuel sprays directly toward the spark plug rather than traveling along the piston crown.

Figure 1: 40 Spray-Guided GDI

Dual Injection: Some manufacturers use dual injection, which is a blend of direct and port injection. The combination can overcome some of the challenges with direct injection, specifically dirty intake valves and high-RPM efficiency challenges. In dual injection engines, the ECM determines which injectors to use based on engine demand.

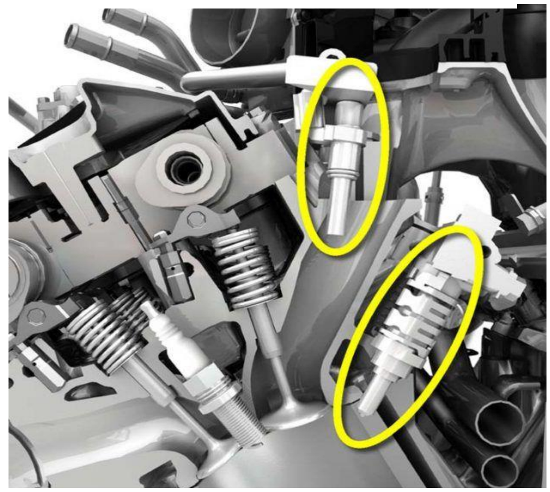


Figure 1: 41 Dual Injection GDI

2.2.2 Injection Strategy

A. Continuous or Grouped Injection

In this, the fuel is injected in intake manifold continuously. Three fourth of fuel injected is stored above intake valve and one fourth of fuel is injected directly into the cylinder. It uses low pressure fuel pump of about 2 to 2.5 bars. The fuel injection duration may vary from 10° (light load) crank angle to 300° (rated load) crank angle.

As shown in below figure, the fuel injection for 6 cylinder engine is divided in two groups. For group 1 the fuel injection starts at crank angle 300° while for group 2 the fuel injection starts at crank angle 660°. The injection duration depends on the load and the speed of the engine. The continuous injection cannot be used in GDI system. It can be used in throttle body injection system and MPFI systems.

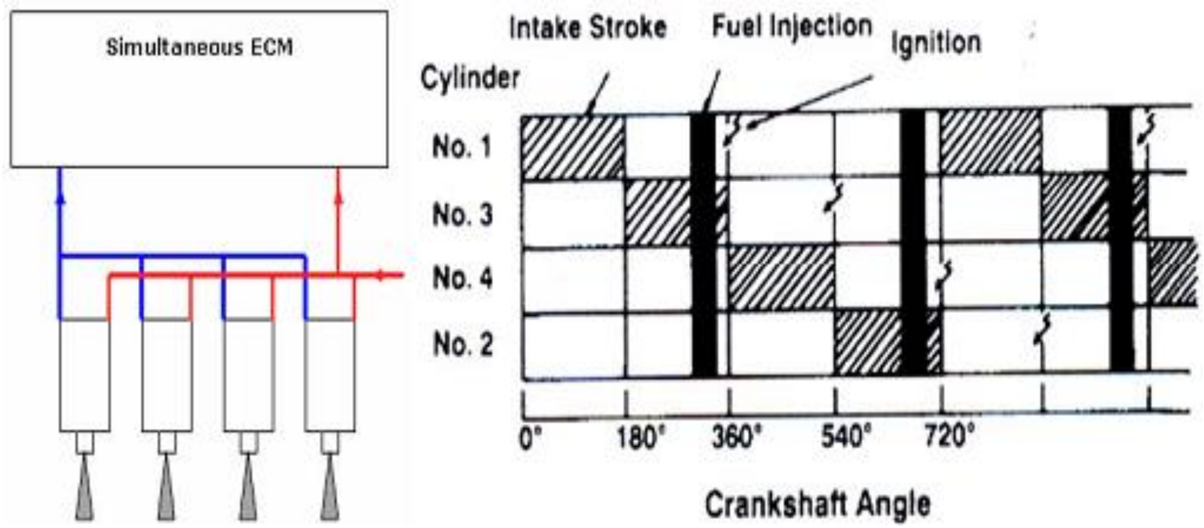


Figure 1: 42 Continuous or Grouped Injection

B. Timed or Sequential Injection

In this, the fuel is injected sequentially or at regular intervals. The fuel injection starts as the relevant intake valve opens as shown in Fig. below. The amount of fuel injected is controlled by the duration of injector valve is open. This system greatly reduces the risk of air-fuel mixture drawn off into adjacent cylinder. The control over air-fuel ratio is extremely accurate. The injection pressure may vary for 10 to 30 bar. The timed injection can be used in MPFI system and GDI system.

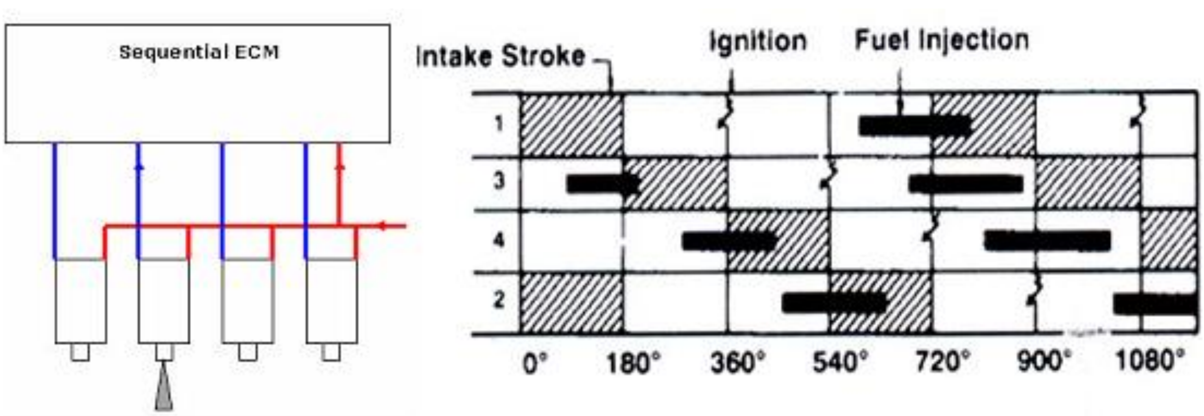


Figure 1: 43 Timed or Sequential Injection

2.2.3 Electronic Engine Control

The engine control system is responsible for controlling fuel and ignition for all possible engine operating conditions. However, there are a number of distinct categories of engine operation, each of which corresponds to a separate and distinct operating mode for the engine control system.

The differences between these operating modes are sufficiently great that different software is used for each. The control system must determine the operating mode from the existing sensor data and call the particular corresponding software routine. For a typical engine there are seven different engine operating modes that affect fuel control:

1. Start Enrichment

The basic injection duration cannot be calculated from the amount of the intake air because the engine speed is low and the changes in the amount of the intake air are large at starting. For this reason, the fuel injection duration at starting is determined from the coolant temperature.

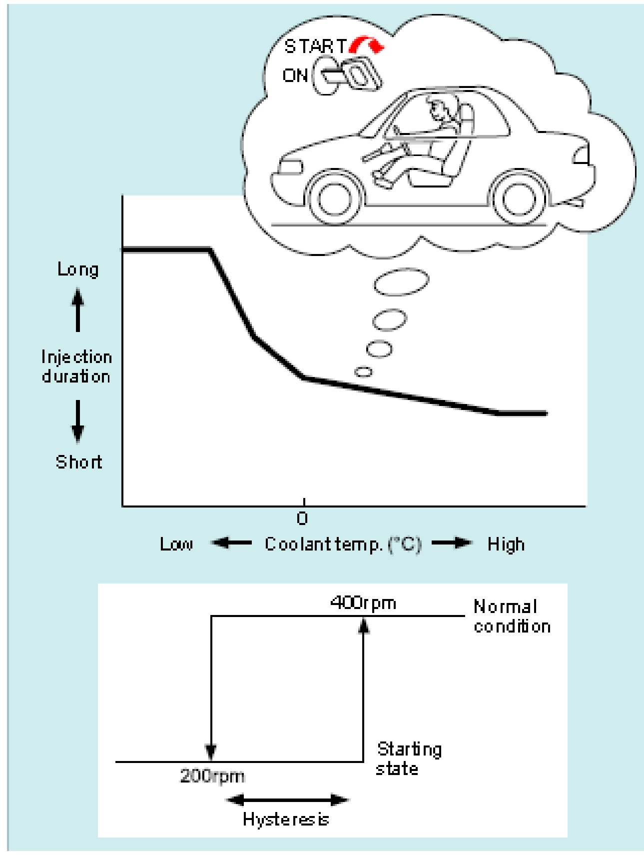


Figure 1: 44Start Enrichment

The coolant temperature is detected by the water temperature sensor. The lower the water temperature is the fuel vaporization becomes worse. Therefore, the air-fuel mixture is made richer by lengthening the injection duration. The engine ECU determines that the engine is being started when the engine speed is 400 rpm or less.

In addition, when the engine speed suddenly falls below 400 rpm due to a sudden increase of the load on the engine, a hysteresis is used to prevent the engine ECU from determining that an engine that has already been started is being started again unless the engine speed falls below 200 rpm.

2.Warm-Up Enrichment

The amount of the fuel injection is increased because the fuel vaporization is poor during the cold engine. When the coolant temperature is low, the fuel injection duration is increased to make the air-fuel mixture richer in order to attain the drivability during the cold engine.The maximum correction is twice as long as normal temperature.

3.Air-fuel ratio feedback correction (For most models)

When there are no major fluctuations in the engine load or engine speed, such as when idling or driving at constant speed after warming up, fuel (air-fuel mixture close to the theoretical air-fuel ratio) is supplied based on the amount of the intake air.

The following corrections are activated when driving at a constant speed after warming up.

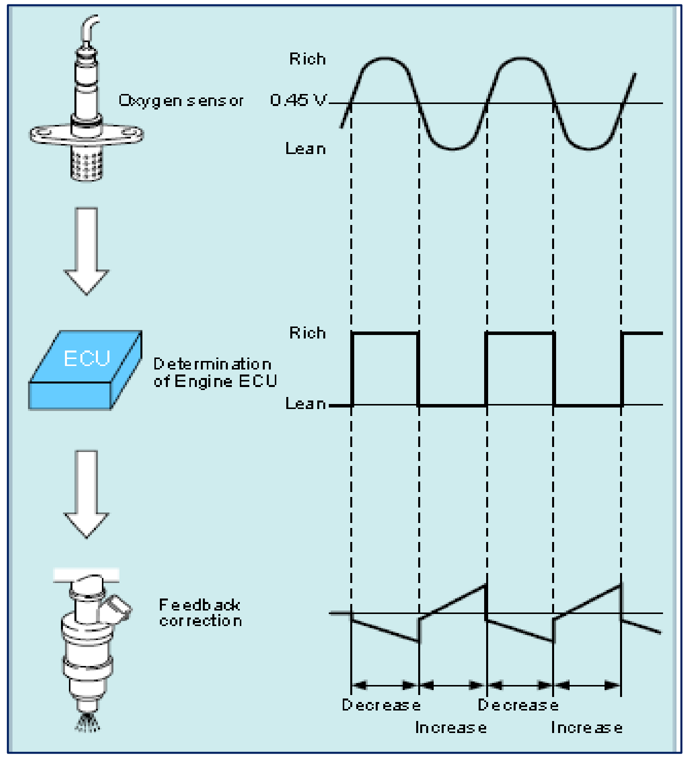


Figure 1: 45 Air-Fuel Ratio Feedback Correction

(1) Feedback control using the oxygen sensor (Air-fuel ratio feedback control):

The engine ECU determines the basic injection duration to achieve the theoretical air-fuel ratio. However, a slight deviation from the theoretical air-fuel ratio occurs in accordance with the actual engine conditions, changes over time, and other conditions.

Therefore, an oxygen sensor detects the oxygen concentration in the exhaust gas to determine if the current fuel injection duration becomes the theoretical air fuel ratio against the amount of the intake air. If the engine ECU determines from signals of the oxygen sensor that the air-fuel ratio is richer than the theoretical air-fuel ratio, it shortens the injection duration to make the air-fuel mixture leaner. Conversely, if it determines that the air-fuel ratio is lean, it will lengthen the injection duration to make the air-fuel mixture richer.

The feedback control operates to maintain the average air-fuel ratio at the theoretical air-fuel ratio by repeatedly performing minor corrections. (This is called a "closed-loop" operation.)

In order to prevent overheating of the catalyst and assure good engine operation, air -furl ratio feedback does not occur under the following conditions (open-loop operation):

- During engine starting
- During after-start enrichment
- During power enrichment
- When the coolant temperature is below a determined level
- When fuel cut-off occurs
- When the lean signal continues longer than a determined time

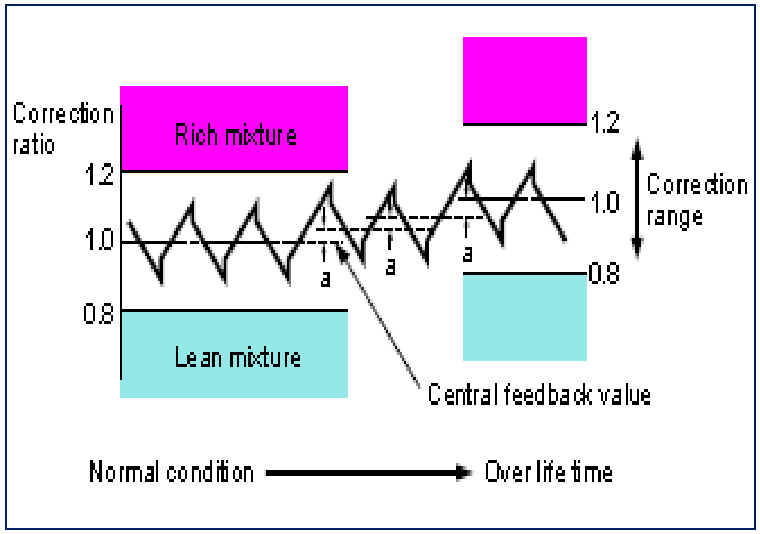
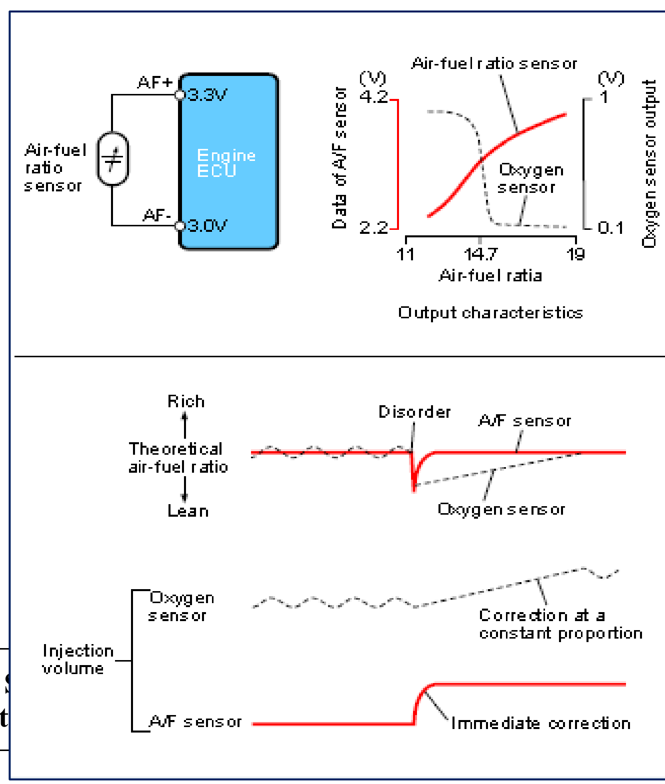


Figure 1: 46 Air Fuel Correction learned Control

The centre point (a) changes during the feedback control such as time passes. In this case, the centre point is forced to be returned to the centre. If it is not, it will cause the out of the correction range of the feedback control. This is called air-fuel ratio learned control or long fuel trim.

(2) Feedback control using the air-fuel ratio sensor

The output voltage of the oxygen sensor changes rapidly around the theoretical air-fuel ratio as shown in the illustration (upper). The A/F sensor data which the engine ECU attains is displayed in the hand-held tester. (When the air-fuel ration is lean, the voltage is high.



Conversely, the voltage is low when rich.) As a result, the detection precision of the air-fuel ratio has been improved. If the current air-fuel ratio changes from the theoretical air-fuel ratio as shown in the illustration (below), the engine ECU continuously corrects the air-fuel ratio using the oxygen sensor signal.

For the A/F sensor, however, the engine ECU corrects instantly by determining the amount of change from the theoretical air-fuel ratio.

(3) CO emission control correction for vehicles without an oxygen sensor or A/F sensor:

Figure 1: 47 Feedback control using the air-fuel ratio sensor

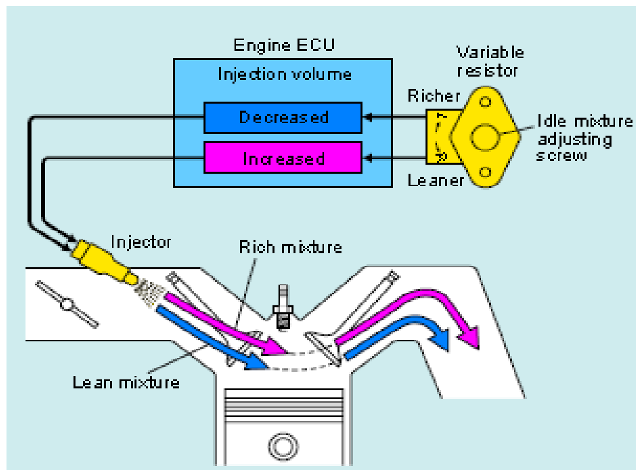
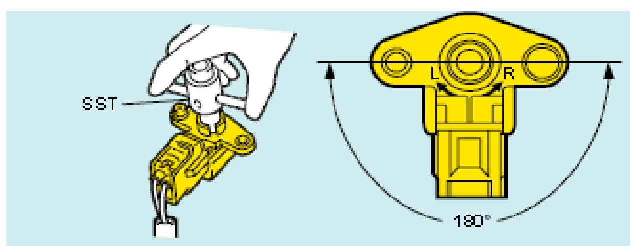


Figure 1: 48 CO Emission Control Correction



For vehicles without an oxygen sensor or A/F sensor, a variable resistor can be used to adjust the CO concentration (%) during idling. Turning the resistor to the R side makes the concentration richer, and turning it to the L side makes it leaner.

For vehicles equipped with an oxygen sensor or A/F sensor, however, CO adjustment is not required during idling because these vehicles are automatically adjusted to the proper air-fuel ratio using the sensor signal.

4.Acceleration Enrichment

The air-fuel ratio becomes lean, especially during the start of acceleration because a fuel supply lag tends to occur during acceleration against the rapid change of the amount of the intake air when the accelerator pedal is depressed.

For this reason, the injection duration is lengthened to increase the fuel injection volume against the intake air to prevent the air-fuel mixture from becoming lean.

The acceleration is determined by the speed of the change in the throttle valve opening angle. The correction during acceleration increases greatly during the start of acceleration and is gradually reduced thereafter until the increase has ended. In addition, the more rapid the acceleration is, the larger the fuel injection volume increase.

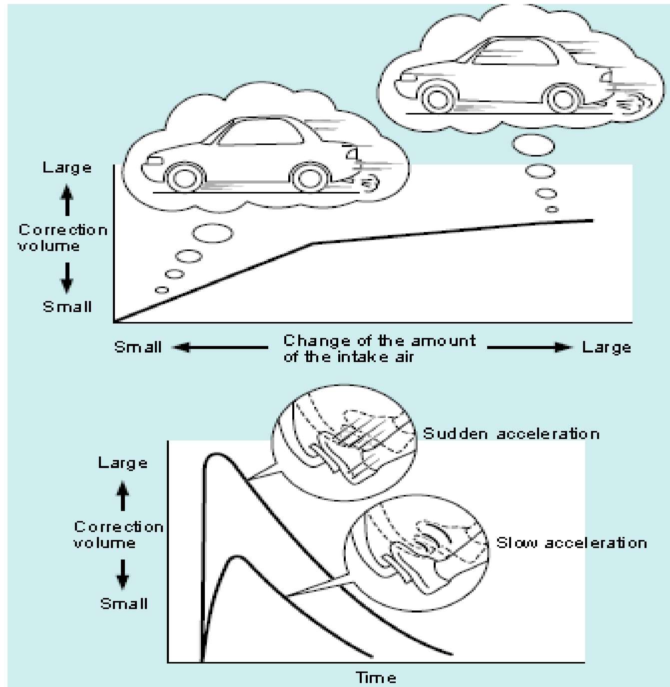


Figure 1: 49 Acceleration Enrichment

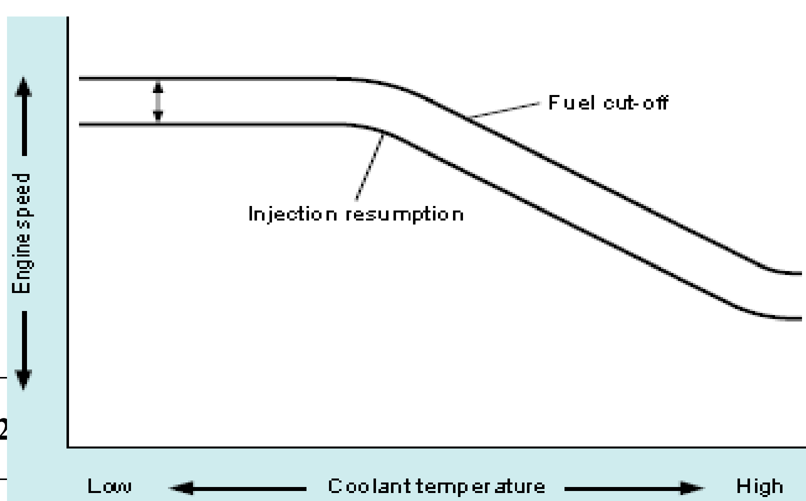
5.Fuel Cut-Off

During deceleration, injection operation is stopped according to the deceleration condition in order to reduce the harmful exhaust gases and improve the engine braking effect. Then the fuel cut-off control is activated to cut-off the fuel injection.

The state of deceleration is determined from the throttle valve opening and the engine speed. When the throttle valve is closed and the engine speed is high, itis determined that the vehicle is decelerating.

Fuel cut-off control

The fuel cut-off control stops the fuel injection when the engine speed is higher than a determined speed and the throttle



valve is closed.

Figure 1: 50 Fuel cut-off control

Fuel injection will resume when the engine speed slows to a determined speed or the throttle valve is opened. The fuel cut-off engine speed and fuel injection resumption engine speed will increase when the coolant temperature is low.

In addition, the fuel cut-off engine speed and fuel injection resumption engine speed are increased when the air conditioner switch is on to prevent the engine speed from falling and an engine from stalling. There are also some engine models in which these engine speeds drop during braking (i.e., when the stop light switch is on).

6.Power Enrichment

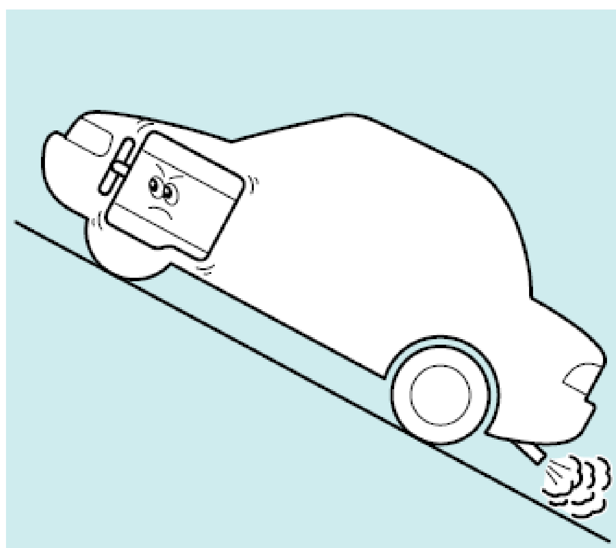


Figure 1: 51Power Enrichment

As there is a large amount of the intake air at heavy loads, such as when climbing a steep hill, it is difficult to sufficiently mix the injected fuel with the intake air. And all of the intake air is not used during combustion, causing some to remain.

Therefore, more fuel than for the theoretical air-fuel ratio is injected to use all of the intake air in combustion to increase power. Heavy loads are determined from the throttle position sensor opening, engine speed, and intake air mass (VG or PIM).

The greater the intake air mass (VG or PIM) or the higher the engine speed is, the ratio of the increased amount becomes larger. In addition, the amount is further increased when the throttle valve opening angle becomes a certain value or more. The correction of the increased amount is from approx. 10% to 30%.

7.Intake Air Temperature Correction

The air density changes depending on the air temperature. For this reason, a correction must be made to increase or decrease the fuel volume in accordance with the intake air temperature to optimize the mixture ratio required for the current engine conditions.

The intake air temperature is detected by the intake air temperature sensor. The engine ECU is set to a standard intake air temperature of 20 °C (68 °F).The correction amount is determined when the temperature rises above or falls below this temperature. When the intake air temperature is low, the amount is increased because the air density is high. When at high temperature, the amount is decreased because the air density is low. The correction of the increased/ decreased amount is approx. 10%.

Hint: For hot-wire type air flow meters, the air flow meter itself outputs a corrective signal for the intake air temperature. Therefore, intake air temperature correction is not required.

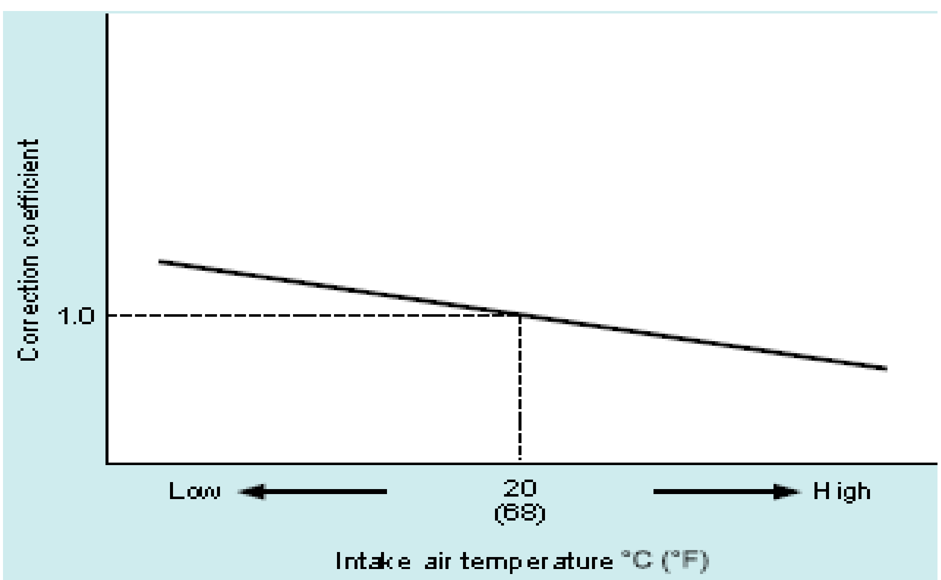


Figure 1: 52 Intake Air Temperature Correction

8.Voltage Correction

There is a slight delay between the time where the engine ECU sends an injection signal to the injector, and the time when the injector actually injects the fuel. If there is a severe drop in battery voltage, then this delay will be longer.

This means that the time the injector injects the fuel is shorter than the time calculated by the engine ECU. Therefore, the ratio of air becomes higher than the mixture ratio required by the engine. For this reason, the engine ECU adjusts this by making the injector injection duration longer in accordance with the battery voltage drop.

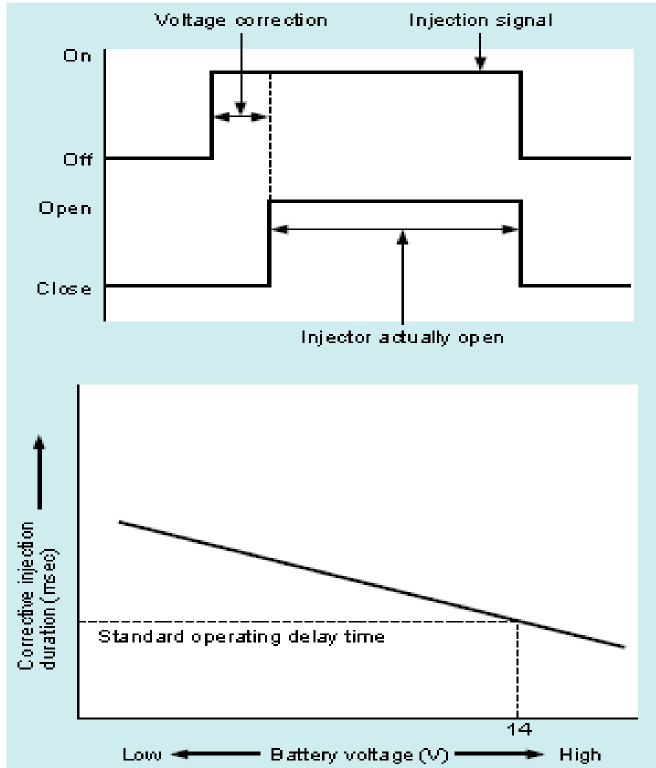


Figure 1: 53 Voltage Correction

9.Spark Timing Control

An engine must be provided with fuel and air in correct proportions, and the means to ignite this mixture in the form of an electric spark. Before the development of electronic ignition the traditional ignition system included spark plugs, a distributor, and a high-voltage ignition coil. The distributor would sequentially connect the coil output high voltage to the correct spark plug.

In addition, it would cause the coil to generate the spark by interrupting the primary current (ignition points) in the desired coil, thereby generating the required spark. The time of occurrence of this spark (i.e., the ignition timing) in relation of the piston to TDC influences the torque generated. In most present-day electronically controlled engines the distributor has been replaced by multiple coils. Each coil supplies the spark to either one or two cylinders. In such a system the controller selects the appropriate coil and delivers a trigger pulse to ignition control circuitry at the correct time for each cylinder. (Note: In some cases the coil is on the spark plug as an integral unit.)

The figure illustrates such a system for an example 4-cylinder engine. In this example a pair of coils provides the spark for firing two cylinders for each coil. Cylinder pairs are selected such that one cylinder is on its compression stroke while the other is on exhaust. The cylinder on compression is the cylinder to be fired (at a time somewhat before it reaches TDC). The other cylinder is on exhaust. The coil fires the spark plugs for these two cylinders simultaneously. For the former cylinder, the mixture is ignited and combustion begins for the power stroke that follows. For the other cylinder (on exhaust stroke), the combustion has already taken place and the spark has no effect.

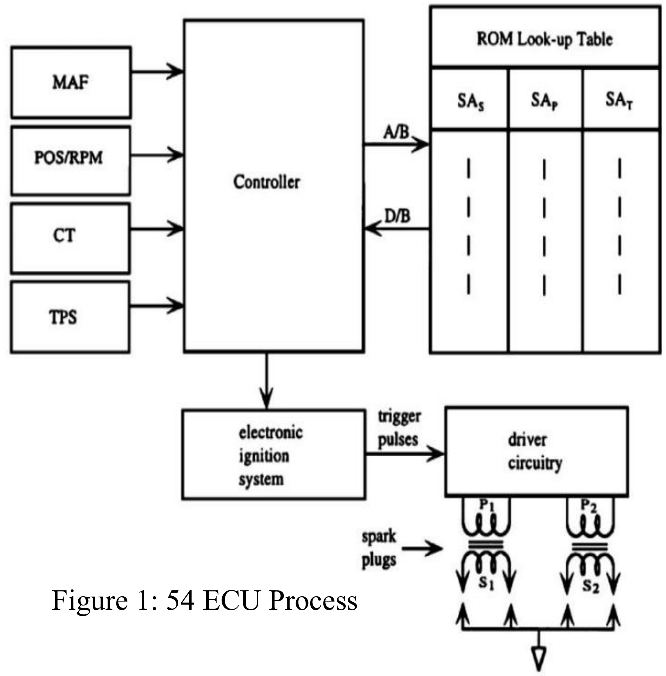
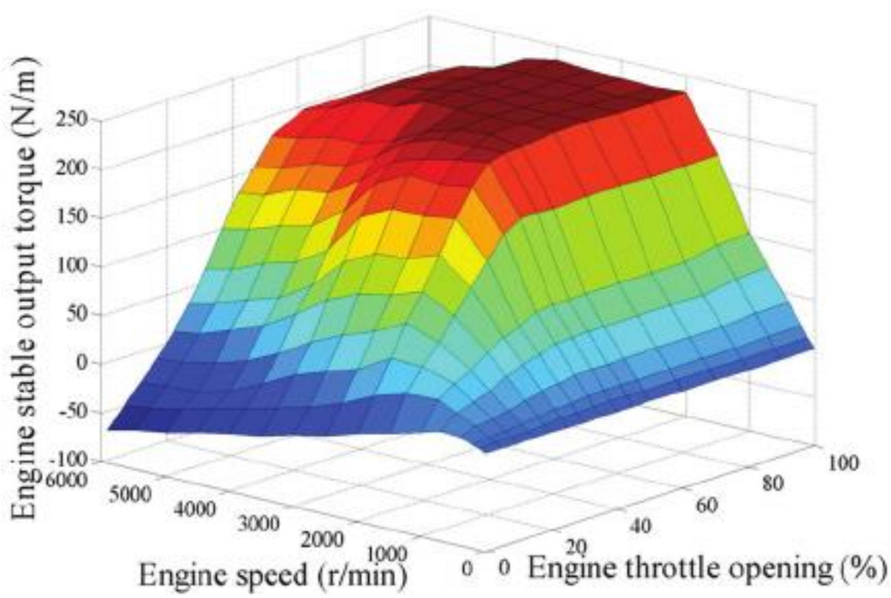


Figure 1: 54 ECU Process

Although the mixture for modern emission regulated engines is constrained to stoichiometry, the spark timing can be varied in order to achieve optimum performance within the mixture constraint. For example, the ignition timing can be chose to produce the best possible engine torque for any given operating condition.



This optimum ignition timing is known for any given engine configuration from studies of engine Figure 1: 55 Engine Mapping performance as measured on an engine dynamometer.

The variables that influence the optimum spark timing at any operating condition include **RPM, manifold pressure (or mass air flow), barometric pressure, and coolant temperature.**

The correct ignition timing for each value of these variables is stored in a ROM lookup table. The engine control system obtains readings from the various sensors and generates an address to the lookup table (ROM). After reading the data from the lookup tables, the control system computes the correct spark advance. An output signal is generated at the appropriate time to activate the spark.

The ignition system described above is known as a distributor less ignition system (DIS) since it uses no distributor. In distributor-equipped engines there is only one coil, and its secondary is connected to the rotary switch or distributor. In a typical electronic ignition control system, the total spark advance, SA (in degrees before TDC), is made up of several components that are added together:

$$SA = SA_S + SA_P + SA_T$$

The first component, SA_S, is the basic spark advance, which is a tabulated function of RPM. The control system reads RPM, and calculates the address in ROM of the SA_S that corresponds to these values. Typically, the advance of RPM from idle to about 1200 RPM is relatively slow.

Then, from about 1200 to about 2300 RPM the increase in RPM is relatively quick. Beyond 2300 RPM, the increase in RPM is again relatively slow. The second component, SA_P, is the contribution to spark advance due to manifold pressure. This value is obtained from ROM lookup tables.

Generally speaking, the SA is reduced as pressure increases. The final component, SA_T, is the contribution to spark advance due to temperature. Temperature effects on spark advance are relatively complex, including such effects as cold cranking, cold start, warm-up, and fully warmed up conditions.

2.2.4 Components of Fuel injection System

Figure 1.29 shows a typical control layout for a fuel injection system. Depending on the sophistication of the system, idle speed and idle mixture adjustment can be either mechanically or electronically controlled.

Figure 1.57 shows a block diagram of inputs and outputs common to most fuel injection systems. The basic fuelling requirement is determined from these inputs in a similar way to the determination of ignition timing. When the ECU has determined the look-up value of the fuel required (injector open time), corrections to this figure can be added for battery voltage, temperature, throttle change or position and fuel cut off. Idle speed and fast idle are also generally controlled by the ECU and a suitable actuator. It is also possible to have a form of closed loop control with electronic fuel injection. This involves a lambda sensor to monitor exhaust gas oxygen content. This allows very accurate control of the mixture strength, as the oxygen content of the exhaust is proportional to the air–fuel ratio. The signal from the lambda sensor is used to adjust the injector open time. The fuel injection system it comprises.

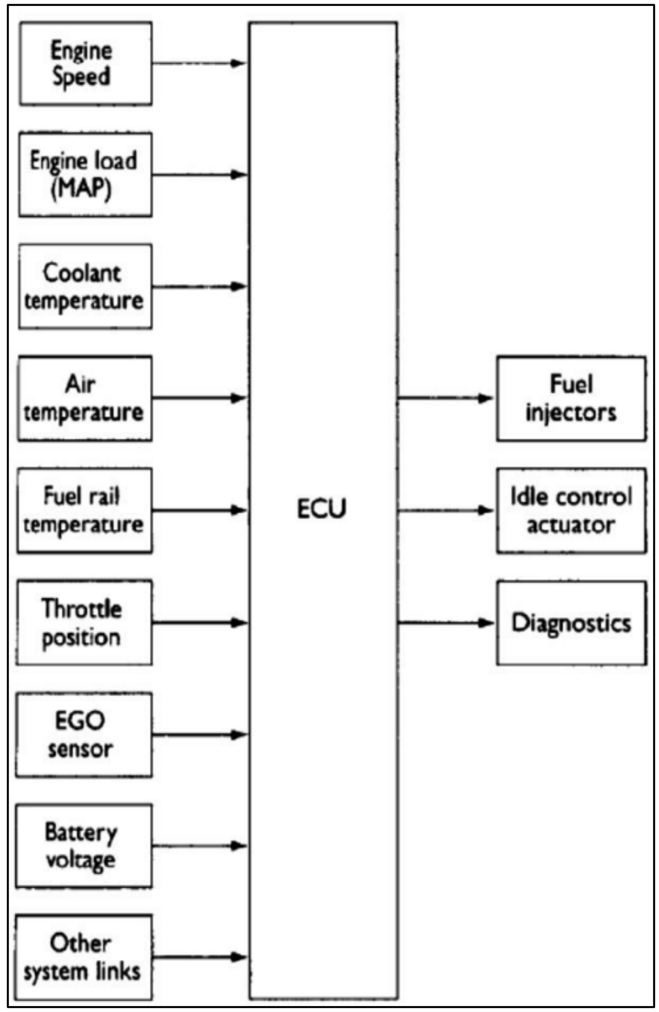


Figure 1: 56 Component of Fuel Injection System

1. Engine speed sensor

Most injection systems, which are not combined directly with the ignition, take a signal from the coil negative terminal. This provides speed data but also engine position to some extent. A resistor in series is often used to prevent high voltage surges reaching the ECU.

2. Temperature sensor

A simple thermistor provides engine coolant temperature information.

3. Throttle position sensor

Various sensors are consisting of the two switch types, which only provide information that the throttle is at idle, full load or anywhere else in between; and potentiometer types, which give more detailed information.

4. Lambda Sensor

This device provides information to the ECU on exhaust gas oxygen content. From this information, corrections can be applied to ensure the engine is kept at or very near to stoichiometry.

5. Idle or Fast Idle Control Actuator

Bimetal or stepper motor actuators are used. The air that it allows through is set by its open/close ratio.

6. Fuel Injector(S)

They are simple solenoid-operated valves designed to operate very quickly and produce a finely atomized spray pattern.

7. Injector Resistors

These resistors were used on some systems when the injector coil resistance was very low. A lower inductive reactance in the circuit allows faster operation of the injectors. Most systems now limit injector maximum current in the ECU in much the same way as for low resistance ignition on coils.

8. Fuel Pump

The pump ensures a constant supply of fuel to the fuel rail. The volume in the rail acts as a swamp to prevent pressure fluctuations as the injectors operate. The pump must be able to maintain a pressure of about 3 bar.

9. Fuel Pressure Regulator

This device ensures a constant differential pressure across the injectors. It is a mechanical device and has a connection to the inlet manifold.

10. Combination Relay

This takes many forms on different systems but is basically two relays, one to control the fuel pump and one to power the rest of the injection system. The relay is often controlled by the ECU or will only operate when ignition pulses are sensed as a safety feature.

11. Electronic Control Unit

Earlier ECUs were analogue in operation. All ECUs now in use employ digital processing.

2.3 Diesel Engine Management System

The advent of electronic control over the diesel injection pump has allowed many advances over the purely mechanical system. The production of high pressure and injection is, however, still mechanical with all current systems. The following advantages are apparent over the non-electronic control system.

- More precise control of fuel quantity injected.
- Better control of start of injection and Idle speed control
- Control of exhaust gas recirculation.
- Drive by wire system (potentiometer on throttle pedal).
- An anti-surge function.
- Output to data acquisition systems etc.
- Temperature compensation.
- Cruise control.

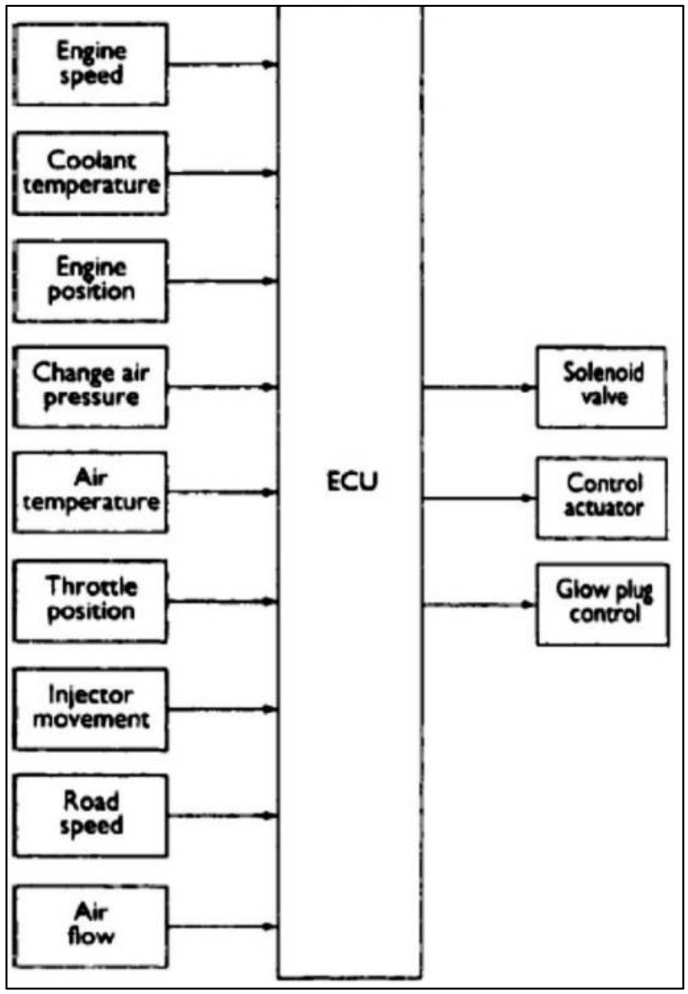


Figure 1: 57 Basic Layout of Diesel Injection Control System

Figure 1.29 shows a block diagram of a typical electronic diesel control system. Ideal values for fuel quantity and timing are stored in memory maps in the electronic control unit. The injected fuel quantity is calculated from the accelerator position and the engine speed. The start of injection is determined from the following:

- Fuel quantity.
- Engine speed.
- Engine temperature.
- Air pressure.

The ECU is able to compare start of injection with actual delivery from a signal produced by the needle motion sensor in the injector.

2.3.1 Diesel EFI System

Diesel engines run at much higher compression ratios than gasoline engines; therefore, the injectors need to release fuel at a much higher pressure. In a typical system, the PCM calculates engine speed using inputs from the CKP. The PCM then determines the ideal fuel requirements for that speed and other operating conditions. In response to these, the PCM, through a fuel injection module, controls the pulse width of the injectors and pressure in the fuel rail. A mechanically driven pump supplies high pressure to the fuel rail. The fuel rail is fitted with a pressure regulator that is controlled by commands from the PCM. The pressure in the fuel rail can range from 2,000 psi (138 bar) to 25,000 psi (1,724 bar).

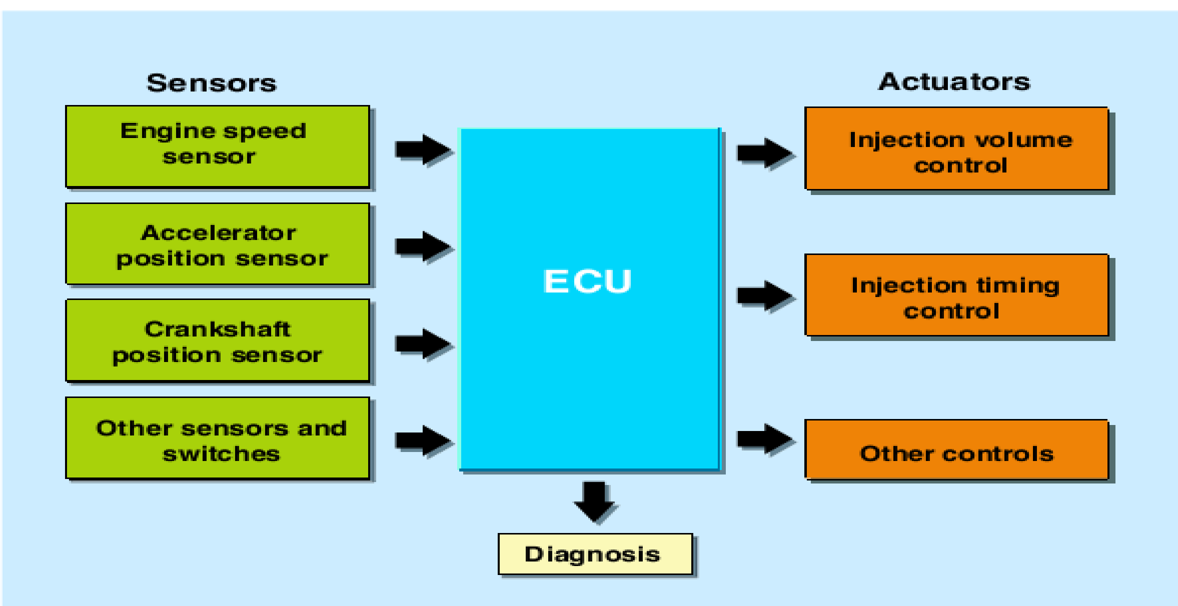


Figure 1: 58 Diesel EFI System

Often, fuel is routed through the fuel injection module to cool it before it is delivered to the injectors. The design of the injectors varies with application; some are solenoid actuated and others use piezoelectric injectors. Some high-pressure common rail fuel systems are capable of injecting fuel five times during one compression stroke. This is done to keep the fuel under high pressure, reduce combustion noise, and provide lower emissions.

High voltage is required to operate most solenoid injectors, normally around 90 volts. Some, however, require only battery voltage. Diesel engines produce 20% to 30% less carbon dioxide (CO2) emissions, lower carbon monoxide (CO) emissions, better fuel economy, and more low-speed torque than a comparably sized gasoline engine. With precise control of fuel delivery through electronics, the use of exhaust-stream after treatment, and an oxidation catalytic converter; oxides of nitro-gen (NOx) and particulate matter (PM) are also drastically reduced.

A. Types of EFI-Diesel

I. Conventional EFI-Diesel

Fuel injection volume and timing is controlled electronically. The control mechanism used for the pumping, distribution, and injection processes is based on the mechanism used in the mechanical type diesel system. As with the mechanical type pump, there are two types of pumps, named based on the shape of their pumping portion. These Axial Plunger Type Pump and Radial Plunger Type Pump.

The fuel that is drawn up by the feed pump travels from the fuel tank through the fuel filter, and is introduced into the pump where it becomes pressurized and then pumped by the

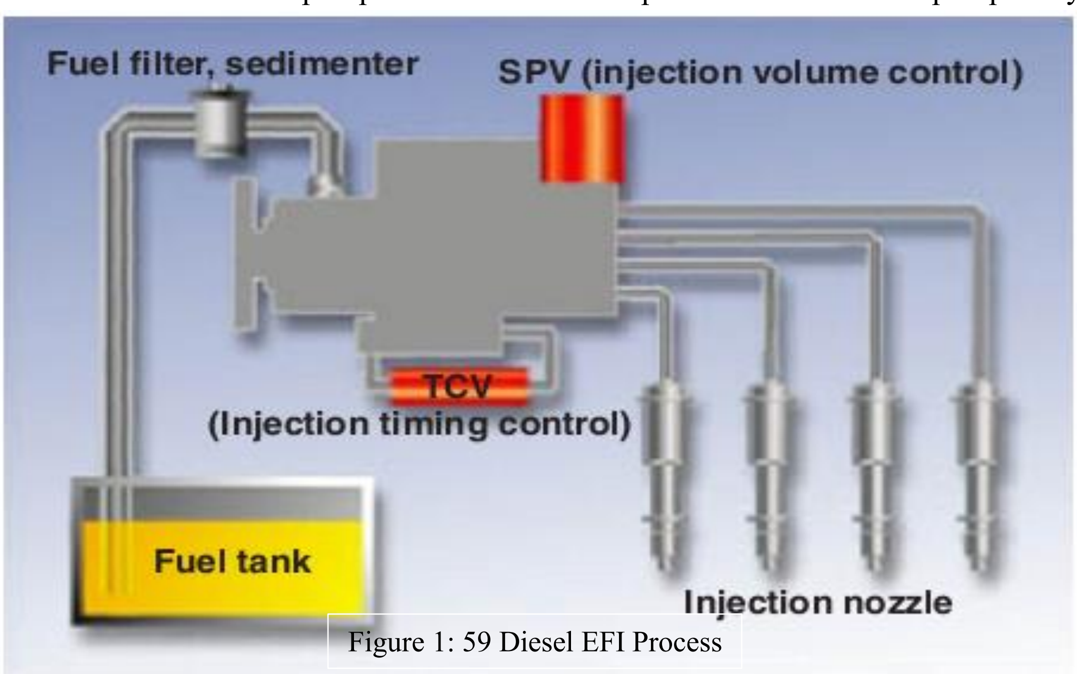
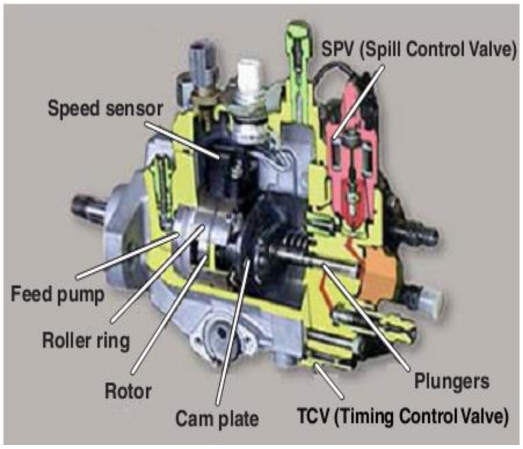


Figure 1: 59 Diesel EFI Process

plunger inside of the injection pump. This process is the same as in an ordinary diesel pump. The fuel in the pump chamber becomes pressurized by the feed pump.



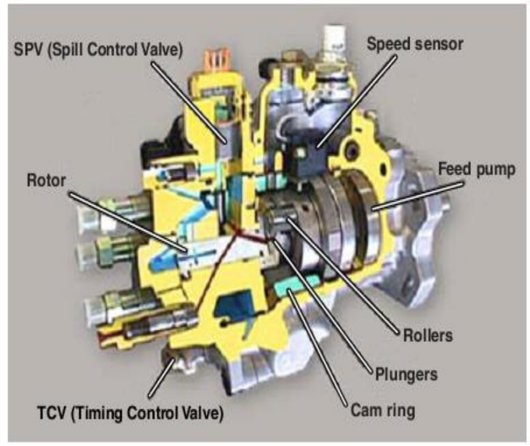


Figure 1: 60 Types of Injection Pump

Further-more, in accordance with the sign als from the ECU, the SPV controls the injection volume (injection duration) and the TCV controls the fuel injection timing (injection starting timing).

B. Components of Diesel EFI

Sensors

- Accelerator Pedal Position Sensor: Detects the accelerator opening angle and the idling
- Intake Air Temperature Sensor: Detects the intake air temperature.
- Turbo Pressure Sensor: Detects the intake manifold pressure.
- Water Temperature Sensor: Detects the water temperature.
- Crankshaft Position Sensor: Detects the crankshaft angle reference position.
- Speed sensor Mounted on the rotor cam of the pump, this sensor detects the engine speed and the cam angle of the pump.
- Fuel temperature sensor: Detects the fuel temperature.

Actuator

- EGR Valve Control the inflow volume of the EGR gases.
- SPV (Spill Control Valve) Controls the fuel injection volume.
- TCV (Timing Control Valve) Controls the fuel injection timing

ECU and other

- ECU (Electronic Control Unit) Determines the operating conditions based on the signals from various sensors and sends optimal engine control signals.
- EDU (Electronic Drive Unit) (radial plunger type pump only) amplifies the ECU signals and actuates the SPV.
- Pump: Pumps and distributes fuel
- Fuel filter and sedimentary Removes foreign particles and water from fuel
- Injection nozzle Injects fuel that has been pumped by the pump.

C. Operation of Conventional EFI-Diesel

- **Flow of Fuel**

The feed pump inside the pump draws up fuel from the fuel tank into the pump. The fuel is pressurized by the pump and distributed to the injection nozzle of each cylinder. The fuel pressure causes the injection nozzle to open injecting fuel into the cylinder.

- **Flow of Signal**

The ECU receives signals from various sensors in order to determine the operating conditions of the engine. Then, the ECU sends signals to control the SPV and TCV in the pump in order to achieve an optimal fuel injection volume and timing.

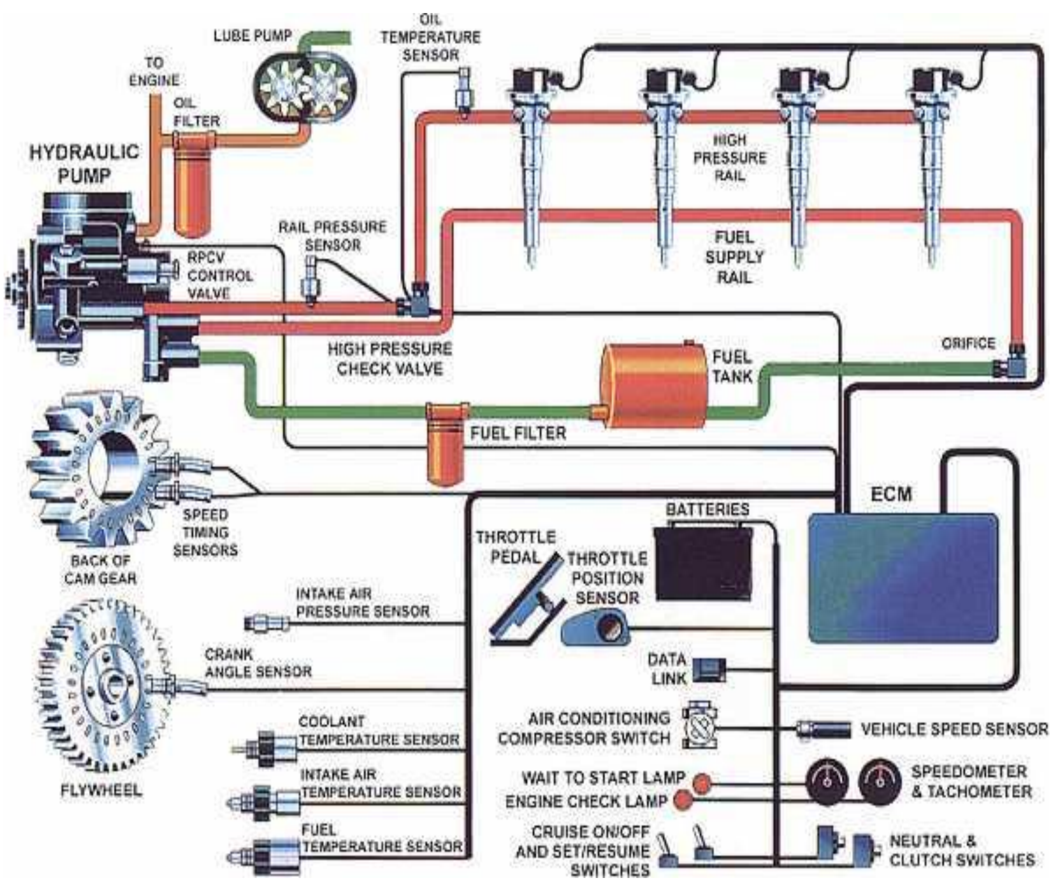


Figure 1: 61 System Outline

II. Common-Rail EFI-Diesel

Instead of having the pump itself distribute fuel to the cylinders, the fuel is stored in the rail at a pressure that is necessary for injection. As with the EFI system of a gasoline engine, the injectors open and close in accordance with the injection signals from the ECU to realize optimal fuel injection. Injection volume control: injector opening duration Injection timing control: injector starting timing.

The fuel that has been drawn up from the feed pump located inside the supply pump is pressurized to the required pressure. The plunger in the pump generates the required injection pressure The ECU commands the SCV (Suction Control Valve) to adjust the fuel pressure, regulating the volume of fuel that enters the supply pump. The ECU constantly detects the fuel pressure in the common-rail by means of the fuel pressure sensor, and effects feedback control.

Generation of Fuel Pressure in the Supply Pump

The two sets of opposing plungers are driven by the inner cam via the rollers. The inner cam is driven by the engine via the timing belt. The inside of the inner cam, which is elliptic, comes in contact with the roller. As the inner cam rotates, it causes the plunger to move reciprocally, and the resulting suction and pumping of fuel generates pressure.

Sensors

- Air flow meter: Detects the intake air volume.
- Accelerator pedal position sensor Detects the accelerator opening angle and idling conditions.
- Camshaft position sensor identifies the cylinders.
- Intake air temperature sensor detects the intake air temperature.
- Turbo pressure sensor detects the intake manifold pressure.
- Water temperature sensor detects the coolant temperature.
- Crankshaft position sensor detects the rotational angle of the crankshaft.
- Fuel pressure sensor detects the fuel pressure in the common-rail.
- Fuel temperature sensor detects the fuel temperature.

Actuator

- Injector Injects fuel in accordance with signals.
- EGR valve Opens and closes in accordance with the signals from the ECU to recirculate the exhaust gases in order to reduce the amount of emissions.
- SCV Mounted on the supply pump, the SCV regulates the volume of fuel that is drawn into the supply pump.

ECU and Other parts

- ECU (Electronic Control Unit) Determines the operating conditions based on the signals from various sensors in order to send optimal control signals to the engine.
- EDU Amplifies the ECU signals to actuate the injectors.
- Common-rail Stores the fuel that has been compressed by the sup-ply pump to a pressure that is required for injection.
- Supply pump Increase the pressure of the fuel required for injection and feeds the fuel to the common-rail.
- Fuel filter and sedimentary Removes foreign particles and water from the fuel.

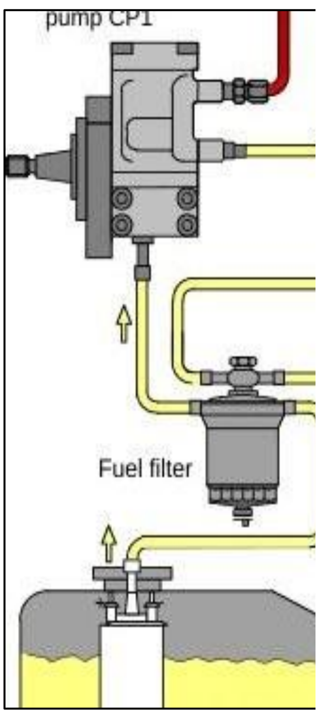


Figure 1: 62 Common-Rail EFI-Diesel

A. Operation of Common-Rail EFI-Diesel

- **Flow Of Fuel and Signal in Common Diesel**

The feed pump in the supply pump draws up the fuel from the fuel tank. The fuel that has been pressurized by the supply pump to reach the proper injection pressure is fed into the common-rail where it is stored. The stored fuel is distributed via the injection pipes to the injectors of the cylinders, and when the injectors are operated, the fuel is injected.

- **Flow of Signal**

The ECU collects information from the sensors and sends signals to the SCV in order to attain the target fuel pressure. In addition, the pressure signal from the common-rail is fed back into the ECU. The ECU sends signals to the EDU to operate the injectors, the EDU applies the raised voltage to the injectors, and the injectors inject the fuel.

2.3.2 Electromechanical Systems

A few diesels have mechanically actuated injectors that are fitted with a solenoid to control fuel pressure. In these units, the high-pressure pump and injector are in a single assembly and there is one these for each cylinder. The pumps are driven by a special lobe on the camshaft; this third lobe sits next to the intake and exhaust lobes for each cylinder. Because the injectors are mechanically driven, their timing is fixed. Fuel control is accomplished by regulating fuel pressure. To do this, the PCM controls the solenoids at the injectors.

A. Diesel Throttle

The diesel throttle is mounted on the intake manifold. The throttle valve, which operates independently from the accelerator pedal, uses the diesel throttle control motor (step motor) to regulate the throttle opening accordance with the signals received from the ECU.

Figure 1: 63 Diesel Throttle

Purpose:

1. Ensures an optimal amount of EGR volume throughout the operating range by increasing the intake manifold vacuum.
2. Reduces the intake noise and vibration by closing the throttle valve at idle.
3. Reduces vibrations by fully closing the throttle when stopping the engine in order to reduce the amount of air intake volume.

Diesel throttle operation

1. When the engine is running, the opening of the throttle is optimally adjusted according to the engine speed, engine load conditions, and the EGR volume.
2. When the engine is stopped, the throttle closes fully to shut off the intake of air. By minimizing the compression in the cylinder, vibrations that occur when stopping the engine are reduced.

B. Exhaust Gas Recirculation Systems (EGR)

The EGR system releases a sample of exhaust gases into the intake's air-fuel mixture. This lowers the peak temperature of combustion and therefore reduces the chances of NOx being formed. The recirculated exhaust gas dilutes the air-fuel mixture. Because exhaust gas does not burn, this lowers the combustion temperature and reduces NOx emissions. At lower combustion temperatures, the nitrogen in the incoming air is simply carried out with the exhaust gases.

Figure 1: 64 EGR Valve

Drivability problems can result from having too much recirculated exhaust gas in the combustion chamber. This is especially true when the there is a high demand for engine power.

Also, poor control of EGR flow can cause starting and idling problems. This is why EGR flow is disabled during cold starting, at idle, and at throttle openings of more than 50%. There is maximum EGR flow only when the vehicle is at a cruising speed with a very light load.

This dilutes the mixture so combustion temperatures are minimized. On some engines, the exhaust gas

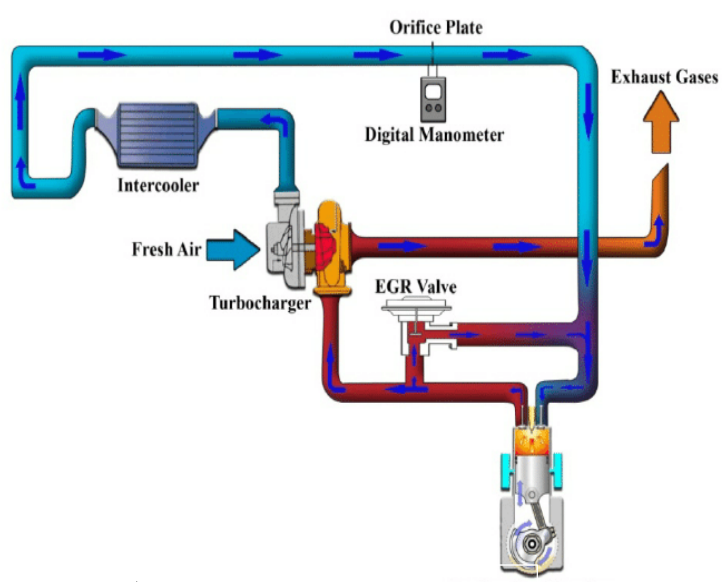


Figure 1: 65 EGR System Layout

from the EGR system is distributed through passages in the cylinder heads and distribution plates to each intake port. The distribution plates are positioned between the cylinder heads and the intake manifold.

2.1.1 Fuel-Injection Control

An overview of the various control functions which are possible with the EDC control units is given in Fig. 1:67 opposite shows the sequence of fuel-injection calculations with all functions, a number of which are special options. These can be activated in the ECU by the workshop when retrofit equipment is installed.

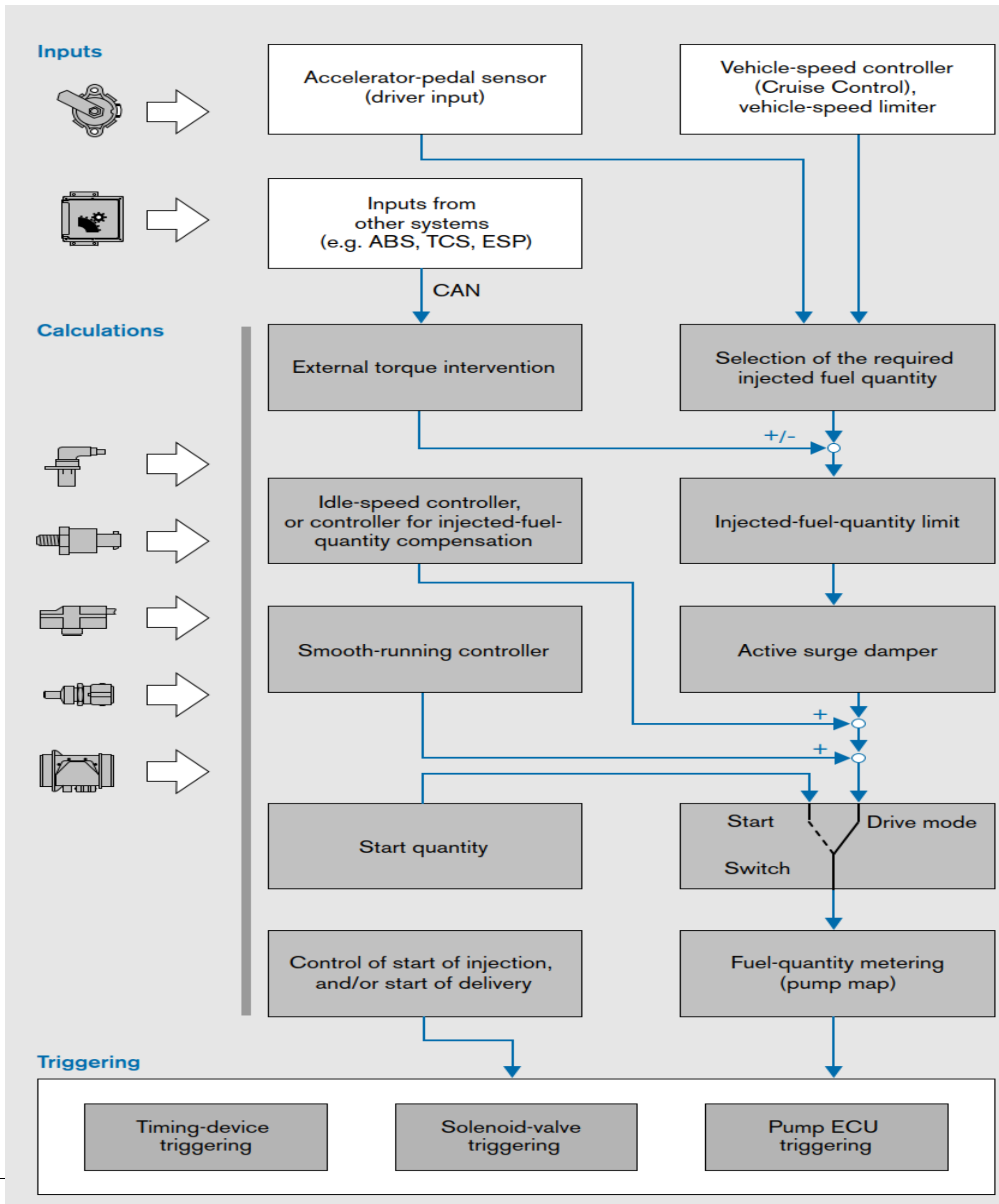


Figure 1: 66 Calculation of fuel-injection process in the ECU

In order that the engine can run with optimal combustion under all operating conditions, the ECU calculates exactly the right injected fuel quantity for all conditions. Here, a number of parameters must be taken into account. On a number of solenoid-valve-controlled distributor pumps, the solenoid valves for injected fuel quantity and start of injection are triggered by a separate pump ECU.

A. Start Quantity

For starting, the injected fuel quantity is calculated as a function of coolant temperature and cranking speed. Start-quantity signals are generated from the moment the starting switch is turned (Fig. 1, switch in “Start” position) until a given minimum engine speed is reached. The driver cannot influence the start quantity.

B. Drive mode

When the vehicle is being driven normally, the injected fuel quantity is a function of the accelerator-pedal setting (accelerator-pedal sensor) and of the engine speed. Calculation depends upon maps which also take other influences into account (e. g. fuel and intake-air temperature). This permits best-possible alignment of the engine’s output to the driver’s wishes.

C. Idle-Speed Control

The function of idle speed control is to regulate a specific set point speed at idle when the accelerator pedal is not operated. This can vary depending on the engine’s particular operating mode. For instance, with the engine cold, the idle speed is usually set higher than when it is hot. There are further instances when the idle speed is held somewhat higher. For instance, when the vehicle’s electrical-system voltage is too low, when the air-conditioning system is switched on, or when the vehicle is freewheeling. When the vehicle is driven in stop-and-go traffic, together with stops at traffic lights, the engine runs a lot of the time at idle. Considerations concerning emissions and fuel consumption dictate, therefore, that idle speed should be kept as low as possible. This, of course, is a disadvantage with respect to smooth-running and pulling away.

When adjusting the stipulated idle speed, the idle-speed control must cope with heavily fluctuating requirements. The input power needed by the engine-driven auxiliary equipment varies considerably. At low electrical-system voltages, for instance, the alternator consumes far more power than it does when the voltages are higher. In addition, the power demands from the A/C compressor, the steering pump, and the high-pressure generation for the diesel injection system must all be taken into account.

Added to these external load moments is the engine's internal friction torque which is highly dependent on engine temperature, and must also be compensated for by the idle- speed control.

In order to regulate the desired idle speed, the controller continues to adapt the injected fuel quantity until the actual engine speed corresponds to the desired idle speed.

D. Maximum-Rpm Control

The maximum-rpm control ensures that the engine does not run at excessive speeds. To avoid damage to the engine, the engine manufacturer stipulates a permissible maximum speed which may only be exceeded for a very brief period.

Above the rated-power operating point, the maximum-speed governor reduces the injected fuel quantity continuously, until just above the maximum-speed point when fuel-injection stops completely. In order to prevent engine surge, a ramp function is used to ensure that the drop-off in fuel injection is not too abrupt. This is all the more difficult to implement, the closer the nominal performance point and maximum engine speed are to each other.

E. Intermediate-Speed Control

Intermediate-speed control is used on commercial vehicles and light-duty trucks with power take-offs, e.g. crane), or for special vehicles. With the control in operation, the engine is regulated to a load-independent intermediate speed.

With the vehicle stationary, the intermediate-speed control is activated via the cruise control operator unit. A fixed rotational speed can be called up from the data store at the push of a button. In addition, this operator unit can be used for preselecting specific engine speeds. The intermediate-speed control is also applied on passenger cars with automated transmissions (e.g. Tiptronic) to control the engine speed during gearshifts.

F. Vehicle-Speed Controller (Cruise Control)

Cruise control allows the vehicle to be driven at a constant speed. It controls the vehicle speed to the speed selected by the driver without him/her needing to press the accelerator pedal. The driver can set the required speed either by operating a lever or by pressing buttons on the steering wheel. The injected fuel quantity is either increased or decreased until the desired (set) speed is reached.

Self-check 2

Directions: Answer all the questions listed below.

Part I: Say True or False

1. A resistor in series is often used to prevent high voltage surges reaching the ECU.
2. Bimetal or stepper motor actuators are used.
3. A lower inductive reactance in the circuit allows faster operation of the injectors
4. The relay is often controlled by the ECU or will only operate when ignition pulses are sensed as a safety feature.
5. The PCM calculates engine speed using inputs from the CKP.

Part II: Fill in the Blank Space

1. ___________is to regulate a specific set point speed at idle when the accelerator pedal
2. ___________ensures that the engine does not run at excessive speeds.
3. ___________allows the vehicle to be driven at a constant speed
4. ___________calculated as a function of coolant temperature
5. __________ Start-quantity signals are generated from the moment the starting switch is turned

Part-III: Answer the following questions accordingly.

1. Discuss about EMS Layout and Working briefly
   - Open Loop Control
   - Feed Forward Control
   - Closed Loop Control
   - Sequential Control
2. For a typical engine there are nine different engine operating modes that affect fuel control.
3. Describe about The following EFI
   - Throttle Body Injection
   - Multi-Point Fuel Injection (MPFI)
   - Gasoline Direct Injection

Unit Three: Sensor Diagnostics

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Introduction to Sensor
- Inductive Sensor
- Variable Resistance
- Thermistors
- Hall Effect Sensors
- Piezo Accelerometer
- Oxygen Sensors
- Pressure Sensors
- Variable Capacitance

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Introduce Sensor
- Diagnosis Inductive Sensor
- Diagnosis Variable Resistance
- Diagnosis Thermistors
- Diagnosis Hall Effect Sensors
- Diagnosis Piezo Accelerometer
- Diagnosis Oxygen Sensors
- Diagnosis Pressure Sensors
- Diagnosis Variable Capacitance

3.1 Introduction to Sensor

A sensor is a device that measures a physical quantity and converts it into a signal which can be read by an electronic control unit (ECU), an observer or an instrument. For accuracy, most sensors are calibrated against known standards. Most vehicle sensors produce an electrical signal, so checking their output on an oscilloscope is often the recommended method. However, many can also be checked using a multimeter.

3.2 Inductive Sensors

Inductive-type sensors are used mostly for measuring the speed and position of a rotating component. They work on the very basic principle of electrical induction (a changing magnetic flux will induce an electromotive force in a winding). The output voltage of most inductive-type sensors approximates to a sine wave. The amplitude of this signal depends on the rate of change of flux. This is determined mostly by the original design as in the number of turns, magnet strength and gap between the sensor and the rotating component. Once in use, though, the output voltage increases with the speed of rotation. In the majority of applications, it is the frequency of the signal that is used.

3.2.1 Crankshaft and Camshaft Sensors

Inductive-type crank and cam sensors work in the same way. A single tooth, or toothed wheel, induces a voltage into a winding in the sensor. The cam sensor provides engine position information as well as which cylinder is on which stroke. The crank sensor provides engine speed. It also provides engine position in many cases by use of a 'missing' tooth.

In this particular waveform, we can evaluate the out-put voltage from the crank sensor. The voltage will differ between manufacturers, and it also increases with engine speed. The waveform will be an alternating voltage signal. If there is a gap in the trace, it is due to a 'missing tooth' on the flywheel or reluctor and is used as a reference for the ECU to determine the engine's position. Some systems use two reference points per

Figure 1: 67 Crankshaft Sensor

revolution.

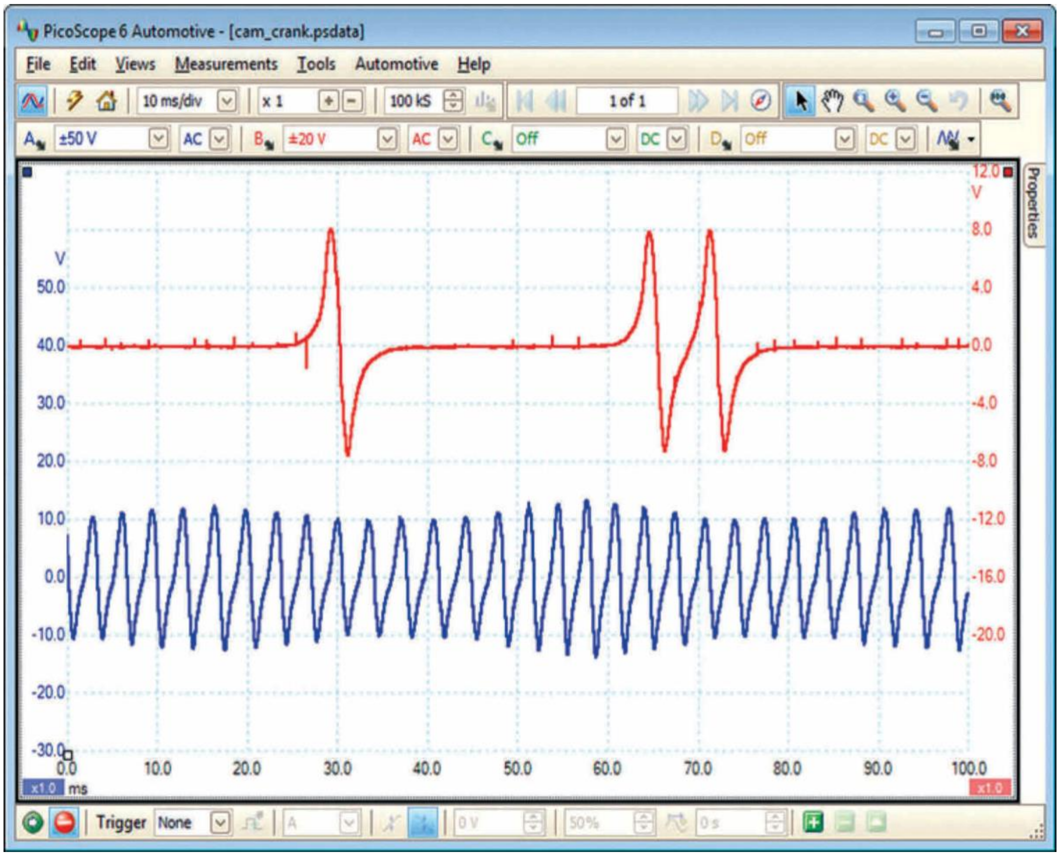


Figure 1: 68 Crank and Cam Sensor Output Signals

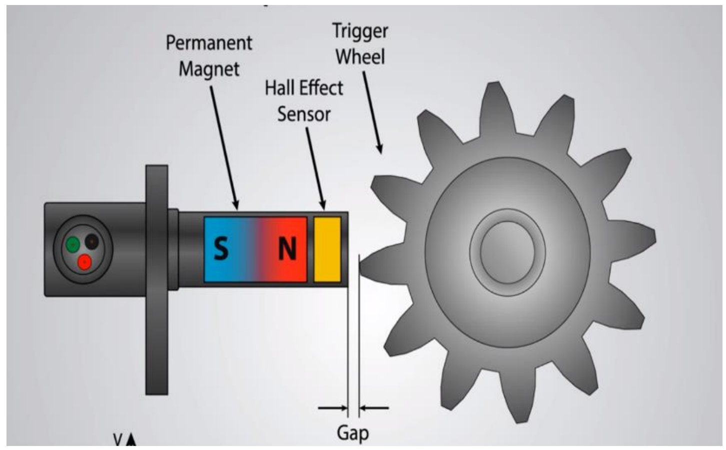
The camshaft sensor is sometimes referred to as the cylinder identification (CID) sensor or a 'phase' sensor and is used as a reference to time sequential fuel injection. The voltage produced by the camshaft sensor will be determined by several factors, these being the engine's speed, the proximity of the metal rotor to the pick-up and the strength of the magnetic field offered by the sensor. The ECU needs to see the signal when the engine is started for its reference; if absent, it can alter the point at which the fuel is injected. The driver of the vehicle may not be aware that the vehicle has a problem if the CID sensor fails, as the driveability may not be affected. However, the MIL should illuminate.

The characteristics of a good inductive camshaft sensor waveform is a sine wave that increases in magnitude as the engine speed is increased, and usually provides one signal per 720° of crankshaft rotation (360° of camshaft rotation). The voltage will be approximately 0.5 V peak to peak while the engine is cranking, rising to around 2.5 V peak to peak at idle.

3.2.2 ABS Wheel Speed Sensors

The ABS wheel speed sensors have become smaller and more efficient in the course of time. Recent models not only measure the speed and direction of wheel rotation but can be integrated into the wheel bearing as well. ABS relies upon information coming in from the sensors to determine what action should be taken.

If, under heavy braking, the ABS ECU loses a signal from one of the road wheels, it assumes that the wheel has locked and releases that brake momentarily until it sees the signal return. It is therefore imperative that the sensors are capable of providing a signal to the ABS ECU. If the signal produced from one wheel sensor is at a lower frequency than the others, the ECU may also react.



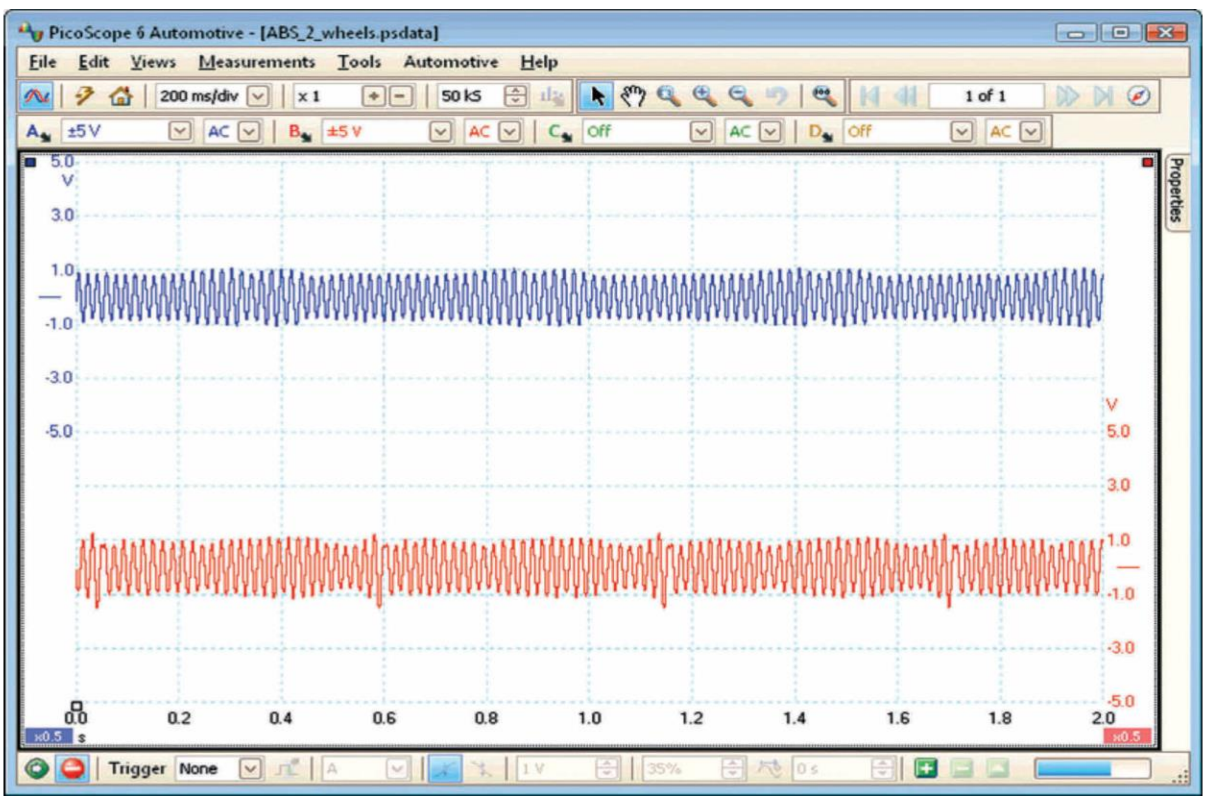


Figure 1: 69 ABS Sensor Square Wave

The operation of most ABS sensors is similar to that of a crank angle sensor (CAS). A small inductive pick-up is affected by the movement of a toothed wheel, which moves in close proximity. The movement of the wheel next to the sensor results in a 'sine wave'. The sensor, recognisable by its two electrical connections (some may have a coaxial braided outer shield), will produce an output that can be monitored and measured on the oscilloscope. Some are now Hall Effect types so expect to see a square wave output.

3.2.3 Inductive Distributor Pick-Up

Not used on modern cars, but there are still plenty out there! The pick-up is used as a signal to trigger the ignition amplifier or an ECU. The sensor normally has two connections. If a third connection is used, it is normally a screen to reduce interference. As a metal rotor spins, a magnetic field is altered, which induces an AC voltage from the pick-up. This type of pick-up could be described as a small alternator because the output voltage rises as the metal rotor approaches the winding, sharply dropping through zero volts as the two components are aligned and producing a voltage in the opposite direction as the rotor passes.

The waveform is similar to a sine wave; however, the design of the components is such that a more rapid switching is evident.

The voltage produced by the pick-up will be deter-mined by three main factors:

- Engine speed – the voltage produced will rise from as low as 2–3 V when cranking, to over 50 V at higher engine speeds.
- The proximity of the metal rotor to the pick-up winding – an average air gap will be in the order of 0.2–0.6 mm, a larger air gap will reduce the strength of the magnetic field seen by the winding and the output voltage will be reduced.
- The strength of the magnetic field offered by the magnet – the strength of this magnetic field determines the effect it has as it 'cuts' through the windings, and the output voltage will be reduced accordingly.

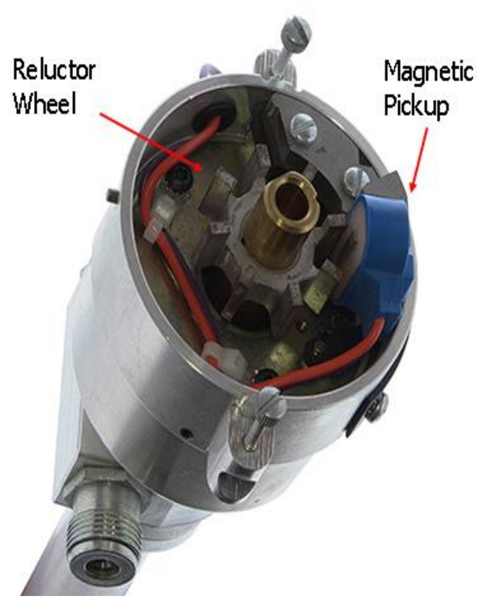


Figure 1: 70 inductive Distributor Pick-Up

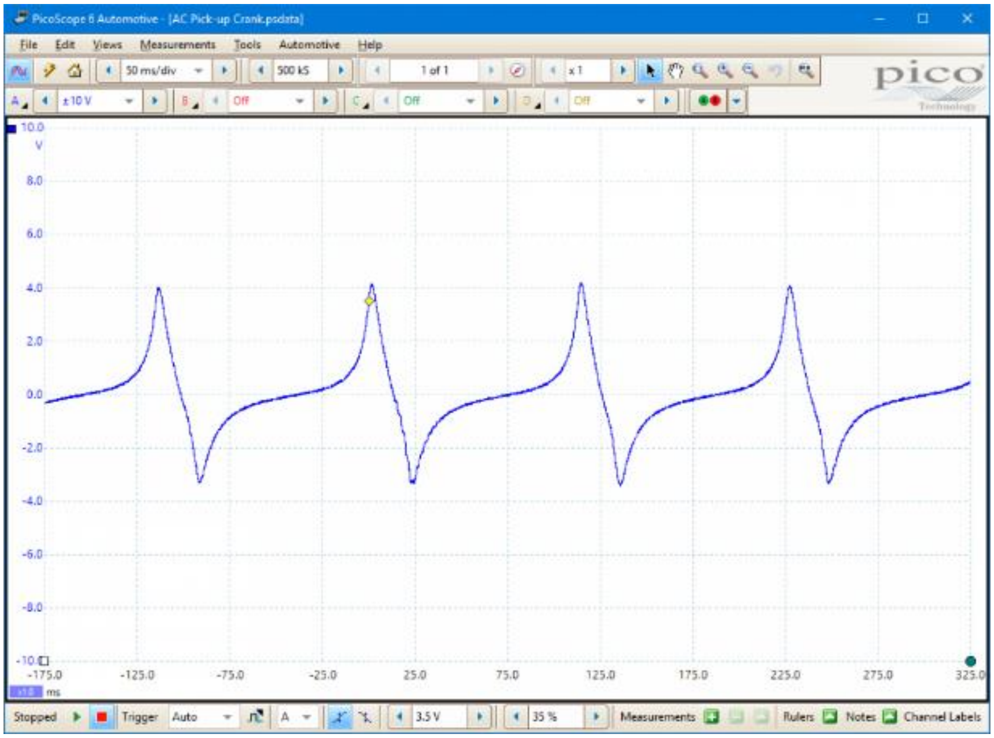


Figure 1: 71 Inductive Distributor Pick-Up

3.3 Variable Resistance

The two best examples of vehicle applications for variable resistance sensors are the throttle position sensor and the flap-type airflow sensor. Although variable capacitance sensors are used to measure small changes, variable resistance sensors generally measure larger changes in position. This is due to lack of sensitivity inherent in the construction of the resistive track. The throttle position sensor is a potentiometer in which, when supplied with a stable voltage, often 5 V, the voltage from the wiper contact will be proportional to throttle position. The throttle potentiometer is mostly used to indicate rate of change of throttle position.

This information is used when implementing acceleration enrichment or overrun fuel cut-off. The output voltage of a rotary potentiometer is proportional to its position.

3.3.1 Throttle Position Sensor

This sensor or potentiometer is able to indicate to the ECU the exact amount of throttle opening due to its linear output. The majority of modern management systems use this type of sensor. It is located on the throttle butterfly spindle. The ‘throttle pot’ is a three-wire device having a 5 V supply (usually), an earth connection and a variable output from the centre pin. As the output is critical to the vehicle’s performance, any ‘blind spots’ within the internal carbon track’s swept area will cause ‘flat spots’ and ‘hesitations’. This lack of continuity can be seen on an oscilloscope.

A good throttle potentiometer should show a small voltage at the throttle closed position, gradually rising in voltage as the throttle is opened and returning back to its initial voltage as the throttle is closed. Although many throttle position sensor voltages will be manufacturer specific, many are non-adjustable and the voltage will be in the region of 0.5–1.0 V at idle, rising to 4.0 V (or more) with a fully opened throttle. For the full operational range, an oscilloscope time scale around two seconds is used.

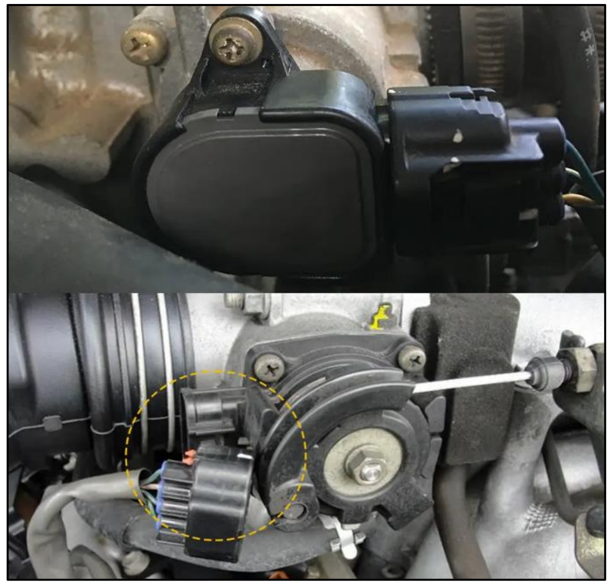


Figure 1: 73 TP Sensor

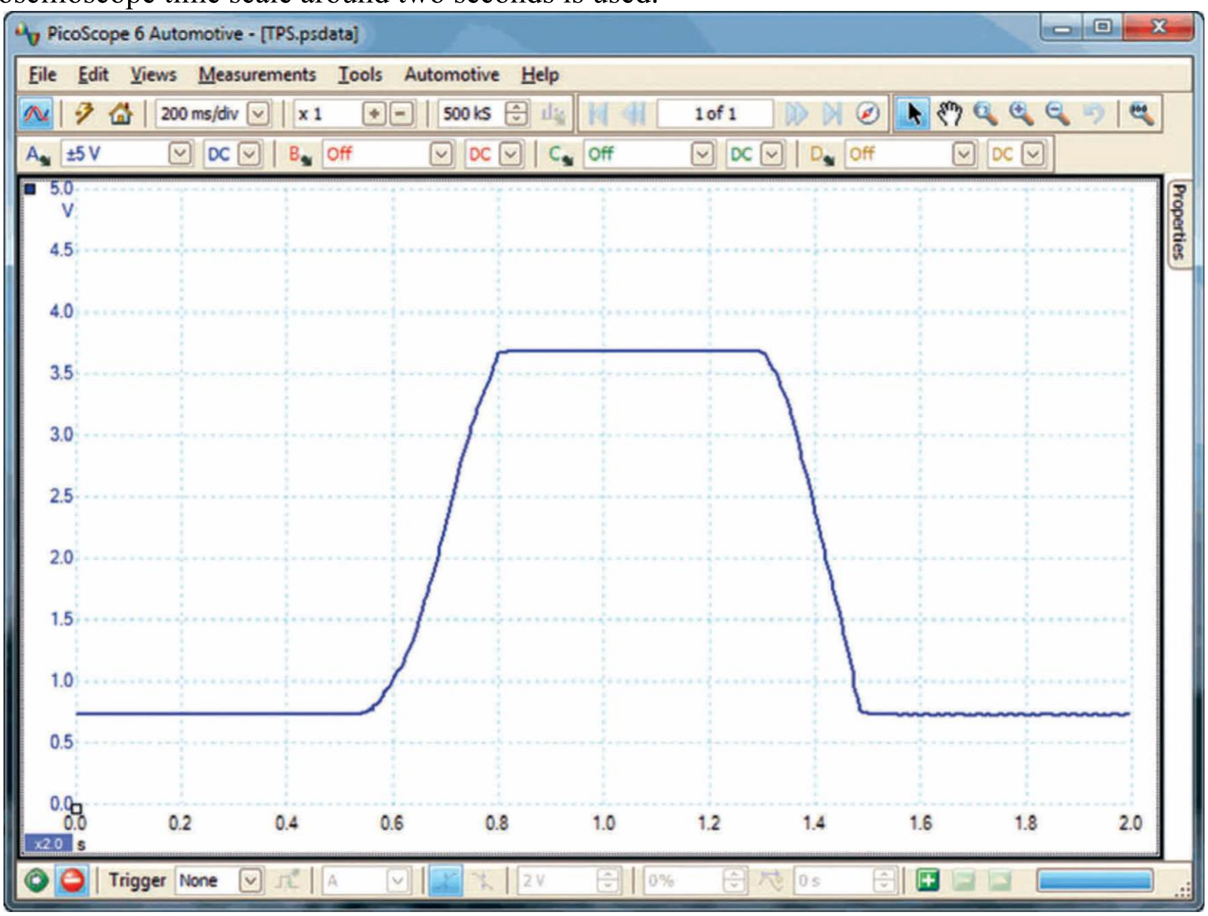


Figure 1: 72 Square Wave

3.3.2 Airflow meter – Air Vane

The vane-type airflow meter is a simple potentiometer that produces a voltage output that is proportional to the position of a vane. The vane in turn positions itself proportional to the amount of air flowing. The voltage output from the internal track of the air-flow meter should be linear to flap movement; this can be measured on an oscilloscope .The waveform should show approximately 1.0 V when the engine is at idle; this voltage will rise as the engine is accelerated and will produce an initial peak.

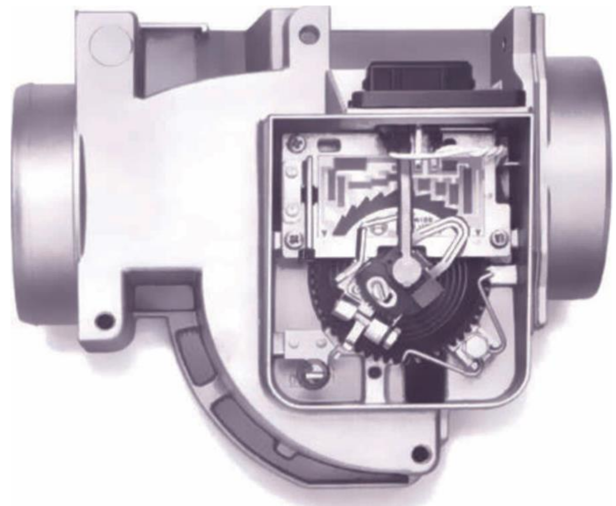


Figure 1: 74 Airflow meter – Air Vane

This peak is due to the natural inertia of the air vane and drops momentarily before the voltage is seen to rise again to a peak of approximately 4.0–4.5 V. This voltage will, however, depend on how hard the engine is accelerated, so a lower voltage is not necessarily a fault within the airflow meter. On deceleration, the voltage will drop sharply as the wiper arm, in contact with the carbon track, returns back to the idle position. This voltage may in some cases ‘dip’ below the initial voltage before returning to idle voltage.

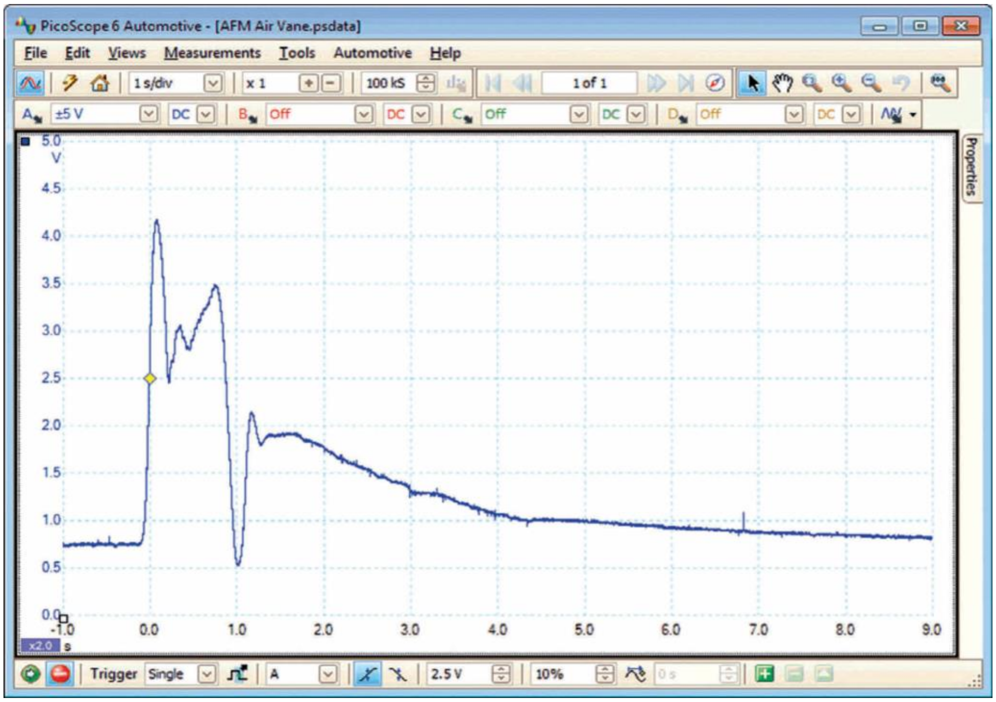


Figure 1: 75 Air Vane Airflow meter

3.3.3 Hot Wire Airflow Sensor

The advantage of this sensor is that it measures air mass flow. The basic principle is that as air passes over a hot wire, it tries to cool the wire down. If a circuit is created such as to increase the current through the wire, then this current will be proportional to the airflow. A resistor is also incorporated to compensate for temperature variations. The 'hot wire' is made of platinum and is only a few millimetres long and approximately 70 µm thick.

Because of its small size, the time constant of the sensor is very short, in fact in the order of a few milliseconds. This is a great advantage as any pulsations of the airflow will be detected and reacted to in a control unit accordingly.

The output of the circuit involved with the hot wire sensor is a voltage across a precision resistor. The resistance of the hot wire and the precision resistor are such that the current to heat the wire varies between 0.5 and 1.2 A with different air mass flow rates. High-resistance resistors are used in the other arm of the bridge and so current flow is very small.

The temperature-compensating resistor has a resistance of approximately 500 Ω, which must remain constant other than by way of temperature change. A platinum film resistor is used for these reasons. The compensation resistor can cause the system to react to temperature changes within about three seconds.

The output of this device can change if the hot wire becomes dirty. Heating the wire to a very high temperature for one second every time the engine is switched off prevents this, by burning off any contamination. In some air mass sensors, a variable resistor is provided to set idle mixture. The nickel film airflow sensor is similar to the hot wire system. Instead of a hot platinum wire, a thin film of nickel is used. The response time of this system is even shorter than the hot wire. The advantage which makes a nickel thick-film thermistor ideal for inlet air temperature sensing is its very short time constant. In other words, its resistance varies very quickly with a change in air temperature.

A. Airflow Meter – Hot Wire

As air flows over the hot wire, it cools it down, and this produces the output signal. The sensor measures air mass because the air temperature is taken into account due to its cooling effect on the wire.

The voltage output should be linear to airflow. The waveform should show approximately 1.0 V when the engine is at idle. This voltage will rise as the engine is accelerated and air volume is increased producing an initial peak. This peak is due to the initial influx of air and drops momentarily before the voltage is seen to rise again to another peak of approximately 4.0–4.5 V. This voltage will, however, depend on how hard the engine is accelerated; a lower voltage is not necessarily a fault within the meter.

Figure 1: 76 Airflow Meter – Hot Wire

Hot-Film Air-Mass Meter

To provide precise pilot control of the air/fuel ratio, it is essential for the supplied air mass to be exactly determined in the respective operating state. The hot-film air-mass meter measures some of the actually inducted air-mass flow for this purpose.

It takes into account the pulsations and reverse flows caused by the opening and closing of the engine's intake and exhaust valves. Intake-air temperature or air-pressure changes have no effect upon measuring accuracy.

The most important components in the sensor are the measuring cell in the air inlet and the integrated evaluation electronics. The sensor measuring cell consists of a semiconductor substrate. The sensitive surface is formed by a diaphragm which has been manufactured in micromechanical processes. This diaphragm incorporates temperature-sensitive resistors. The elements of the evaluation electronics (hybrid circuit) are installed on a ceramic substrate.

Figure 1: 77 Hot-Film Air-Mass Meter

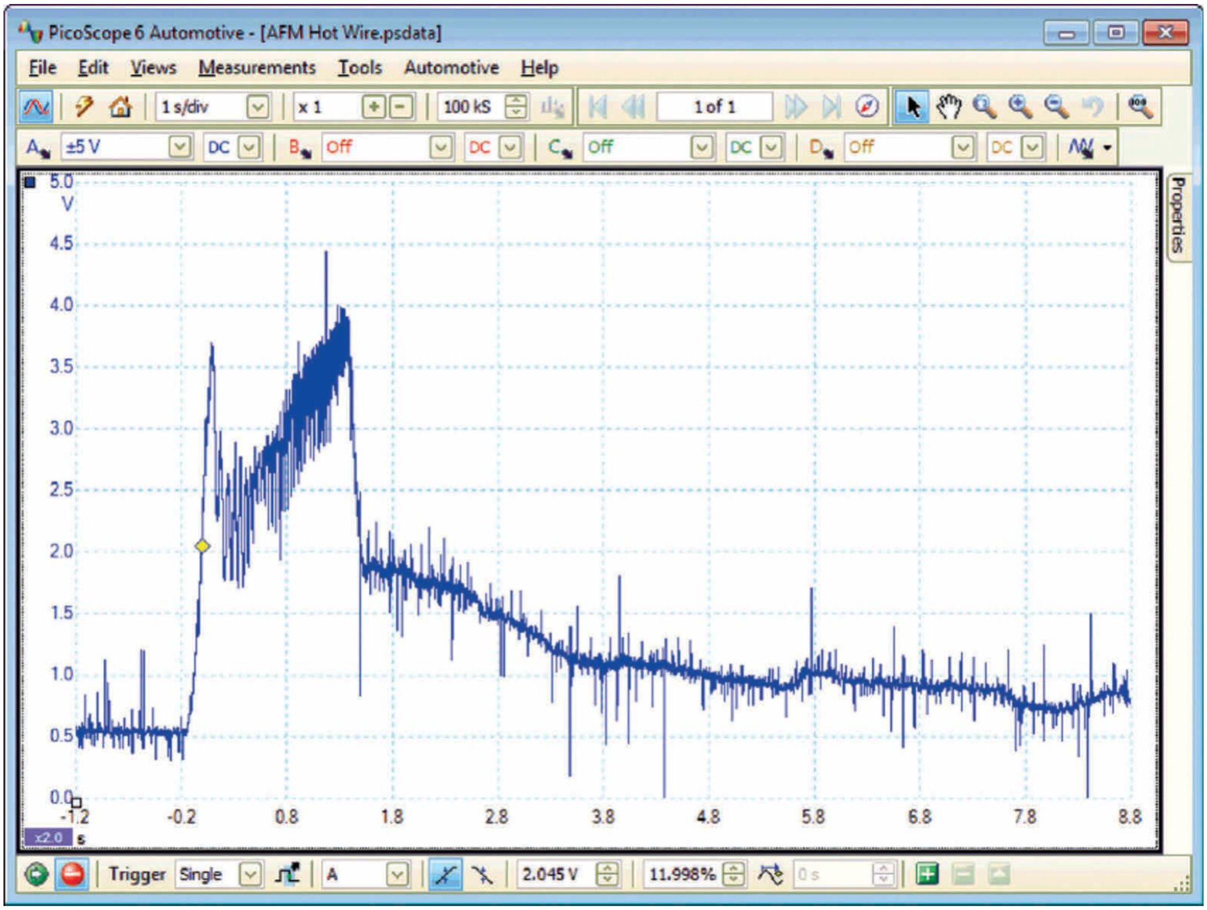


Figure 1: 78 Air mass hot wire waveform

3.4 Thermistors

Thermistors are the most common device used for temperature measurement on the motor vehicle. The principle of measurement is that a change in temperature will cause a change in resistance of the thermistor and hence an electrical signal proportional to the temperature being measured. Most thermistors in common use are of the negative temperature coefficient (NTC) type. The actual response of the thermistors can vary but typical values for those used on motor vehicles will vary from several kilo-ohms at 0°C to few hundred ohms at 100°C. The large change in resistance for a small change in temperature makes the thermistor ideal for most vehicles uses. It can also be easily tested with simple equipment. Thermistors are constructed of semi-conductor materials. The change in resistance with a change in temperature is due to the electrons being able to break free more easily at higher temperatures.

3.4.1 Coolant Temperature Sensor

Most coolant temperature sensors (CTSs) are NTC thermistors; their resistance decreases as temperature increases. This can be measured on most systems as a reducing voltage signal. The CTS is usually a two-wire device with a voltage supply of approximately 5 V. The resistance change will therefore alter the voltage seen at the sensor and can be monitored for any discrepancies across its operational range.

By selecting a time scale of 500 seconds and connecting the oscilloscope to the sensor, the output voltage can be monitored. Start the engine and in the majority of cases the voltage will start in the region of 3–4 V and fall gradually. The voltage will depend on the temperature of the engine. The rate of voltage change is usually linear with no sudden changes to the voltage, if the sensor displays a fault at a certain temperature, it will show up in this test.

3.4.2 Intake Air Temperature Sensor

The intake-air temperature sensor determines the temperature in the suction pipe and forwards the voltage signals arising from the temperature to the control unit. This evaluates the signals and influences the mixture formation and the firing angle.

Figure 1: 79 IAT Sensor

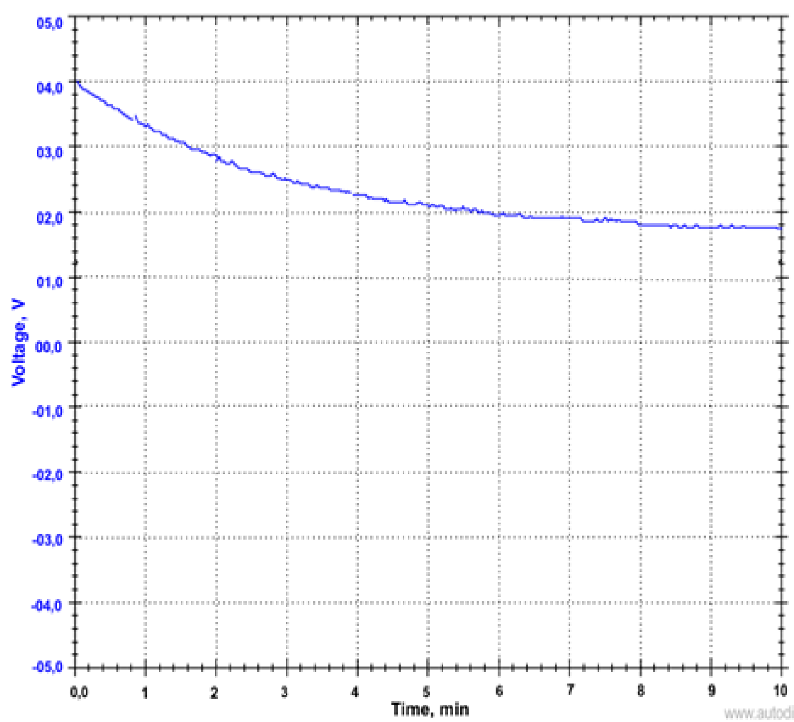


Figure 1: 80 IAT sensor Square Wave

3.4.3 EGR Temperature Sensor

The EGR temperature sensor is an engine management sensor that is part of the EGR system. It works together with the EGR solenoid to control the flow of the EGR system. The sensor is installed in between the exhaust and intake manifold, and monitors the temperature of the exhaust gases.

Figure 1: 81 EGR Sensor

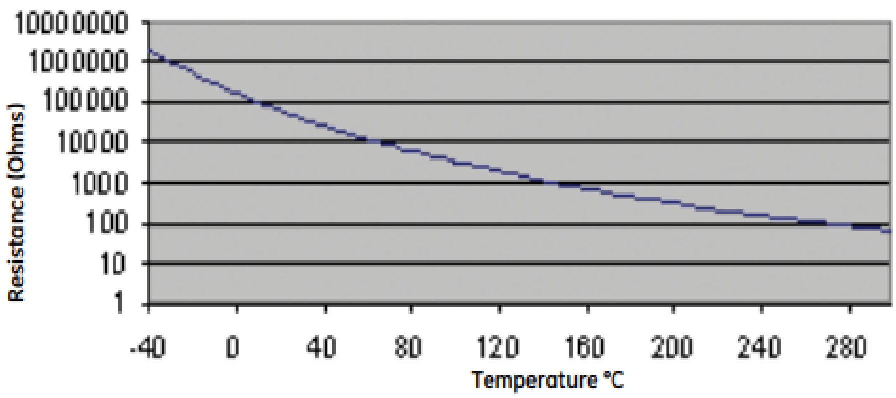


Figure 1: 82 EGR Sensor Square Wave

3.4.4 Fuel Temperature Sensor

A fuel temperature sensor is installed in vehicles to gauge the amount of fuel required for consistent performance. The sensor transmits this information to the Engine Control Unit (ECU) of the vehicle.

When the fuel is warm it burns easily, as it's less dense, the ECU is then signalled by the temperature sensor to inject fuel in the combustion chamber. But, you can expect the opposite if the fuel is dense and cold.

Figure 1: 83 Fuel Temperature Sensor

3.5 Hall Effect Sensors

If a conductor is carrying a current in a transverse magnetic field, then a voltage will be produced at right angles to the supply current. This voltage is proportional to the supply current and to the magnetic field strength.

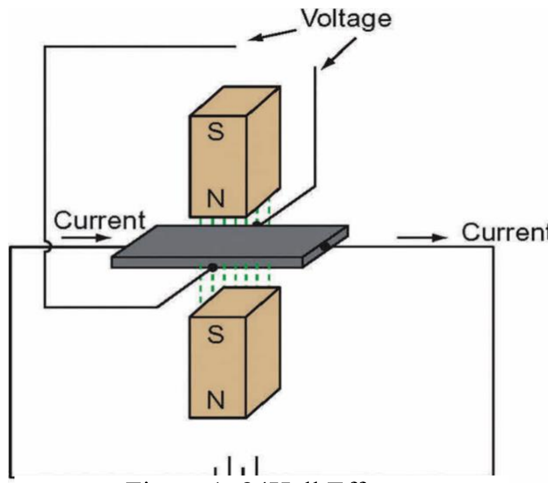


Figure 1: 84Hall Effect

Many distributors employ Hall Effect sensors, but they are now also used as rotational sensors for the crank and ABS, for example. The output of this sensor is almost a square wave with constant amplitude.

The Hall Effect can also be used to detect current flowing in a cable, the magnetic field produced round the cable being proportional to the current flowing. The Hall Effect sensors are becoming increasingly popular because of their reliability and also because they produce a constant amplitude square wave in speed measurement applications and a varying DC voltage for either position sensing or current sensing. The two main advantages are that measurement of lower (or even zero) speed is possible and that the voltage output of the sensors is independent of speed.

3.5.1 Hall Effect Distributor Pick-Up

Hall sensors are used in a number of ways. The ignition distributor was very common but they are not used now. This form of trigger device is a simple digital 'on/off switch' which produces a square wave output that is recognised and processed by the ignition control module or engine management ECU.

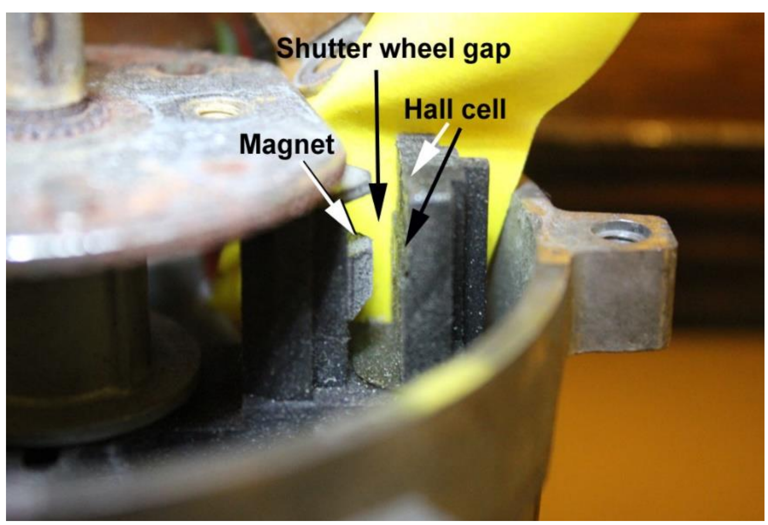


Figure 1: 85 Hall Effect distributor pick-up

The trigger has a rotating metal disc with openings that pass between an electromagnet and the semiconductor (Hall chip). This action produces a square wave that is used by the ECU or amplifier.

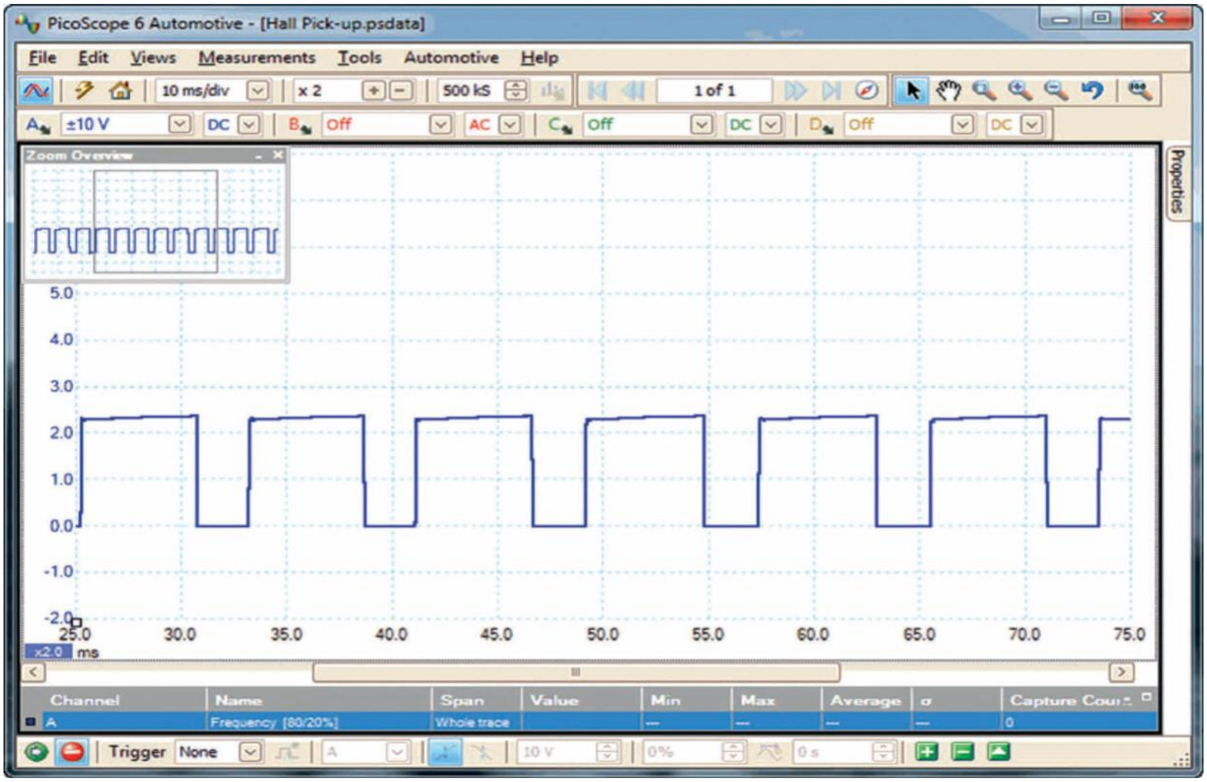


Figure 1: 86 Hall Effect Distributor Pick-Up

3.5.2 ABS Hall sensor

The sensor when used by ABS for monitoring wheel speed and as transmission speed sensors works using the same effect. The sensor will usually have three connections: a stabilised supply voltage (often 4 or 5 V), an earth and the output signal.

The square wave when monitored on an oscilloscope may vary a little in amplitude; this is not usually a problem as it is the frequency that is important. However, in

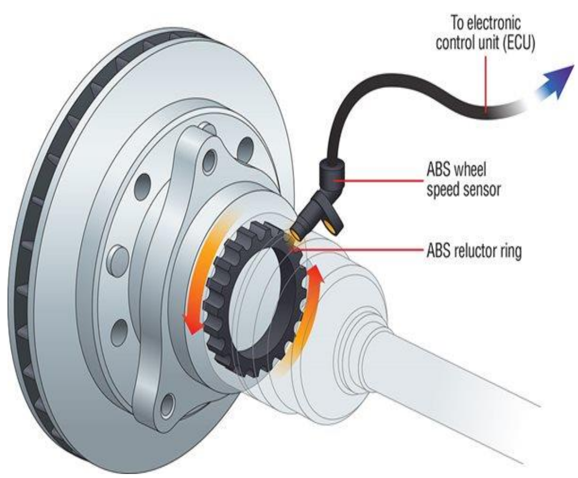


Figure 1: 87 ABS Hall sensor

most cases, the amplitude/voltage will remain constant.

3.5.3 Road Speed Sensor (Hall Effect)

To measure the output of this sensor, jack up the driven wheels of the vehicle and place on axle stands on firm level ground. Run the engine in gear and then probe each of the three connections (+, − and signal).

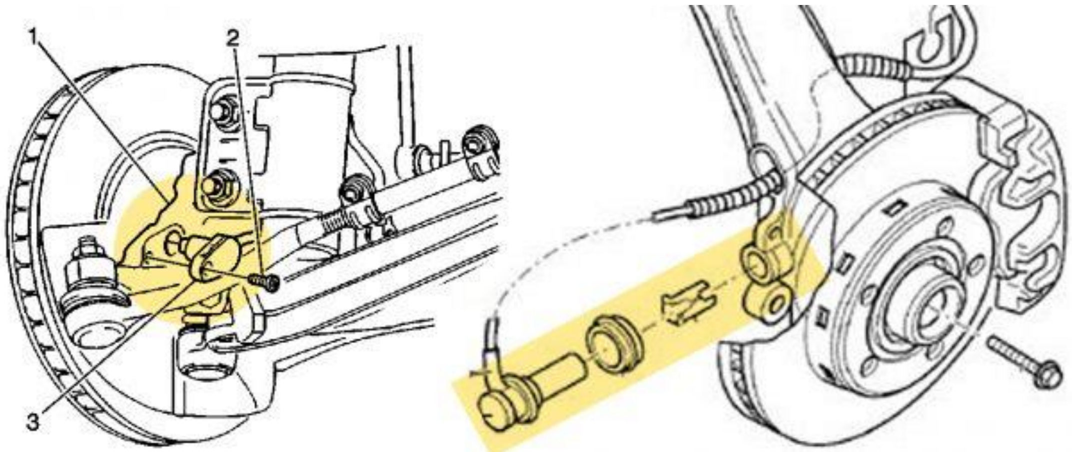


Figure 1: 88 Road Speed Sensor

As the road speed is increased, the frequency of the switching should be seen to increase. This change can also be measured on a multimeter with frequency capabilities. The sensor will be located on either the speedometer drive output from the gearbox or to the rear of the speedometer head if a speedo cable is used. The signal is used by the engine ECU and, if appropriate, the transmission ECU. The actual voltage will vary with sensor design.

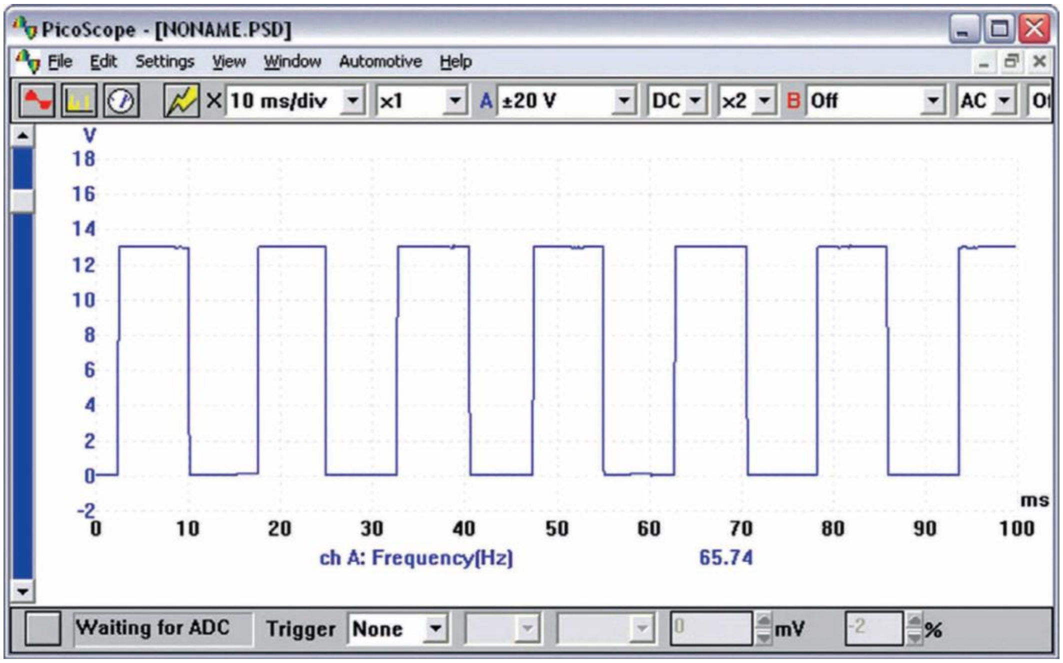


Figure 1: 89 Hall Effect road speed sensor waveform.

3.6 Piezo Accelerometer

A piezoelectric accelerometer is a seismic mass accelerometer using a piezoelectric crystal to convert the force on the mass due to acceleration into an electrical output signal. The crystal not only acts as the transducer but as the suspension spring for the mass. The crystal is sandwiched between the body of the sensor and the seismic mass and is kept under compression. Acceleration forces acting on the seismic mass cause variations in the amount of crystal compression and hence generate the piezoelectric voltage.

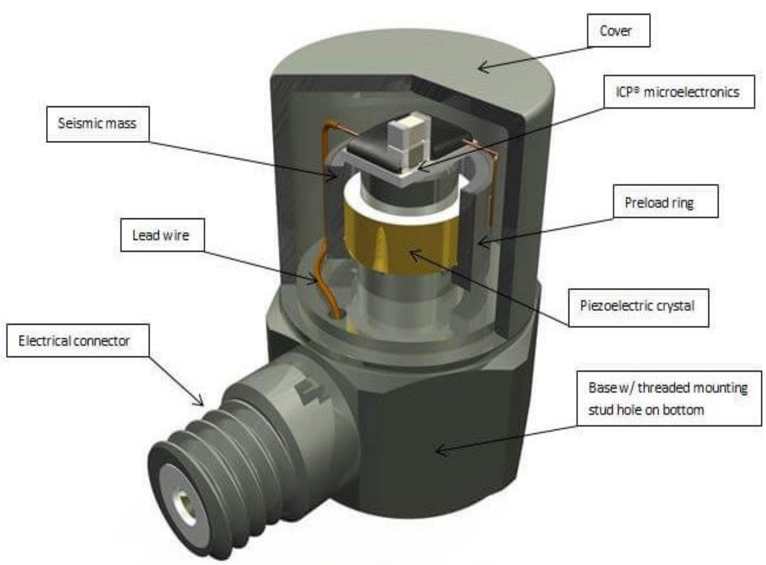


Figure 1: 90 Piezo Accelerometer

3.6.1 Knock Sensor

The sensor, when used as an engine knock sensor, will also detect other engine vibrations. These are kept to a minimum by only looking for ‘knock’, a few degrees before and after top dead centre (TDC). Unwanted signals are also filtered out electrically. The optimal point at which the spark ignites the air/fuel mixture is just before knocking occurs. However, if the timing is set to this value, under certain conditions knock (detonation) will occur. This can cause serious engine damage as well as increase emissions and reduce efficiency.

A knock sensor is used by some engine management systems. When coupled with the ECU, it can identify when knock occurs and retard the ignition timing accordingly. The frequency of knocking is approximately 15 kHz. As the response of the sensor is very fast, an appropriate time scale must be set, in the case of the example wave-form a 0 to 500 ms time base and a −5 to +5 V voltage scale.

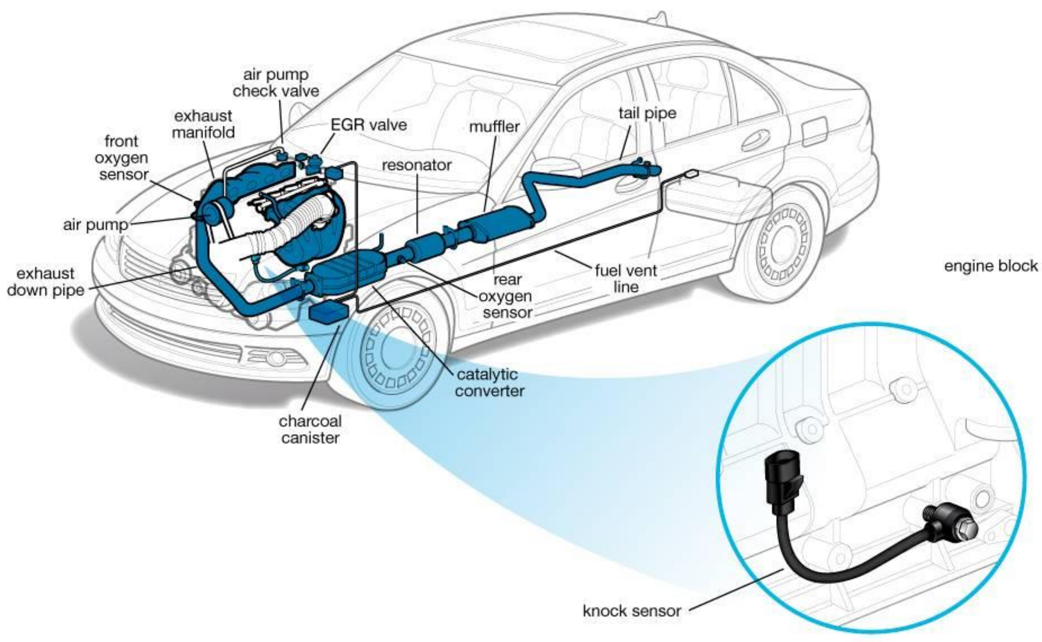


Figure 1: 91 Location of Knock Sensor

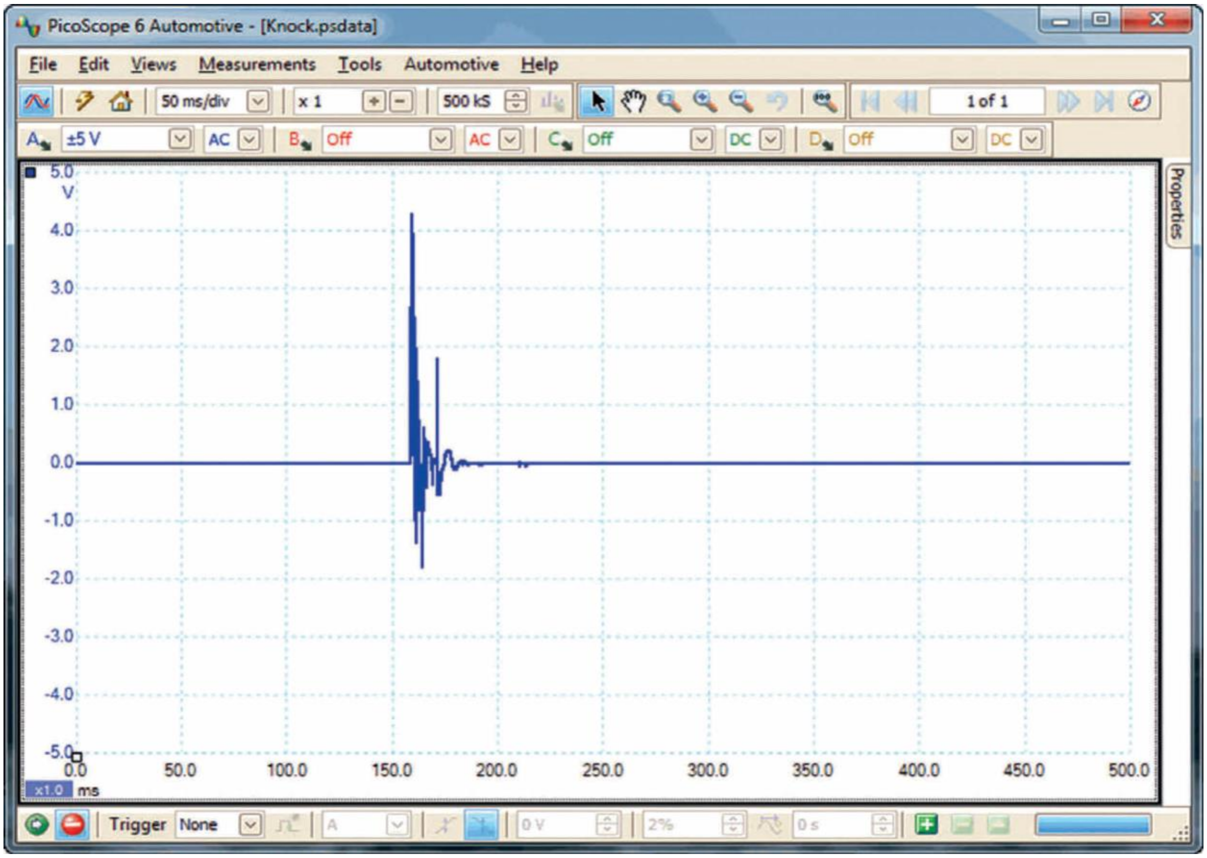


Figure 1: 92 Knock Sensor Square wave

3.7 Oxygen Sensors

The vehicle application for an oxygen sensor is to provide a closed loop feedback system for engine management control of the air/fuel ratio.

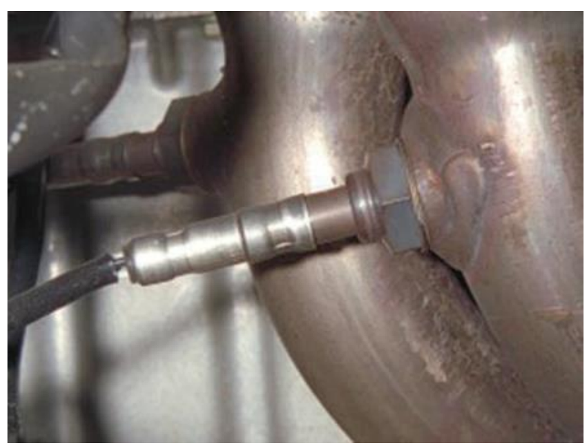


Figure 1: 93 Lambda sensor in the exhaust downpipe.

The amount of oxygen sensed in the exhaust is directly related to the mixture strength or air/fuel ratio. The ideal air/fuel ratio of 14.7:1 by mass is known as a lambda (λ) value of 1. Exhaust gas oxygen (EGO) sensors are placed in the exhaust pipe near to the manifold to ensure adequate heating. The sensors operate best at temperatures over 300°C. In some cases, a heating element is incorporated to ensure that this temperature is reached quickly. This type of sensor is known as a **heated exhaust gas oxygen sensor (HEGO).**

The heating element (which consumes approximately 10 W) does not operate all the time to ensure that the sensor does not exceed 850°C, at which temperature damage may occur to the sensor. This is why the sensors are not fitted directly in the exhaust manifold. The main active component of most types of oxygen sensors is zirconium dioxide (ZrO_2). This ceramic is housed in gas permeable electrodes of platinum.

Figure 1: 94 HEGO Sensor

A further ceramic coating is applied to the side of the sensor exposed to the exhaust gas as a protection against residue from the combustion process. The principle of operation is that at temperatures in excess of 300°C, the ZrO_2 will conduct the negative oxygen ions. The sensor is designed to be responsive very close to a lambda value of 1. As one electrode of the sensor is open to a reference value of atmospheric air, a greater quantity of oxygen ions will be present on this side. Because of electrolytic action, these ions permeate the electrode and migrate through the electrolyte (ZrO_2). This builds up a charge rather like a battery.

3.7.1 Oxygen Sensor (Titania)

The lambda sensor, also referred to as the oxygen sensor, plays a very important role in the control of exhaust emissions on a catalyst equipped vehicle. The main lambda sensor is fitted into the exhaust pipe before the catalytic converter. The sensor will have four electrical connections. It reacts to the oxygen content in the exhaust system and will produce an oscillating volt-age between 0.5 (lean) and 4.0 V, or above (rich) when running correctly. A second sensor to monitor the catalyst performance may be fitted downstream of the converter.

Figure 1: 95 Titania Oxygen Sensor

Titania sensors, unlike Zirconia sensors, require a voltage supply as they do not generate their own voltage. A vehicle equipped with a lambda sensor is said to have ‘closed loop’, this means that after the fuel has been burnt up during the combustion process, the sensor will analyse the emissions and adjust the engine’s fuelling accordingly. Titania sensors have a heating element to assist the sensor to reach its optimum operating temperature. The sensor when working correctly will switch approximately once per second (1 Hz) but will only start to switch when at normal operating temperature. This switching can be seen on the oscilloscope, and the waveform should look similar to the one in the example

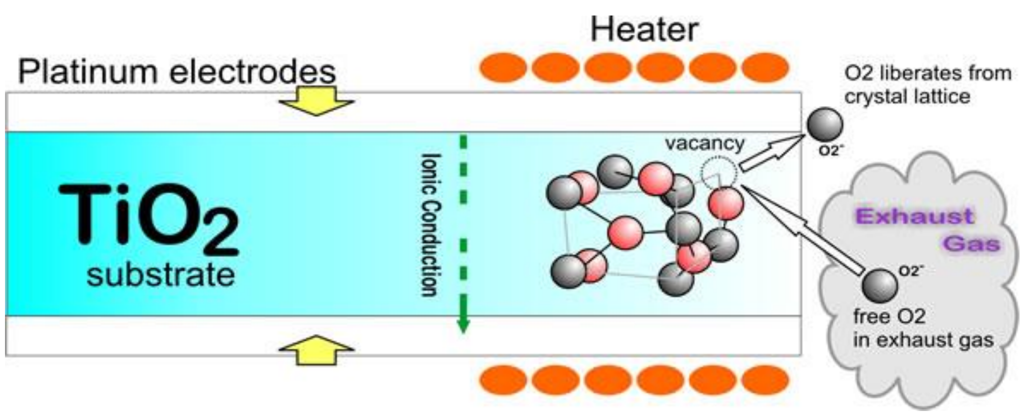


Figure 1: 96 Titania Working Process

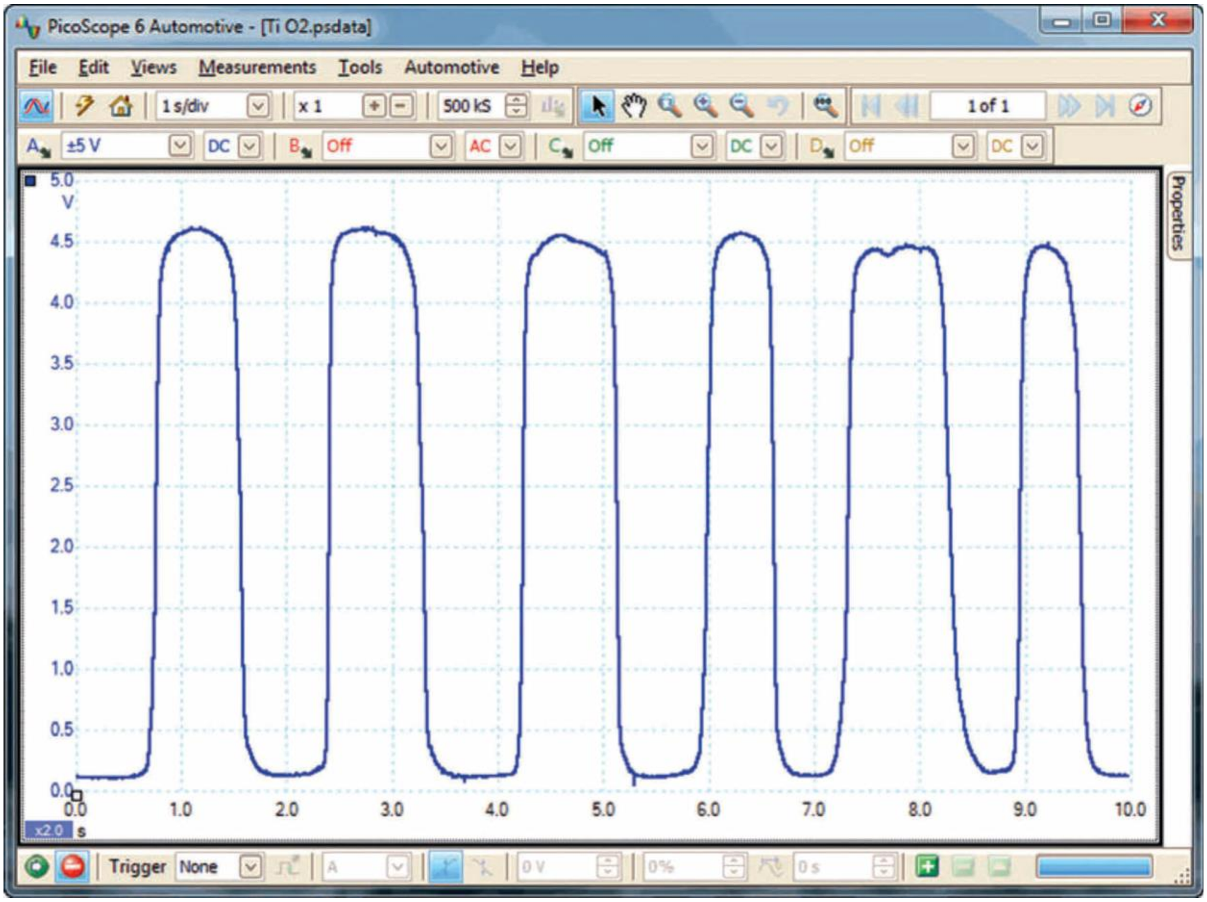


Figure 1: 97 Titania Oxygen Sensor Square Wave

3.7.2 Oxygen sensor (Zirconia)

The sensor will have varying electrical connections and may have up to four wires. It reacts to the oxygen content in the exhaust system and will produce a small voltage depending on the air/fuel mixture seen at the time. The voltage range seen will, in most cases, vary between 0.2 and 0.8 V. The 0.2 V indicates a lean mixture and a voltage of 0.8 V shows a richer mixture.

Lambda sensors can have a heating element to assist the sensor reaching its optimum operating temperature. Zirconia sensors when working correctly will switch approximately once per second (1 Hz) and will only start to switch when at normal operating temperature. This switching can be seen on the oscilloscope, and the waveform should look similar to the one in the example waveform.

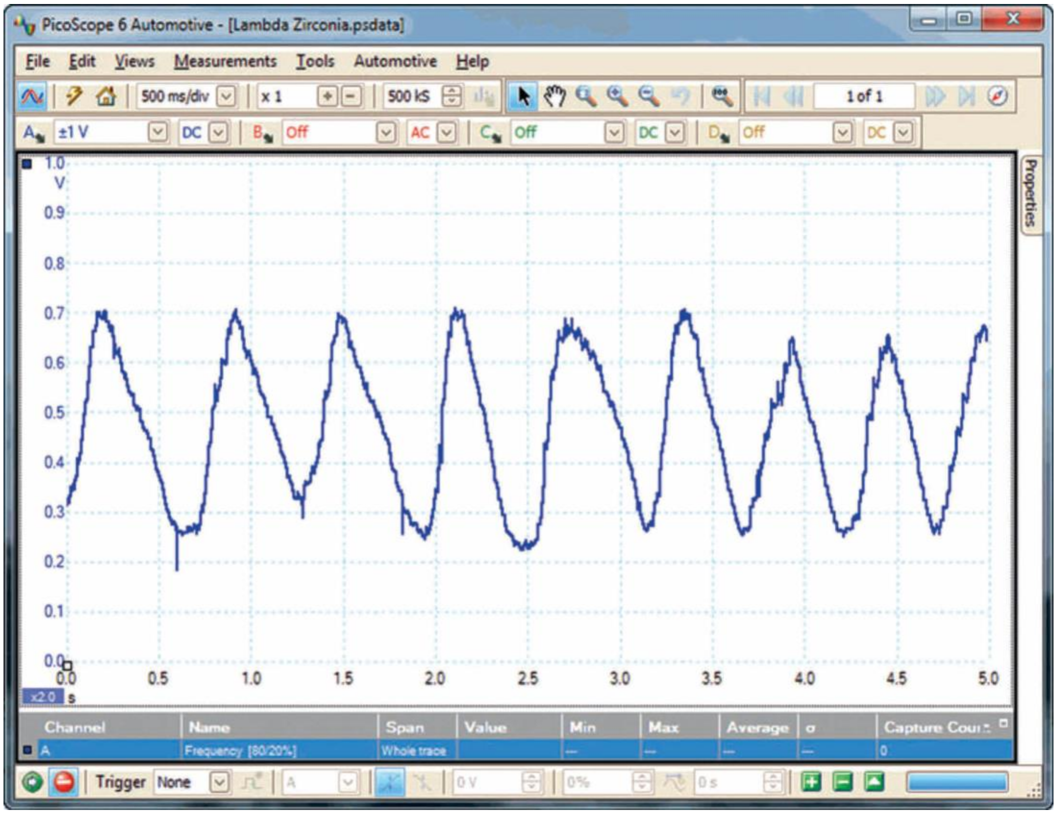


Figure 1: 98 Zirconia oxygen sensor output.

Many vehicles now have a pre- and post-cat lambda sensor. Comparing the outputs of these two sensors is a good indicator of catalyst operation and condition.

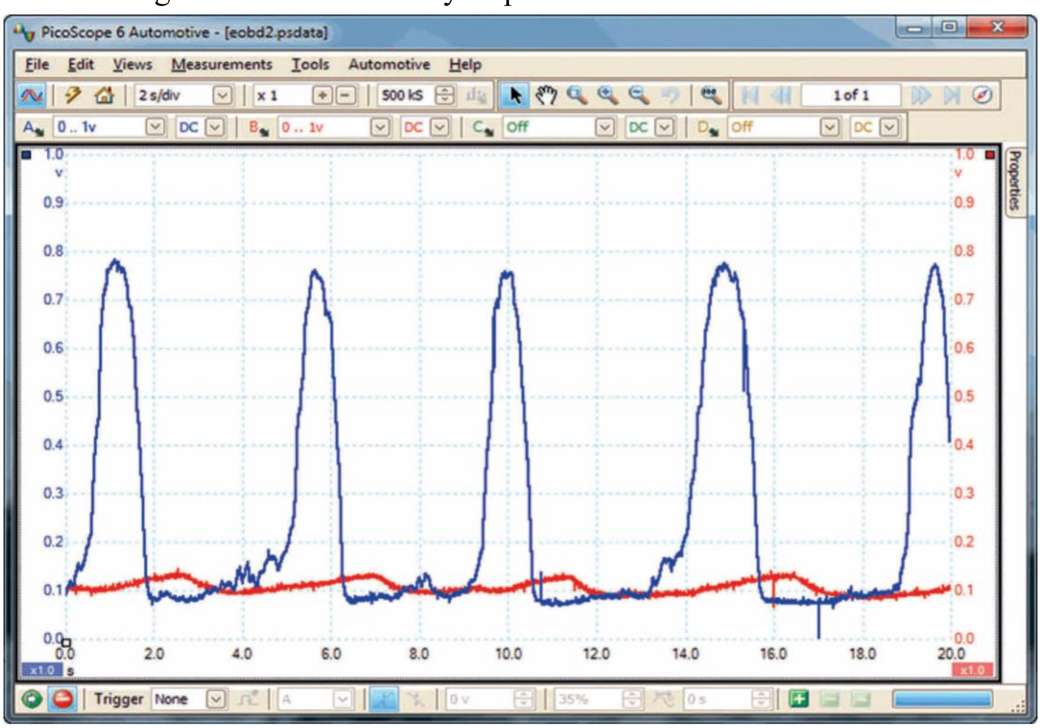


Figure 1: 99 Pre-cat signal shown in blue and post-cat in red.

3.8 Pressure Sensors

3.8.1 Strain Gauges

When a strain gauge is stretched its resistance will increase, and when it is compressed its resistance decreases. Most strain gauges consist of a thin layer of film that is fixed to a flexible backing sheet. This in turn is bonded to the part where strain is to be measured. Most resistance strain gauges have a resistance of approximately 100 Ω.

Strain gauges are often used indirectly to measure engine manifold pressure. Figure 4.28 shows an arrangement of four strain gauges on a diaphragm forming part of an aneroid chamber used to measure pressure. When changes in manifold pressure act on the diaphragm, the gauges detect the strain. The output of the circuit is via a differential amplifier, which must have a very high input resistance so as not to affect the bridge balance. The actual size of this sensor may be only a few millimetres in diameter. Changes in temperature are compensated for by using four gauges which when affected in a similar way cancel out any changes.

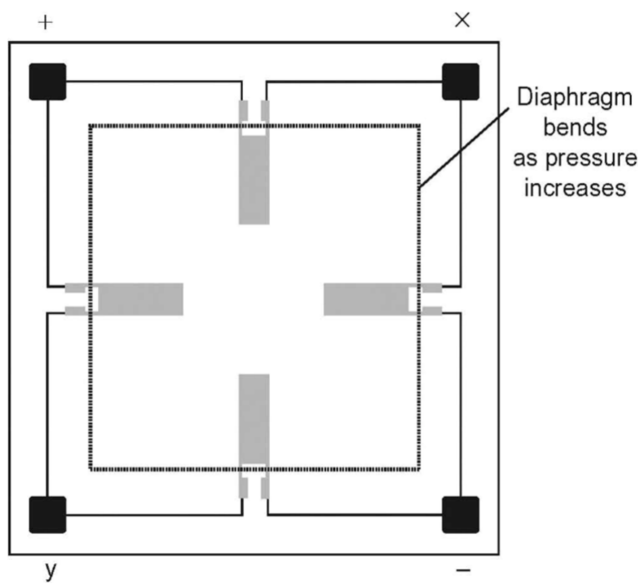


Figure 1: 100 Strain gauge pressure sensor (+ and − are the supply,

Figure 1: 101 Fuel Pressure Sensor

3.8.2 Fuel Pressure Sensor

Common rail diesel system pressure signals can be tested (remember these systems operate at very high pressure). The pulse width modulation (PWM) signal should be at the same amplitude but the on/off ratio can vary.

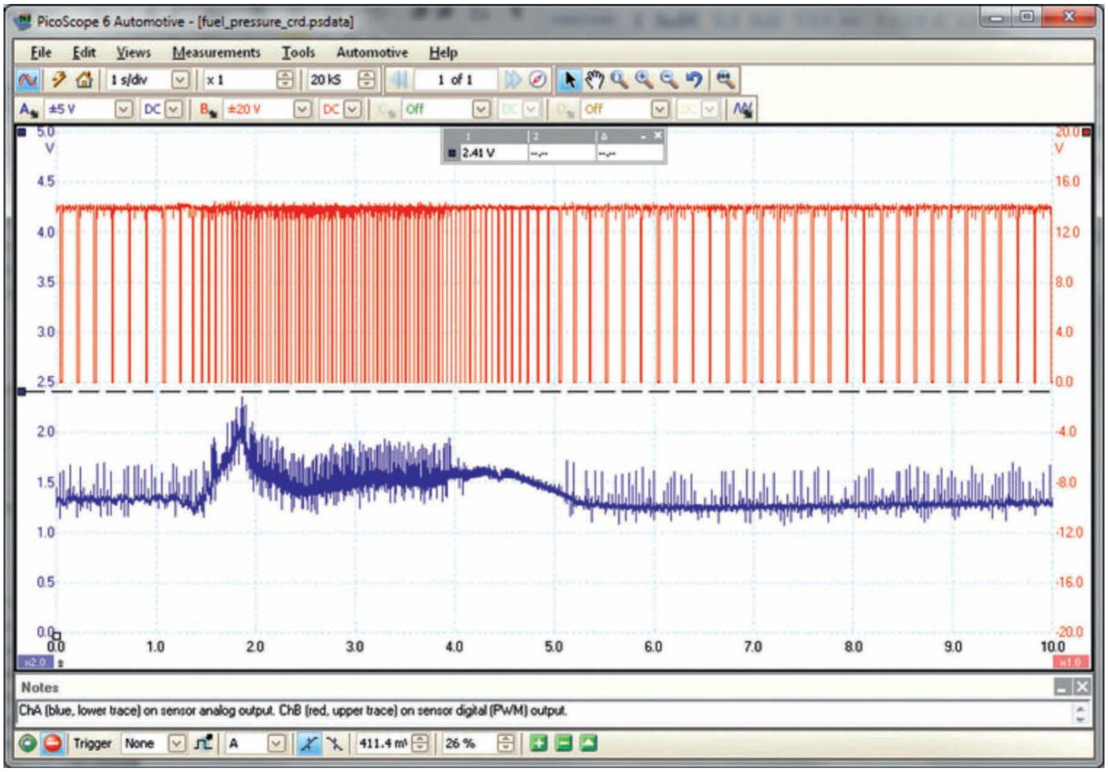


Figure 1: 102 Fuel Pressure Sensor Square Wave

3.8.3 Manifold Absolute Pressure (MAP)

Manifold absolute pressure (MAP) is a signal used to determine engine load. There are two main types: analogue and digital. The analogue signal voltage output varies with pressure whereas the digital signal varies with frequency.

These sensors use a piezo crystal, strain gauges or variable capacitance sensors or similar. The signals are also processed internally.

Figure 1: 103 Internal Construction pf MAP Sensor

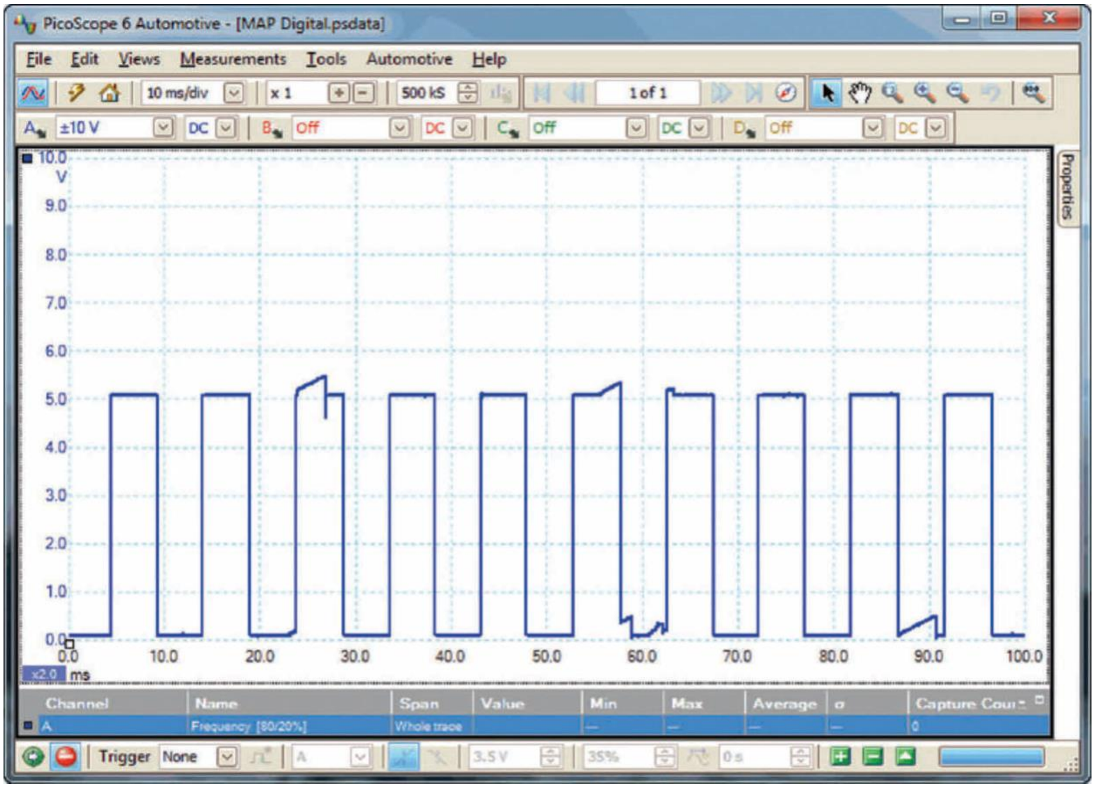


Figure 1: 104 Digital MAP sensor.

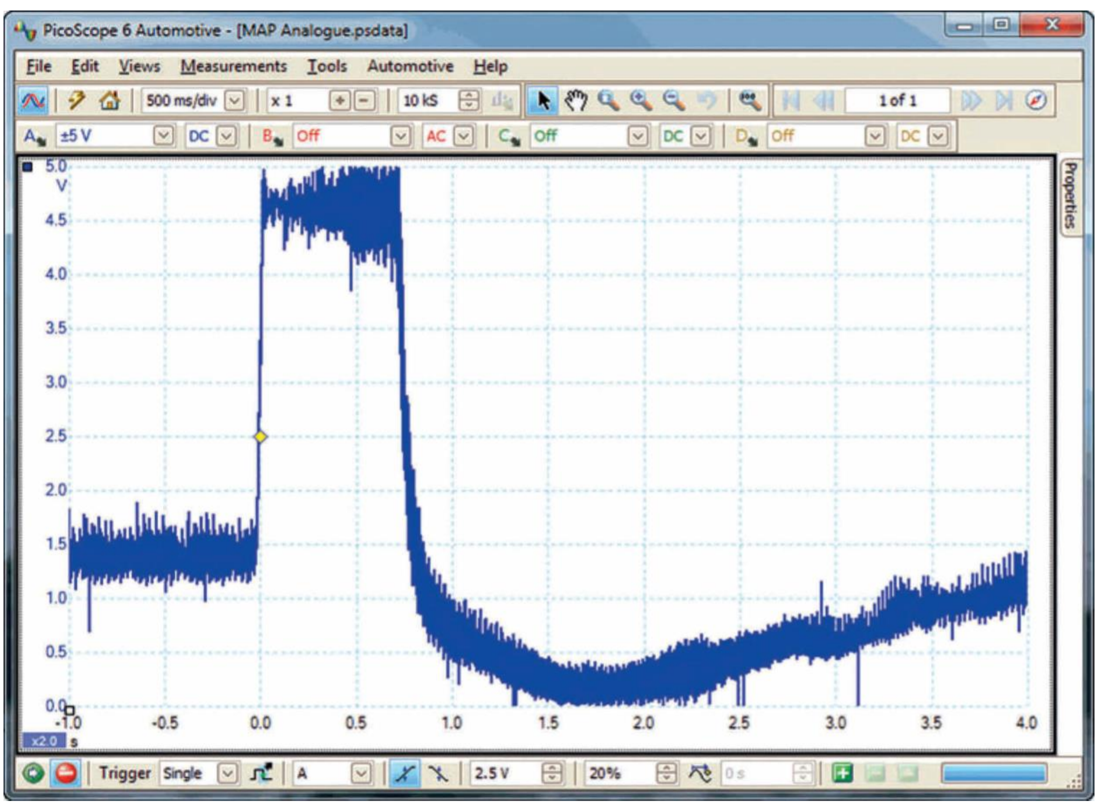


Figure 1: 105 Analogue MAP sensor.

3.9 Variable Capacitance

The value of a capacitor is determined by the:

- Surface area of its plates;
- Distance between the plates;
- Dielectric (insulation between the plates).

Sensors can be constructed to take advantage of these properties. Three sensors, each using the variable capacitance technique, are shown in Figure 1.108 These are (a) liquid level sensor in which the change in liquid level changes the dielectric value; (b) pressure sensor similar to the strain gauge pressure sensor in which the distance between capacitor plates changes; and (c) position sensor which detects changes in the area of the plates.

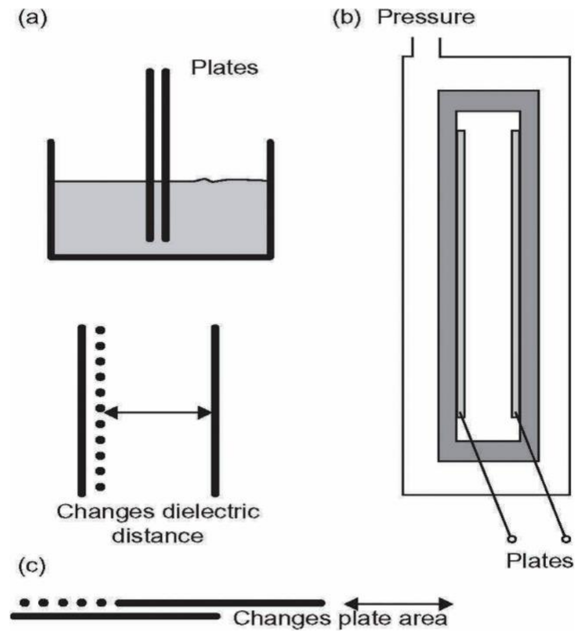


Figure 1: 106 Variable capacitance sensors: (a) liquid level, (b) pressure and (c) position.

3.9.1 Oil Quality Sensor

An interesting sensor used to monitor oil quality is now available, which works by monitoring changes in the dielectric constant of the oil. This value increases as antioxidant additives in the oil deplete. The value rap-idly increases if coolant contaminates the oil. The sensor output increases as the dielectric constant increases.

Figure 1: 107 Oil Quality Sensor

3.9.2 Optical Sensors

An optical sensor for rotational position is a relatively simple device. The optical rotation sensor consists of a phototransistor as a detector and a light-emitting diode (LED) light source. If the light is focused to a very narrow beam then the output of the circuit shown will be a square wave with frequency proportional to speed.

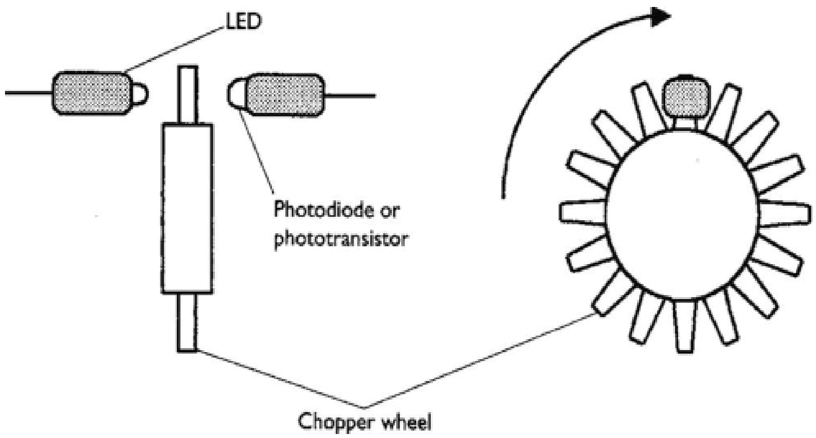


Figure 1: 108 Optical Sensor

3.9.3 Dynamic position sensors

A dynamic position or movement of crash sensor can take a number of forms; these can be described as mechanical or electronic. The mechanical system works by a spring holding a roller in a set position until an impact (acceleration/deceleration) above a predetermined limit provides enough force to over-come the spring and the roller moves, triggering a micro switch. The switch is normally open with a resistor in parallel to allow the system to be monitored. Two switches similar to this may be used to ensure that an airbag is deployed only in the case of sufficient frontal impact.

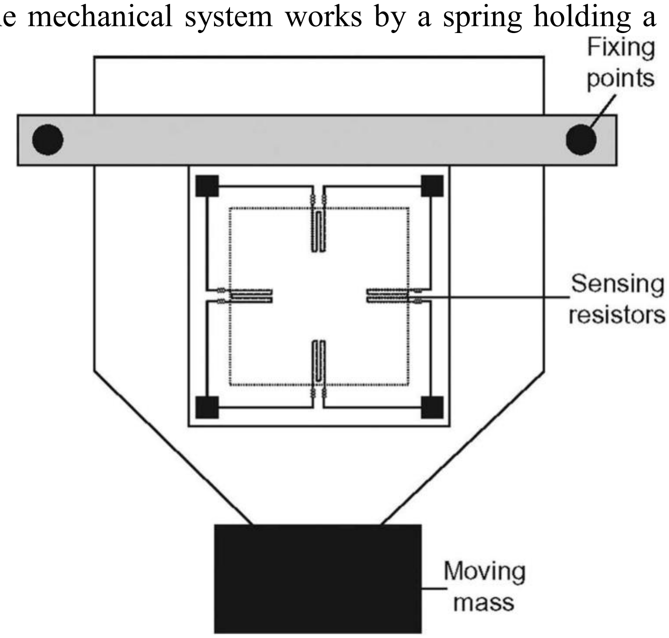


Figure 1: 109 Strain gauge accelerometer.

Self-Check 3

Directions: Answer all the questions listed below.

Part II: Fill in the Blank Space

1. ___________evaluates the signals and influences the the firing angle.
2. ___________can have a heating element to assist the sensor reaching its optimum operating temperature
3. ___________when working correctly will switch approximately once per second (1 Hz)
4. ___________stretched its resistance will increase, and when it is compressed its resistance decreases.
5. ____________signal should be at the same amplitude but the on/off ratio can vary.

Part II: Choose the best answer in a given alternatives following questions

1. What does a sensor do?
   a) It selects transmission gear ratio.
   b) It measures some variable.
   c) It is an output device.
   d) It sends signals to the driver.
2. What does an actuator do?
   a) It is an input device for an engine control system.
   b) It provides a mathematical model for an engine.
   a) It causes an action to be performed in response to an electrical signal.
   b) It indicates the results of a measurement.
3. What is a MAP sensor?
   a) a sensor that measures manifold absolute pressure
   b) a vacation route planning scheme
   c) a measurement of fluctuations in manifold air
   d) an acronym for mean atmospheric pressure
4. What is an EGO sensor?
   a) a measure of the self-centeredness of the driver
   b) a device for measuring the oxygen concentration in the exhaust of an engine
   c) a spark advance mechanism
   d) a measure of crankshaft acceleration

5. The crankshaft angular position sensor measures
    a) the angle between the connecting rods and the crankshaft
    b) the angle between a line drawn through the crankshaft axis
    a) and a reference line
    b) the pitch angle of the crankshaft
    c) the oil pressure angle
6. The Hall Effect is
    a) the resonance of a long, narrow corridor
    b) the flow of air through the intake manifold
    c) zero crossing error in camshaft position measurements
    d) a semiconductor materials in which a voltage is generated
7. A mass air flow sensor measures
    a) the density of atmospheric air
    b) the composition of air
    c) measured in terms of its mass
    d) the flow of exhaust out of the engine
8. A thermistor is
    a) a semiconductor temperature sensor
    b) a device for regulating engine temperature
    c) a temperature control system for the passenger
    d) a new type of transistor

Part-III: Answer the following questions accordingly.

1. Discuss about the Oxygen Sensor diagnosing
2. Figure out at least 10 sensors square wave
3. What is the Hall effect working principle and their types
4. Differentiate hot wire and hot film type air flow meter

Unit Four: Actuators Diagnostic

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Introduction to Actuator
- Motorised and solenoid Valve
- Solenoid Actuators
- Thermal Actuator

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Introduce an Actuator
- Diagnosis Motorised and solenoid Valve
- Diagnosis Solenoid Actuators
- Diagnosis Thermal Actuator

4.1 Introduction to Actuators

There are many ways of providing control over variables in and around the vehicle. 'Actuators' is a general term used here to describe a control mechanism. When controlled electrically, they will work either by a thermal or by a magnetic effect. In this section, the term actuator will generally be used to mean a device which converts electrical signals into mechanical movement.

Testing actuators can be simple as many are operated by windings. The resistance can be measured with an ohmmeter. A good tip is that where an actuator has more than one winding (e.g. a stepper motor), the resistance of each should be about the same. Even if the expected value is not known, it is likely that if all the windings read the same then the device is in working order.

With some actuators, it is possible to power them up from the vehicle battery. A fuel injector should click, for example, and a rotary air bypass device should rotate about half a turn. Be careful with this method as some actuators could be damaged. At the very least, use a fused supply (jumper) wire.

4.2 Motorised and Solenoid Actuators

4.2.1 Motors

Permanent magnet electric motors are used in many applications and are very versatile. The output of a motor is of course rotation, and this can be used in many ways. If the motor drives a rotating 'nut' through which a plunger is fitted on which there is a screw thread, the rotary action can easily be converted to linear movement. In most vehicle applications, the output of the motor has to be geared down, this is to reduce speed and increase torque. Permanent magnet motors are almost universally used now in place of older and less practical motors with field windings. Some typical examples of the use of these motors are listed as follows:

- Windscreen Wipers;
- Windscreen Washers;
- Headlight Lift;
- Electric Windows;

- Electric Sunroof;
- Electric Aerial Operation;
- Seat Adjustment;
- Mirror Adjustment;
- Headlight Washers;
- Headlight Wipers;
- Fuel Pumps;
- Ventilation Fans.

4.2.2 Rotary Idle Speed Control Valve

The rotary ISCV will have two or three electrical connections, with a voltage supply at battery voltage and either a single- or a double-switched earth path. The device is like a motor but only rotates about half a turn in each direction.

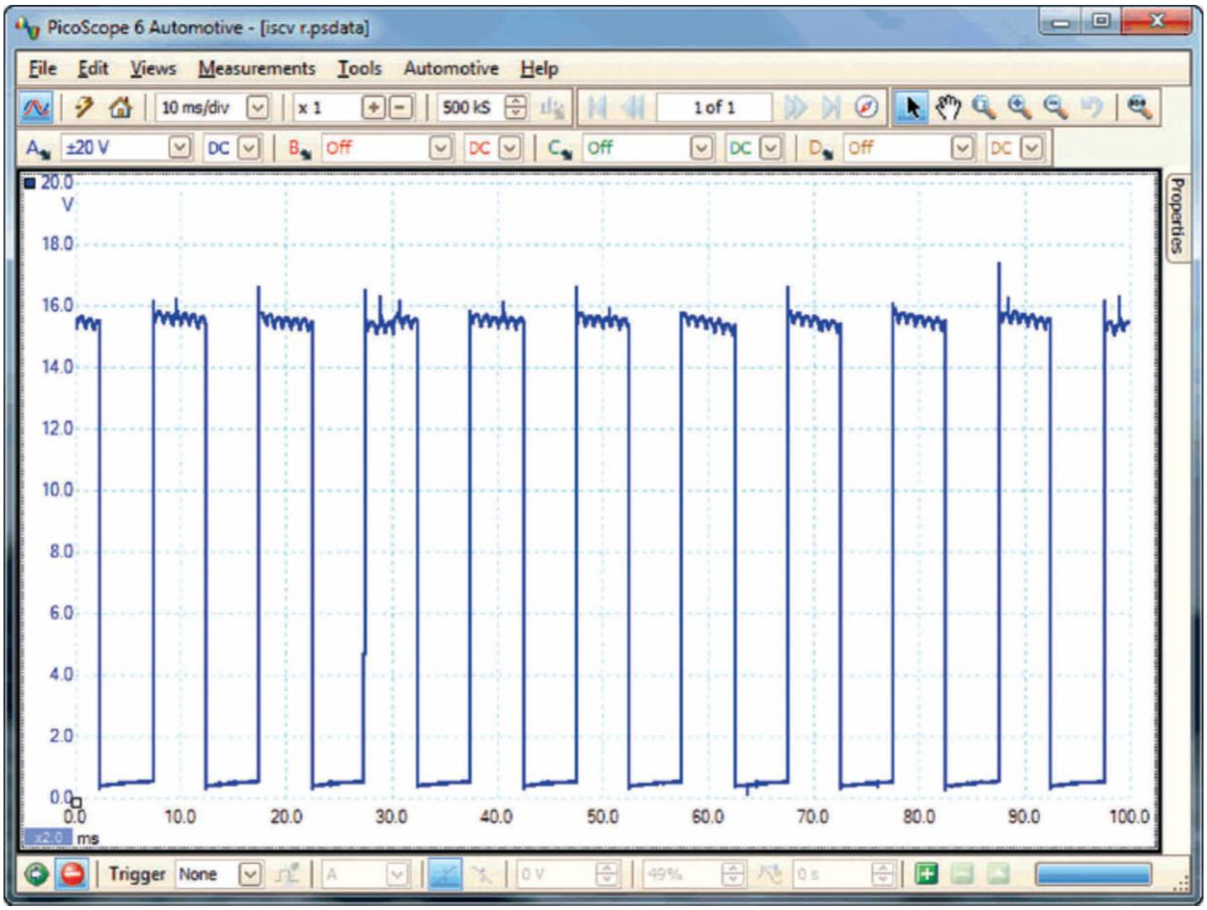
This device is used to control idle speed by controlling air bypass. There are two basic types in common use.

These are single-winding types, which have two terminals, and double-winding types, which have three terminals. Under ECU, the motor is caused to open and close a shutter, controlling air bypass. These actuators only rotate approximately 90° to open and close the valve. As these are permanent magnet motors, the 'single or double windings' refer to the armature.

Figure 1: 110 Rotary Idle Speed Control Valve

The single-winding type is fed with a square wave signal causing it to open against a spring and then close again, under spring tension. The on/off ratio or duty cycle of the square wave will determine the average valve open time and hence idle speed. With the double- winding type, the same square wave signal is sent to one winding but the inverse signal is sent to the other. As the windings are wound in opposition to each other, if the duty cycle is 50% then no movement will take place. Altering the ratio will now cause the shutter to move in one direction or the other.

Probing onto the supply side will produce a straight line at system voltage, and when the earth circuit is monitored, a square wave will be seen. The frequency can also be measured as can the on/off ratio.



4.2.3 Stepper Motors

Stepper motors are becoming increasingly popular as actuators in the motor vehicle. This is mainly because of the ease with which they can be controlled by electronic systems. Stepper motors fall into the following three distinct groups, the

basic principles of which are shown in this figure.

Figure 1: 111 Stepper Motors

- Variable Reluctance Motors;
- Permanent Magnet (Pm) Motors;
- Hybrid Motors.

The underlying principle is the same for each type. All of them have been and are being used in various vehicle applications. The basic design for a permanent magnet stepper motor comprises two double stators. The rotor is often made of barium-ferrite in the form of a sintered annular magnet. As the windings are energised in one direction then the other, the motor will rotate in 90° steps. Half step can be achieved by switching on two windings. This will cause the rotor to line up with the two stator poles and implement a half step of 45°.

The direction of rotation is determined by the order in which the windings are switched on or off or reversed. The main advantages of a stepper motor are that feed-back of position is not required. This is because the motor can be indexed to a known starting point and then a calculated number of steps will move the motor to any suitable position.

The stepper motor, when used to control idle speed, is a small electro-mechanical device that allows either an air bypass circuit or a throttle opening to alter in position depending on the amounts that the stepper is indexed.

Stepper motors are used to control the idle speed when an ISCV is not employed. The stepper may have four or five connections back to the ECU.

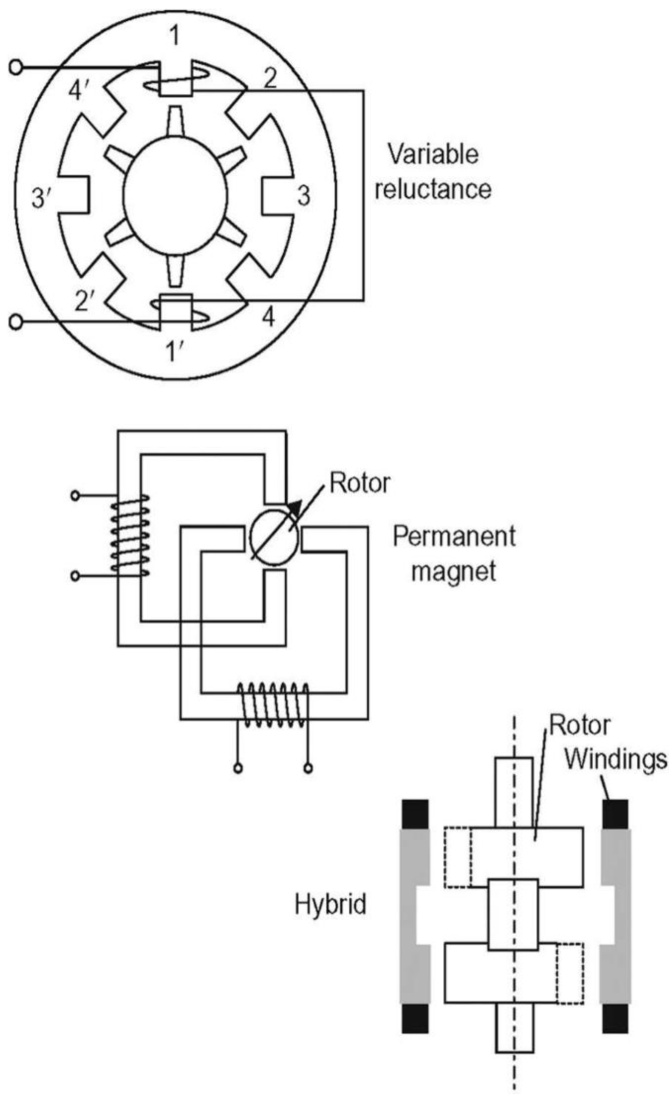


Figure 1: 112 Stepper Motor Principle.

These enable the control unit to move the motor in a series of 'steps' as the circuits are earthed to ground.

These devices may also be used to control the position of control flaps, for example, as part of a heating and ventilation system.

Figure 1: 113Stepper Motor Square Wave

4.3 Solenoid Actuators

The basic operation of solenoid actuators is very simple. The term 'solenoid' actually means 'many coils of wire wound onto a hollow tube'. This is often misused but has become so entrenched that terms like 'starter solenoid', when really it is a starter actuator or relay, are in common use. A good example of a solenoid actuator is a fuel injector.

When the windings are energised, the armature is attracted due to magnetism and compresses the spring. In the case of a fuel injector, the movement is restricted to approximately 0.1 mm. The period that an injector remains open is very small; under various operating conditions, between 1.5 and 10 ms being typical. The time it takes an injector to open and close is also critical for accurate fuel metering. Some systems use ballast resistors in series with the fuel injectors. This allows lower inductance and resistance operating windings to be used, thus speeding up reaction time.

Other types of solenoid actuators, for example door lock actuators, have less critical reaction times. However, the basic principle remains the same.

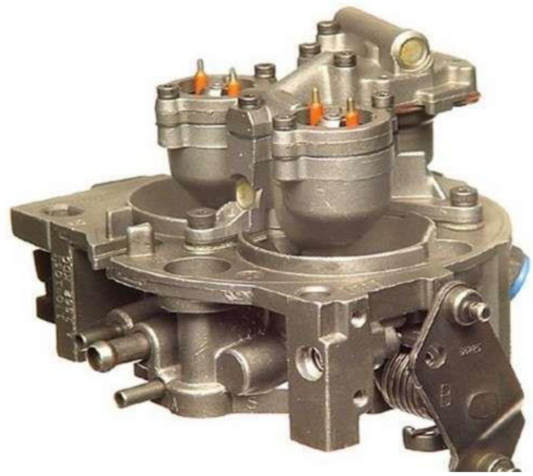


Figure 1: 115 Throttle body with a single injector.

4.3.1 Single-Point Injector

Single-point injection is also sometimes referred to as throttle body injection .A single injector is used (on larger engines two injectors can be used) in what may have the outward appearance to be a carburettor housing.

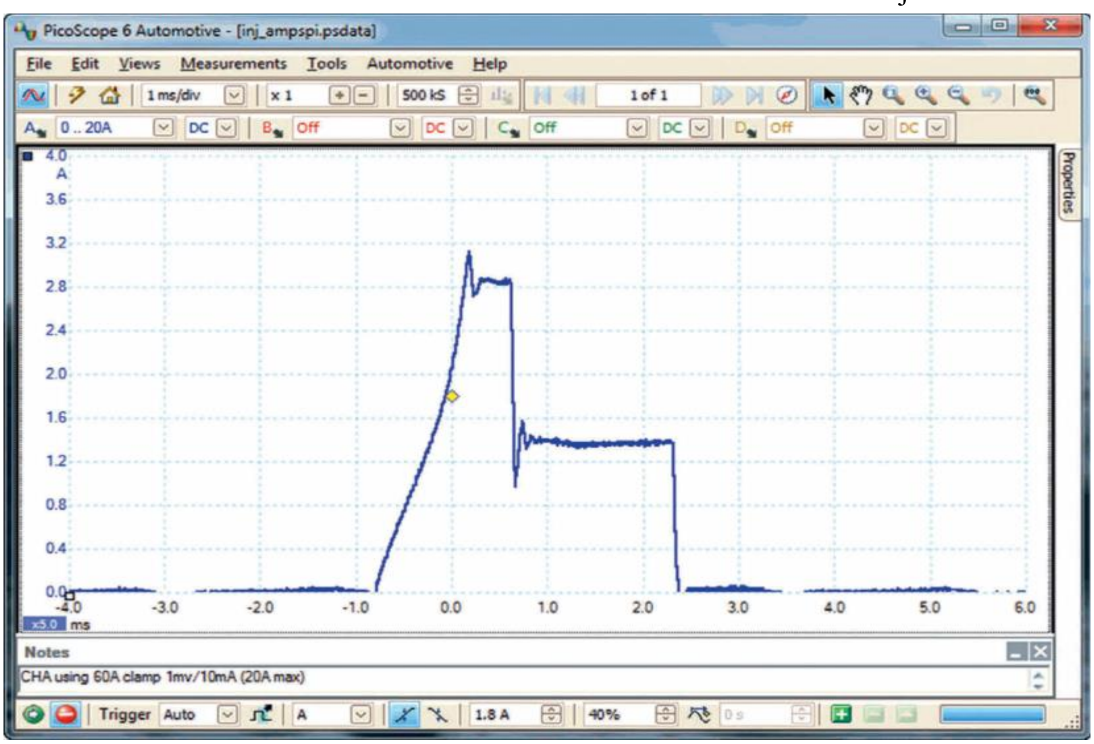


Figure 1: 114 Single-Point Injector

4.3.2 Multi-Point Injector

This injector is an electro-mechanical device which is fed by a 12 V supply. The voltage will only be present when the engine is cranking or running because it is controlled by a relay that operates only when a speed signal is available from the engine. Early systems had this feature built into the relay; most modern systems control the relay from the ECU. The length of time the injector is held open will depend on the input signals seen by the ECU from its various engine sensors.

The duration of open time or 'injector duration' will vary to compensate for cold engine starting and warm-up periods. The duration time will also expand under acceleration. The injector will have a constant voltage supply while the engine is running and the earth path will be switched via the ECU; the result can be seen in the example waveform. When the earth is removed, a voltage is induced into the injector and a spike approaching 60 V is recorded.

Figure 1: 116 Multi-Point Injector

The height of the spike will vary from vehicle to vehicle. If the value is approximately 35 V, it is because a Zener diode is used in the ECU to clamp the voltage. Make sure the top of the spike is squared off, indicating the Zener dumped the remainder of the spike. If it is not squared, this indicates the spike is not strong enough to make the Zener fully dump, meaning there is a problem with a weak injector winding. If a Zener diode is not used in the computer, the spike from a good injector will be 60 V or more.

Multi-point injection may be either sequential or simultaneous. A simultaneous system will fire all four injectors at the same time with each cylinder receiving two injection pulses per cycle (720° crankshaft rotation). A sequential system will receive just one injection pulse per cycle, which is timed to coincide with the opening of the inlet valve. Monitoring the injector waveform using both voltage and amperage allows display of the 'correct' time that the injector is physically open. The current waveform (the one starting on the zero line) shows that the wave-form is 'split' into two defined areas.

The first part of the current waveform is responsible for the electromagnetic force lifting the pintle; in this example, the time taken is approximately 1.5 ms. this is often referred to as the solenoid reaction time. The remaining 2 ms is the actual time the injector is fully open. This, when taken as a comparison against the injector voltage duration, is different to the 3.5 ms shown. The secret is to make sure you compare like with like.

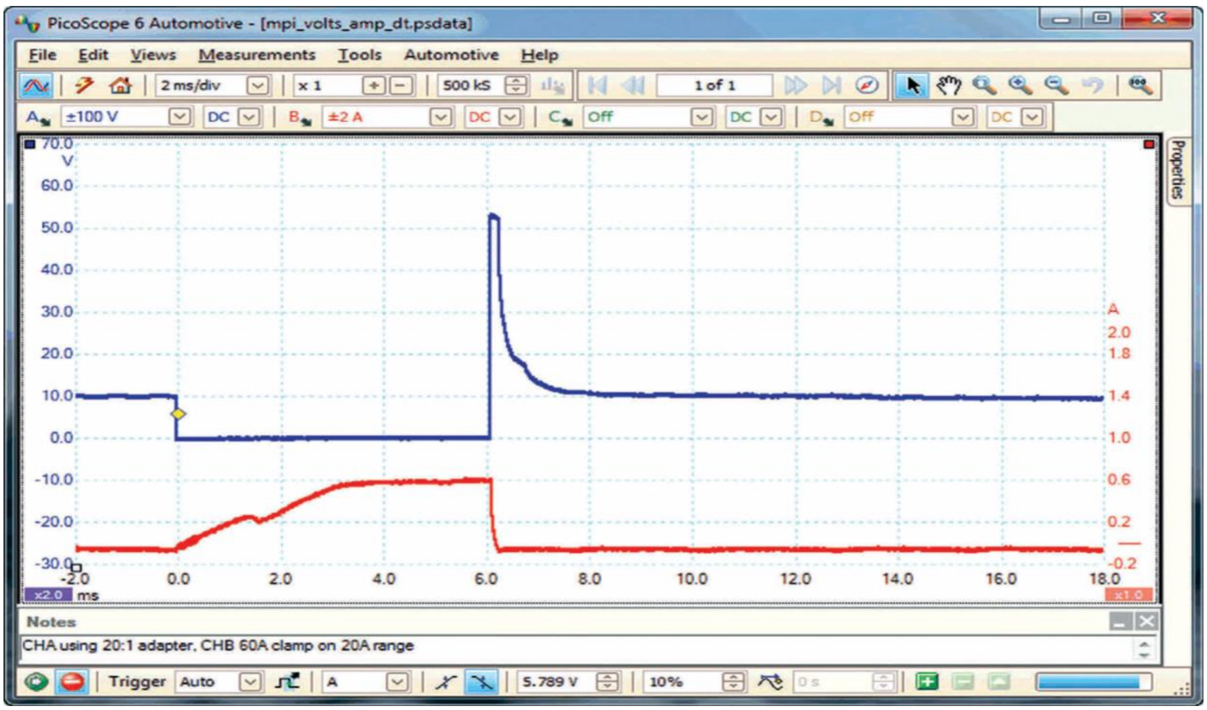
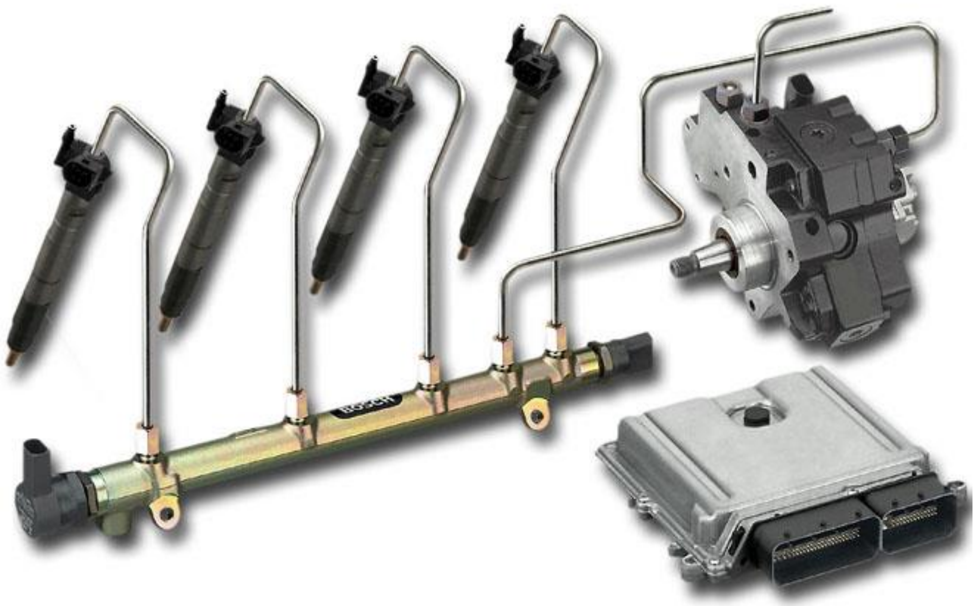


Figure 1: 117 Multi-Point Injector

4.3.3 Common Rail Diesel Injector

Europe It can be clearly seen from the example waveform that there are two distinctive points of injection, the first being the ‘pre-injection’ phase, with the second pulse being the ‘main’ injection phase.



As the throttle is opened, and the engine is accelerated, the ‘main’ injection pulse expands in a similar way to a petrol injector. As the throttle is released, the ‘main’ injection pulse disappears until such time as the engine returns to just above idle. Under certain engine conditions, a third phase may be seen, this is called the ‘post-injection’ phase and is predominantly concerned with controlling the exhaust emissions.

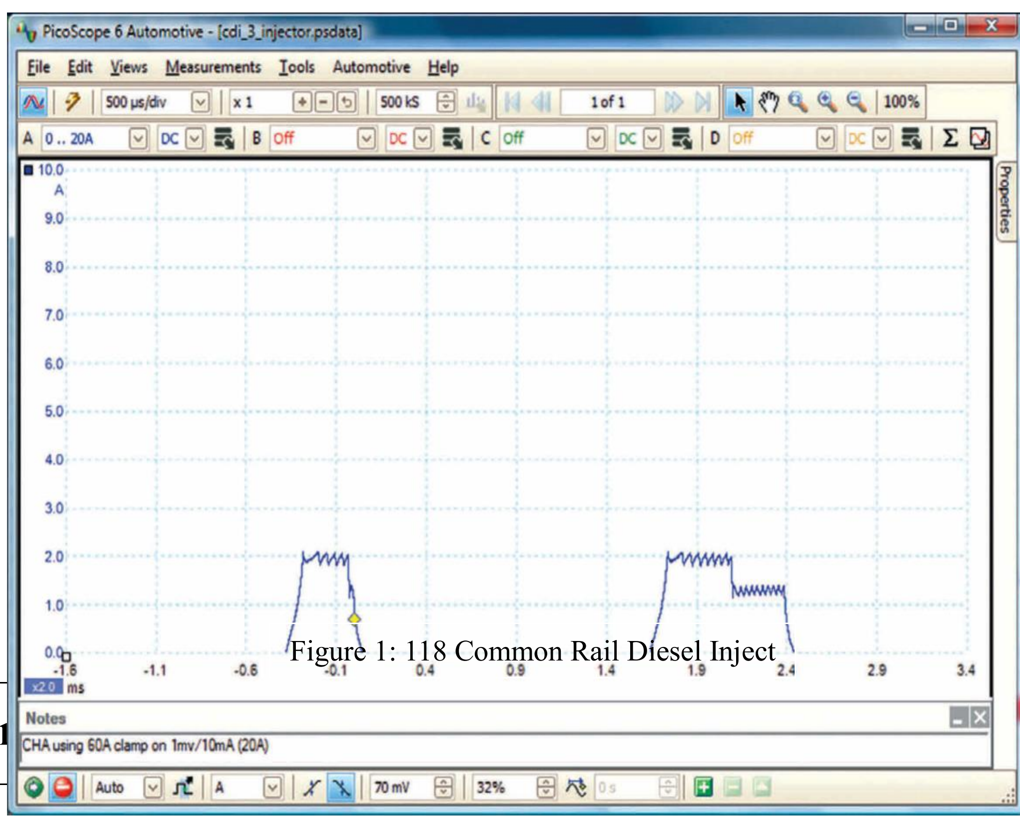


Figure 1: 118 Common Rail Diesel Inject

Figure 1: 119 CR injector (current) waveform showing pre- and main injection pulses.

4.3.4 Idle Speed Control Valve

This device contains a winding, plunger and spring. When energised, the port opens, and when not, it closes. The electromagnetic ISCV will have two electrical connections: usually a voltage supply at battery voltage and a switched earth.

The rate at which the device is switched is determined by the ECU to maintain a prerequisite speed according to its programming.

The valve will form an air bypass around the throttle butterfly. If the engine has an adjustable air bypass and an ISCV, it may require a specific routine to balance the two air paths. The position of the valve tends to take up an average position determined by the supplied signal. Probing onto the supply side will produce a straight line at system voltage.

Figure 1: 120 Electromagnetic idle speed control valve

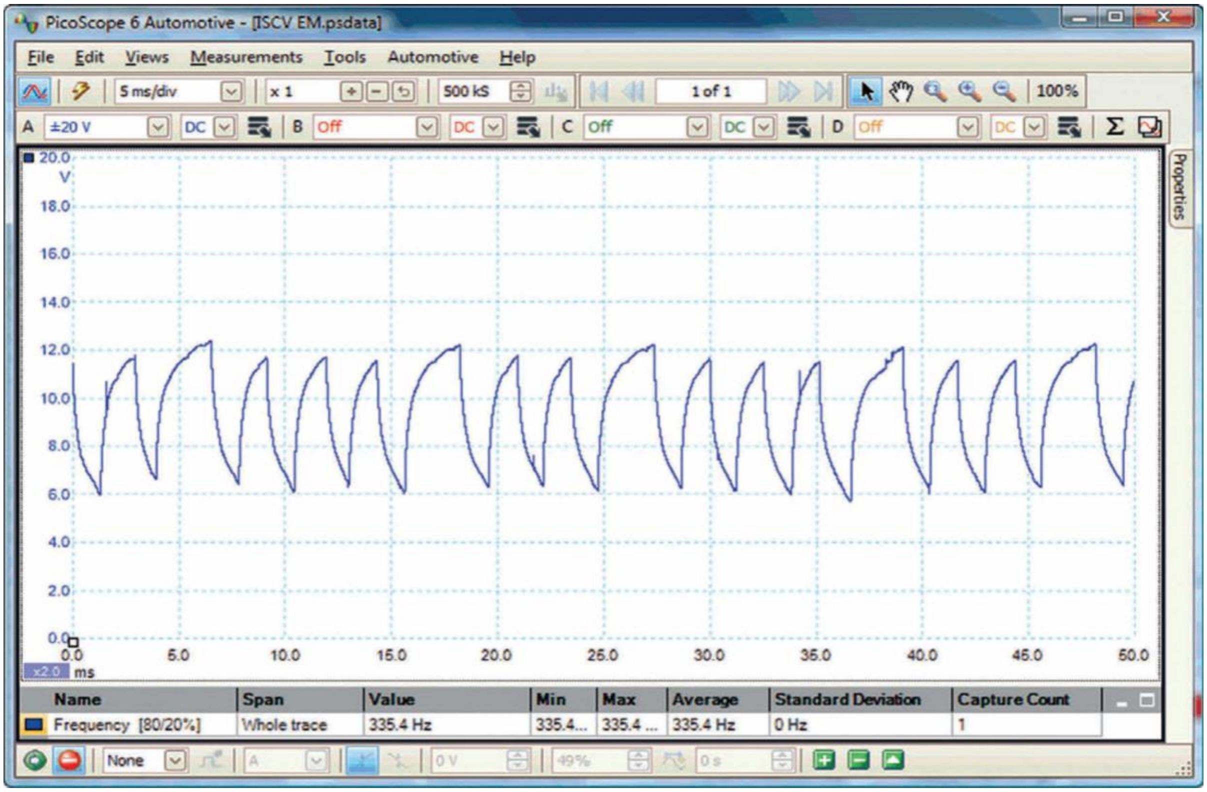


Figure 1: 121 Signal produced by an electromagnetic idle speed control valve.

4.3.5 Exhaust Gas Recirculation Valve

Various types of exhaust gas recirculation (EGR) valve are in use based on simple solenoid operation.

One development in actuator technology is the rotary electric exhaust gas recirculation (EEGR) valve for use in diesel engine applications. It has a self-cleaning action, accurate gas flow control and a fast reaction speed.

4.3.6 Carbon Canister and Other Valves

There are a number of valves used that are effectively simple solenoid controlled devices. Measuring on one terminal will usually show battery supply voltage. The other terminal will show battery voltage when switched off and zero (ground or earth) voltage when the valve is switched on.

Other Valves

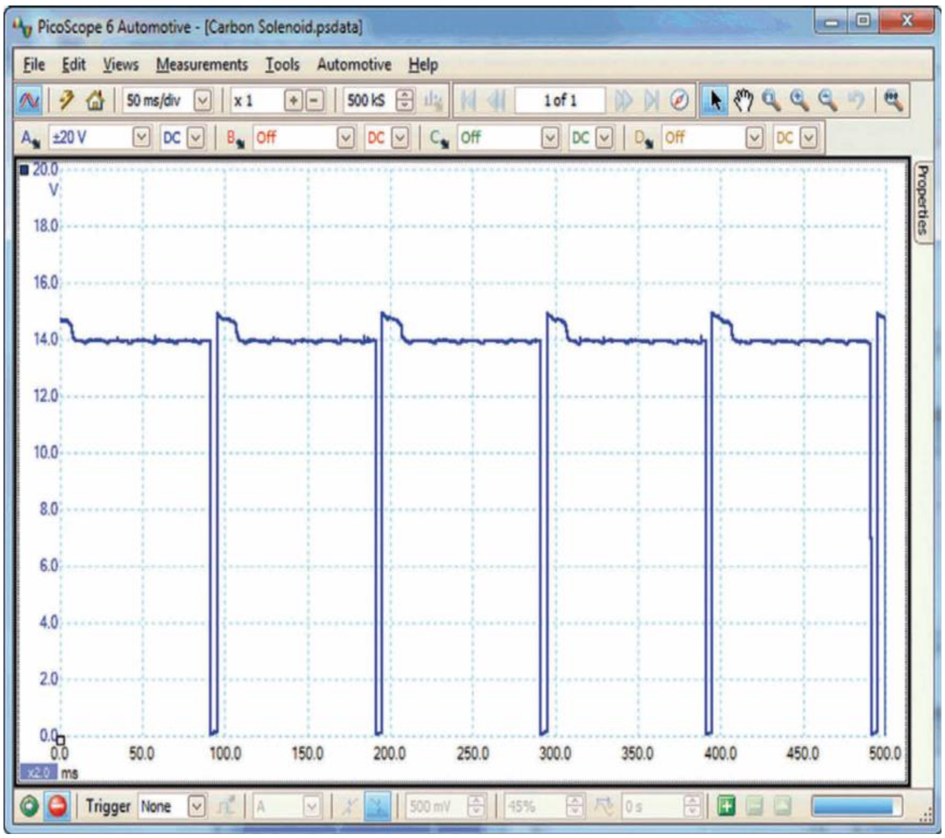
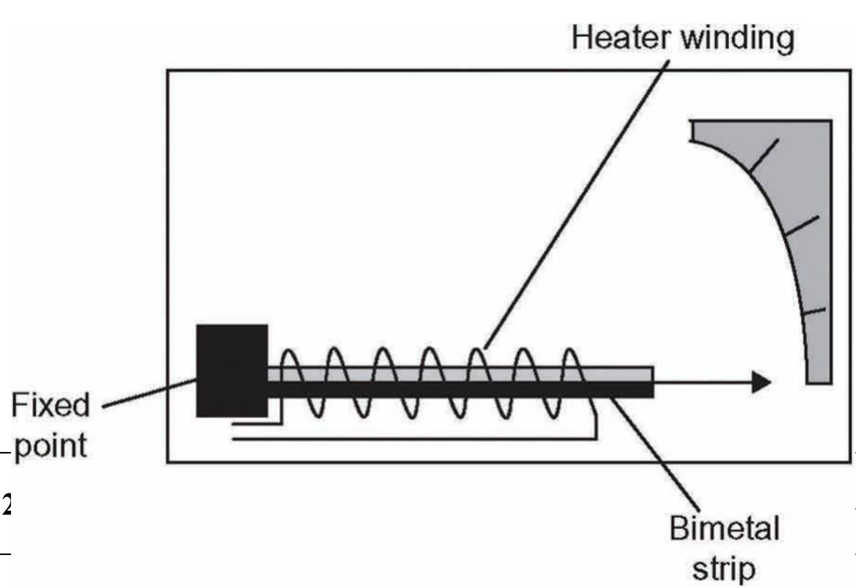


Figure 1: 124 Carbon canister control valve signal.

4.4 Thermal Actuators

An example of a thermal actuator is the movement of a traditional type fuel or temperature gauge needle. A further example is an auxiliary air device used on many earlier fuel injection systems. When current is



supplied to the terminals, a heating element operates and causes a bimetallic strip to bend, which moves the pointer. The main advantage of this type of actuator, when used as an auxiliary device, apart from its simplicity, is that if it is placed in a suitable position, its reaction time will vary with the temperature of its surroundings. This is ideal for applications such as fast idle or cold starting control where, once the engine is hot, no action is required from the actuator.

Figure 1: 125 Thermal Actuator Used as a Gauge

The Control systems are systems that are used to regulate the operation of other systems; the system being controlled is known as the system plant. It is an interconnection of elements and devices for a desired purpose.

The controlling system is called an electronic controller. It is an interconnection of components forming a system configuration that will provide a desired response. A control system is described by

- Its objectives of control
- System components, and
- Results or outputs.

Self-Check 4

Directions: Answer all the questions listed below.

Part I: Fill in the Blank Space

1. _____________are becoming increasingly popular as actuators in the motor vehicle.
2. _____________is the movement of a traditional type fuel or temperature gauge needle.
3. _____________ a voltage supply at battery voltage and a switched earth.
4. ___________ of the square wave will determine the average valve open time
5. ____________are systems that are used to regulate the operation of other systems

Part II: Say True or False the following statements.

1. Temporary magnet electric motors are used in many applications and are very versatile
2. A single injector is used in what may have the outward appearance to be a carburettor housing.
3. The length of time the injector is held open will depend on the input signals seen by the ECU from its various engine sensors.
4. A sequential simultaneous system will fire all four injectors at the same time with each cylinder receiving two injection pulses per cycle (720° crankshaft rotation).
5. A simultaneous system will receive just one injection pulse per cycle, which is timed to coincide with the opening of the inlet valve

Part III: Answer the following questions accordingly

1. What is the difference between single and multipoint injection
2. Differentiate L and D type of MFI types
3. What are the types of GDI
4. Mention about the unique feature of Steeper motor
5. Common rail diesel fuel Injector differ from other types of injectors, what is the reason behind?

LAP-Test

Practical Demonstration

Name: ___________________________ Date: _____________

Time started: _____________________ Time finished: ___________

Instruction I: Perform the following tasks

Task 1: Scenario 1

The driver claims the engine is cranking but not start. How do you diagnose according to the diagnostic process which steps do you follow?

Task 2: Scenario 2

A given engine has a sign of stalling when it is increasing RPM. Which kinds of sensors and actuators needs to diagnose?

Reference

Books

Jack Erjavec, (2010) Automotive Technology: A Systems Approach, 5th Edition

James D. Halderman, (2012) Automotive Technology Principles, Diagnosis, and Service 4th Edition

Konrad Reif, Diesel Engine Management Systems and Components

Konrad Reif, Gasoline Engine Management Systems and Components

Tim Gilles (2011) Automotive Engines: Diagnosis, Repair and Rebuilding, 6th Edition

URL

https://carbiketech.com/engine-management-system-ems/

https://secure.lambdapower.co.uk/TechNotes/Tech-1.asp#:~:text=EGO%20sensor%20%2D%20meaning%20'Exhaust%20Gas,in%20the%20exhaust%20gas%20stream

https://www.gcoeara.ac.in/learning_material/auto/Unit%205-AEE.pdf

Participants of this Training Module Preparation

No	Name	Qualification	Field of Study	Organization/ Institution	Mobile number	E-mail
1)	Amanuel Abdeta	MSc.	Automotive Technology	Ambo PTC	0911799468	Amanuelloko@gmail.com
2)	Biruk Tilahun	BSc.	Automotive Technology	General Wingate PTC	0913789176	biruktilahun1@gmail.com
3)	Fiseha Manyazewal	MSc.	Automotive Technology	Debrebirhan PTC	0910406732	Natifish76@gmail.com
4)	Sisay Legese	MSc.	Automotive Technology	Athlete Kenenisa PTC	0910407622	alemsisay647@gmail.com
5)	Tatek Mamo	PhD	Automotive Engineering	Ethiopian Defense University College of Engineering	0911841121	mimibaba928@gmail.com /