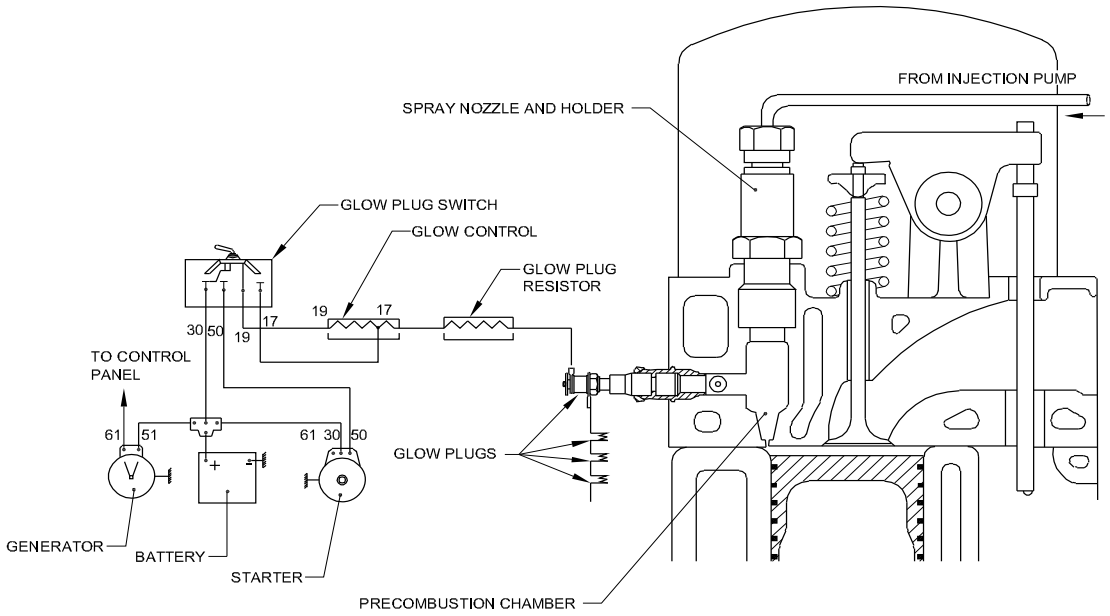
Fig 9



MVN1107649

IGNITION CIRCUIT DIAGRAM OF GLOW PLUG SYSTEM IN A DIESEL ENGINE

- The glow coil is having low electrical resistance and hence it will be very hot when connected to the circuit. Do not touch it, when it is hot.

Detroit diesel cummins diesel

Detroit diesel cummins diesel well known for favouring unit injectors, in which the high-pressure pump is contained within the injector itself. This leads to the development of the modern unit injector.

Cummins PT (pressure-time) is a form of unit injection where the fuel injectors are on a common rail feed by a low-pressure pump and the injectors are actuated by a third lobe on the camshaft. The pressure determines how much fuel the injectors get and the cam determines the time.

Design of the unit injector eliminates the need for high-pressure fuel pipes, and with that their associated failures, as well as allowing for much higher injection pressure to occur. The unit injector system allows accurate injection timing, and amount control as in the common rail system.

The unit injector fitted into the engine cylinder head, where the fuel supplied via integral ducts machined directly into the cylinder head. Each injector has its own pumping element, and in the case of electronic control, a fuel solenoid valve as well. The fuel system is divided into the low pressure <5 bar fuel supply system, and the high-pressure injection system <2000 bar.

Electronic Diesel Control (EDC) system

Objective: At the end of this lesson you shall be able to
- **state the function of electronic diesel control system.**

EDC system

Electronic diesel control (Fig 1 to 2) is a diesel engine fuel injection control system for the precise metering and delivery of fuel into the combustion chamber of modern diesel engines used in trucks and cars.

The electronic control, the system which provides greater ability for precise measuring, data processing environment flexibility and analysis to ensure efficient diesel engine operation.

- It receives the information from sensor, analyze/ calculate it and sends the instructions to the acturators.
- It converts information from analog to digital.
- It consists of microprocessors to process the information from sensor to ECM and ECM to actuators.
- Number of microprocessors are depends upon the number of sensors and actuators.

Fig 1

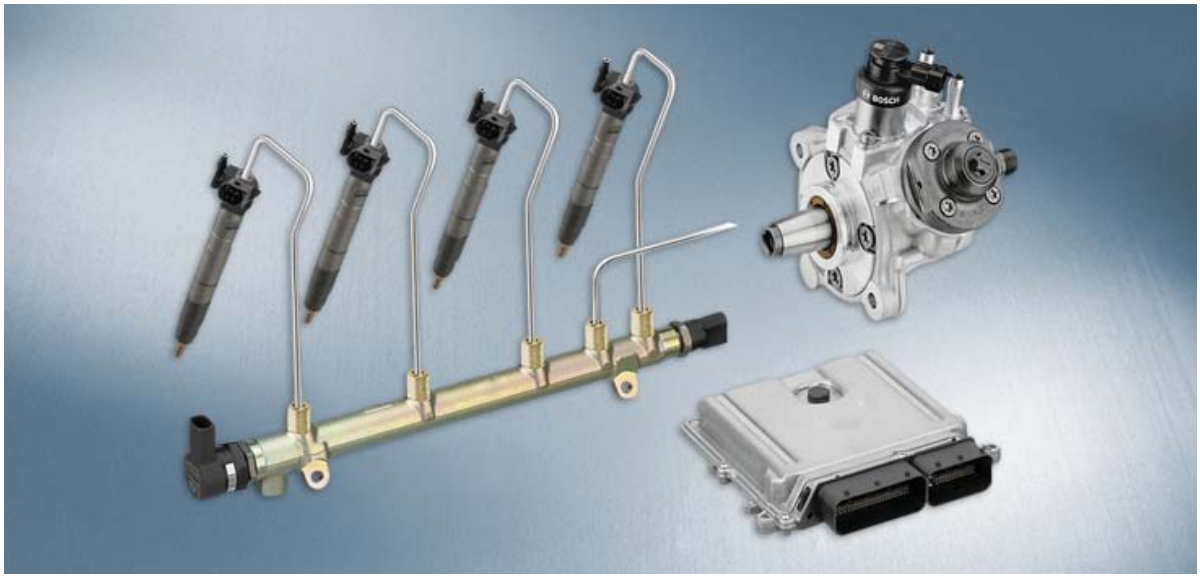
MDN2511411

ELECTRONIC DIESEL CONTROL DEVICE

- It also consists of memory to store the data.
- Speed is in the form of 8 Bit, 16 Bit, 32 Bit, 64 Bit etc., to pass the information from sensor to ECM, ECM to actuator and also in networking system.
- Individual programmes have to be made for each sensor and actuator.

Move the below figure under the common rail direct injection system (Fig.2)

Fig 2



COMMON RAIL WITH FUEL INJECTORS

MDN2511412

Main control systems in diesel engine

- It controls the fuel for idling.
- It controls the fuel for high speed.
- It controls the fuel according to the speed and load conditions.
- It controls the exhaust gas recirculation (EGR) valve.

Working

It gets the input from the different sensors named are as follows.

1 Throttle position **TP** (intake air quantity)
2 Cam position **CMP** (for valve timing)
3 Crank positon **CKP** (for RPM and firing order)
4 Engine coolant temperature **ECT** (Cylinder temperature)
5 Inlet air temperature **IAT** (temperature of inlet air)
6 Manifold absolute pressure **MAP** (inlet air pressure)
7 Oxygen $\mathbf{O_2}$ (percentage of oxygen in exhaust gas)

After receiving the above inputs, it analyzes/calculates the amount of fuel is required for the cylinder, accordingly it supplies the voltage to the injector solenoid. The solenoid will open the injector to supply the fuel into the combustion chamber. The minimum injector opening period is $1/10^{th}$ second.

Minimum 3 important sensors (TP, CKP & CMP) inputs are required at the time of starting, if any one of the sensor fails, engine does not start.

Rest of the sensors (IAT, ECT, MAP, and O2) fails; engine will start but the performance of the engine will affect.

- **In a vehicle minimum one EDC/ECM is required**
- **More than one EDC/ECM are used depends on number of controls.**

Example of control units EDC/ECM in a vehicle

1 Engine management
2 Automatic transmission
3 Power steering
4 SRS (Air Bag) supplemental restraint system
5 ABS (Antilock braking system)

Exhaust gas recirculation (EGR) EGR valve allows the exhaust gases into the inlet manifold, to burn the unburn gases to reduce the emission.

The opening angle of the valve is controlled by the EDC, depending upon the amount - (%) of oxygen passing through exhaust gases.

EDC gets the percentage of oxygen from the oxygen sensor.

Sensor

It senses the information in the form of physical or chemical variables and sends that information to the ECM in the form of voltage i.e. between 0-6 volts or 0-12 volts.

Ex: Throttle valve opening position (angle) information sends to the ECM in the form of voltage.

ECM

It analyzes or calculates the information which have come from the sensors and gives the instruction to the actuators.

Schematic layout system components

Input from senders & switches
Engine speed sender CKP
Hall sender CMP
Accelerator pedal position APP
Air mass meter HFM
Intake air temperature IAT
Coolant temperature ECT
Radiator outlet coolant temperature
Charge pressure sender G31
Fuel temperature sender
Fuel pressure sender
Exhaust gas recirculation potentiometer
Lambda probe
Exhaust pressure sender
Cutch position
Throttle valve potentiometer
Brake light switch

→ **ECU** →

Output from ECU
Fuel pump relay
Fuel pump for pre-supply
Injection valves
Valve for fuel dosage
Fuel pressure regulating valve
Solenoid valve for charge pressure control
Intake manifold flap motor
Throttle valve module
Exhaust gas recirculation valve
Radiator Fan
Automatic glow period control unit
Lambda probe heater

Ex: It supplies the current to the solenoid to open the injector opening duration depends on Inputs

Actuators

Based on instructions from the ECM, it does the mechanical work.

Ex: Injector open duration depends on ECM instruction.

(ECM) Electronic Control Module (or) system

Objectives: At the end of this lesson you shall be able to
- **describe E.C.M Electronic control module (or) system**
- **state the various control system**
- **explain the fuel injection control system**
- **explain the fuel pump control system**
- **explain the injection control system**
- **explain the radiator fan control system.**

Electronic control system

The electronic control system consist of various sensors which detect the state of engine and driving conditions, ECM which controls various devices according to the signals from the sensors and Various controlled devices.

The control systems are as follows

- Fuel injection control system
- Idle speed control system
- Fuel pump control system
- Radiator fan control system

Idle speed control system

This system controls the bypass airflow by means of ECM & IAC valve for the following purposes. To keep the engine idle speed as specified at all times. The engine idle speed can vary due to load applied to engine, to improve starting performance of the engine to compensate air fuel mixture ratio when -decelerating, to improve drivability while engine is warmed up. IAC valve operates according to duty signal sent from ECM. ECM detects the engine condition by using the signals from various signals and switches and controls the bypass airflow by changing IAC valve opening. When the vehicle is at a stop, the throttle valve is at the idle position and the engine is running, the engine speed is kept at a specified idle speed.

Fuel pump control system

ECM controls ON/OFF operation of the fuel pump by turn-

ing it ON, the fuel pump relay under any of the conditions. For two seconds after ignition switch ON. While cranking engine (while engine start signal is inputted to ECM). While crankshaft position sensor or camshaft - position sensor signal is inputted to ECM.

Common Rail Diesel Injection (CRDI)

Objectives: At the end of this lesson you shall be able to

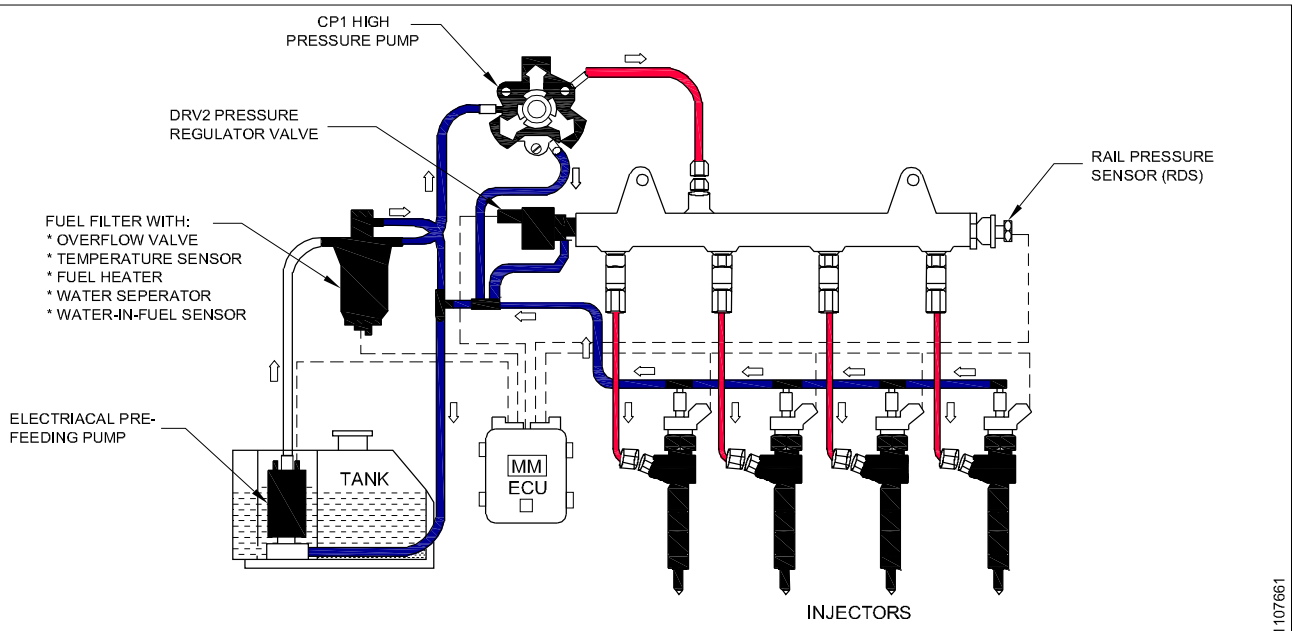
- **describe the construction of CRDI**
- **explain the working of the CRDI**
- **list out the merits and demerits of the CRDI.**

Construction and working of CRDI system (Figs 1&2)

The common rail fuel system consists of fuel tanks fuel pump, common rail, pressure regulator, injectors and sensors. The electrical fuel pump (low pressure) in placed inside the fuel tank, It develops pressure upto 6 bar and supplies to the high pressure fuel pump (CRDI) through fuel filter and water separator. The high pressure fuel pump develops pressure 200 to 2000 bar and supplies to the common rail and common rail to fuel injectors inject fuel into the combustion chamber. Fuel injector are operator by ECM through solenoid valve. Common rail consists of fuel pressure regulator rail pressure sensor and fuel pressure regulator supplies the excess amount of fuel to the fuel tank (≤ 1 bar pressure). The common rail pressure sensor send information to ECM/EDC, the existing pressure in the common rail will control the RPM of the fuel pump. Common rail will distribute the fuel to all the cylinder with equal pressure, then all cylinders will develop uniform power, which will reduce vibration and noise of the engine.

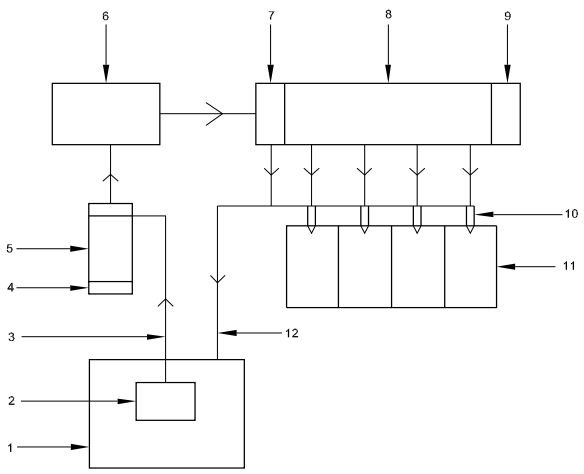
Diesel Direct injection system (Fig.1)

Fig 1



DIESEL DIRECT INJECTION SUSTEM (DDIS) -- FUEL SYSTEM LAYOUT

Fig 2



1. FUEL TANK
2. ELECTRICAL FUEL PUMP
3. FUEL SUPPLY LINE
4. WATER SEPARATOR
5. FUEL FILTER
6. HIGH PRESSURE FUEL PUMP (CRDI PUMP)
7. FUEL PRESSURE REGULATOR
8. COMMON RAIL
9. FUEL RAIL PRESSURE SENSOR
10. FUEL INJECTOR
11. ENGINE
12. FUEL RETURN LINE

COMMON RAIL DIRECT INJECTION SYSTEM (CRDI) FUEL SUPPLY SYSTEM

HEUI Hydraulically actuated electronically controlled unit injector

Objectives: At the end of this lesson you shall be able to
- **describe the HEUI (Hydraulically Actuated Electronically Controlled Unit Injector)**
- **explain basic components**
- **explain the working principle of HEUI**
- **advantages of HEUI.**

HEUI (Hydraulically Actuated Electronically Controlled Unit Injector) (Fig.1)

HEUI Fuel System represents one of the most significant innovations in diesel engine technology in the diesel technology. HEUI made easy of many limitations of mechanical and conventional electronic injectors, and sets new standards for fuel efficiency, reliability and emission control. The highly sophisticated HUEI system uses hydraulic energy instead of mechanical energy to operate fuel injectors. Working along with the engine's ECM (Electronic Control Module), the HEUI system provides extremely accurate control of fuel metering and timing, so that it ensures unmatched engine performance and economy.

Unmatched engine performance and economy.

In the traditional common rail fuel system, the entire fuel line is under high pressure. With the HEUI system, fuel remains at low pressure until it is injected into the cylinder. Fuel pressure is created hydraulically in response to a signal from the Electronic Control Module (ECM).

The HEUI fuel system consists of four basic components:

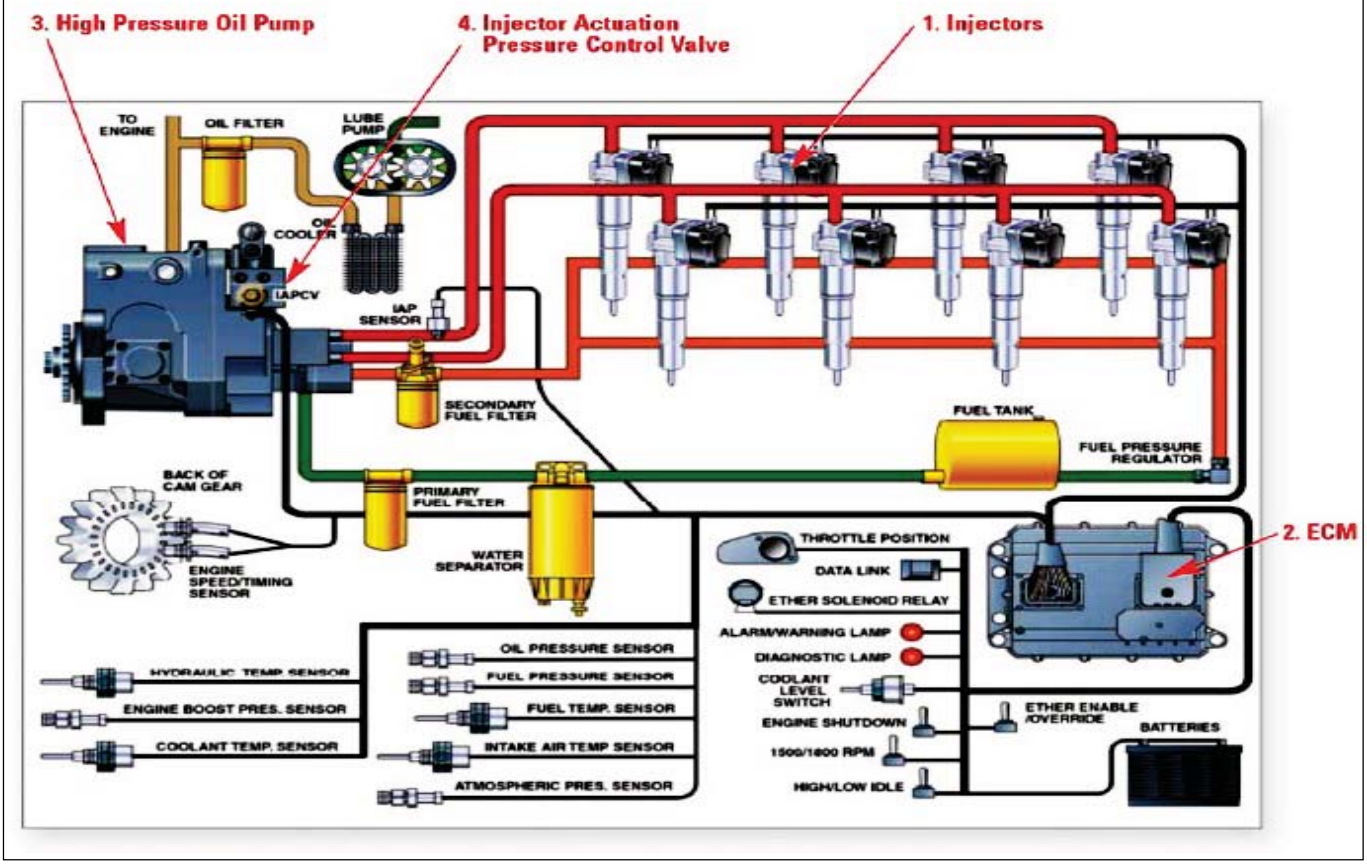
HEUI (Fig 1) Injector Uses hydraulic energy (as opposed to mechanical energy from the engine camshaft) from pressurized engine lube oil for injection. The pressure of the incoming oil (800 to 3300 psi) controls the rate of injection, while the amount of fuel injected is determined by the ECM.

Electronic Control Module (ECM) This sophisticated on-board computer precisely manages fuel injection and other engine systems. The HEUI injector solenoid is energized by an electronic signal generated in the ECM. Using input from multiple sensors, the ECM's dual microprocessors use proprietary software and customer supplied performance parameters to produce maximum engine performance under any conditions.

High Pressure Oil Pump The variable displacement axial pump features a built-in reservoir to immediately supply oil at cold starts.

Injector Actuation Pressure Control Valve This electronically operated valve controls oil pump output and injection pressure.

Fig 1



Working principle

HEUI is divided in two sections. One is low pressure fuel chamber. Another one is high pressure oil chamber, fuel is supplied at low pressure and oil is supplied at high pressure to the respective chamber.

At the time of injections allows the high pressure oil in to the injection body and actuates the intensifier. The intensifier in turn pressurizes the diesel on the other side of it. So that the intensifier pressurizes seven times of the oil pressure and increases the pressure of the diesel. After then the injector lifts the spindle and injects the diesel through the holes of an injector.

Improved fuel economy The ability to inject fuel at any crank angle results in up to 2.7 percent better fuel economy compared to scroll mechanical injectors. Optimum fuel economy also means reduced gaseous emissions and less white smoke during cold engine starts.

Optimum performance The control of fuel delivered during ignition delay and main injection, known as rate shaping, is made possible by the HEUI's ability to operate independent of engine speed. Rate shaping modifies engine heat release characteristics, which also helps reduce emission and noise levels. Rate shaping optimizes engine performance by varying the idle and light load rate characteristics independent of rated and high load conditions.

Reduced smoke and particulate emissions

Since the HEUI injector's performance does not depend on engine speed, it can maintain high injection pressures through a wide operating range. Electronic control of these pressures helps improve emissions and low-speed engine response.

Reduced engine noise A split injection feature leads to a more controlled fuel burn and lower noise levels. Additional benefits include reduced shock loads as well as less wear and tear on drive train components.

Sensors

Types of sensors

1 Engine coolant temperature (ECT)

2 Manifold absolute pressure (MAP)

3 Inlet air temperature (IAT)

4 Oxygen (O_2)

5 Throttle position sensor (TP)

6 Cam position (CMP)

7 Crank position (CKP)

8 Anti-lock braking system (ABS)

The above sensors are being used for the engine management system.

Recently one more sensor is added i.e ABS

Apart from the above so many other sensors are using in the vehicle. In modern vehicles 10 to 100 plus sensors are using.

Classification & working principle of sensors

Switches

Resistive sensor

Current generating sensor

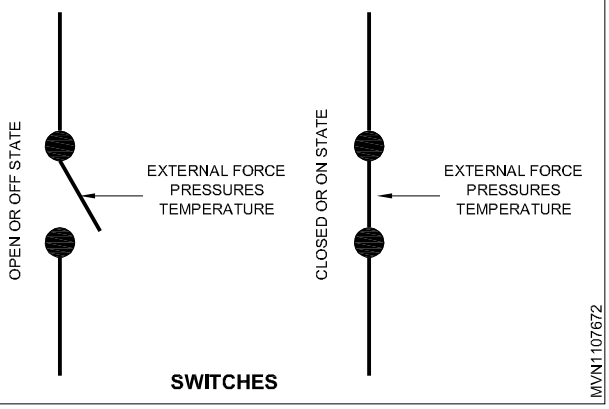
Hall effect sensor

Hot film air mass meter

Lambda sensor

Switches (Fig 2)

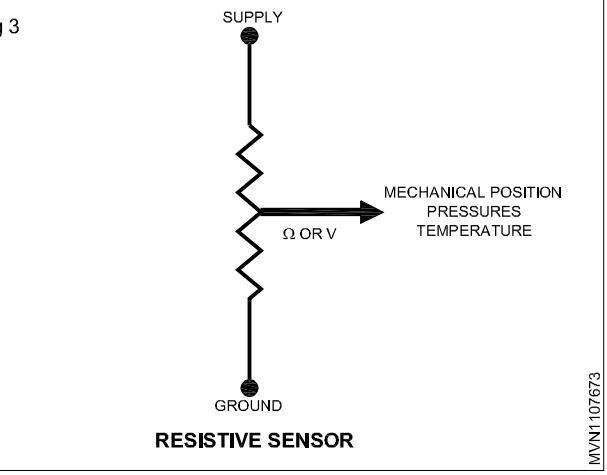
Fig 2



Switches are basically on-off sensors & the input given to ECU is normally in two states i.e either “ON” or “OFF” physical position of the switch can be change by operating condition like temperature, pressure, external force etc.

Resistive sensor (Fig 3)

Fig 3



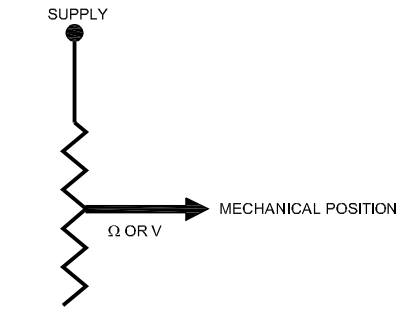
In resistive sensor the variation is resistance happens due to change in input data like position, temperature pressure etc. Input to the control unit is not necessarily the resistance but can be the voltage also.

Types of resistive sensor

1 Rheostat (Fig 4)

Generally 2 wire sensor. Change is resistance happen due to change in mechanical position. Value of resistance or voltage is interpreted by ECU for calculation. Measurement of value happen inside the control unit.

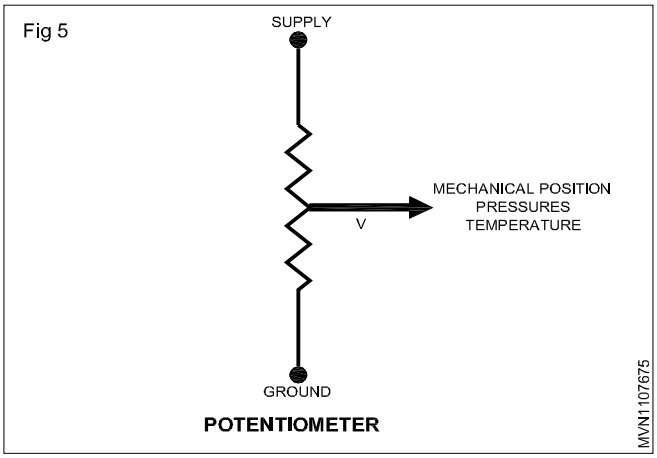
Fig 4



2 Potentiometer (Fig 5)

Generally 3 wire sensor. Change is resistance happen due to change in mechanical position. Value of voltage is interpreted by ECU for calculation. Measurement of value happen outside the control unit.

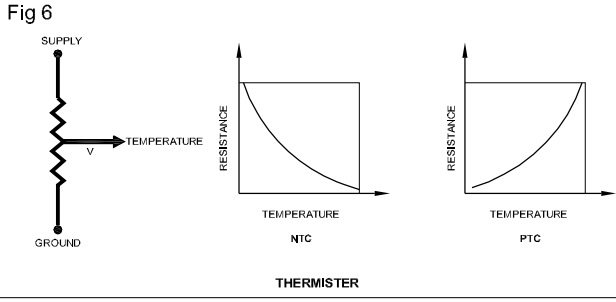
Fig 5



3 Thermistor (Fig 6)

Thermistor are those sensors whose resistance value changes due to change in temperature. Thermistor are supplied with constant voltage. Out put voltage changes due to change in resistance which is continuously monitor by control unit to decide the temperature value. Thermistor can have either negative temperature co efficient [NTC] or positive temperature co efficient [PTC].

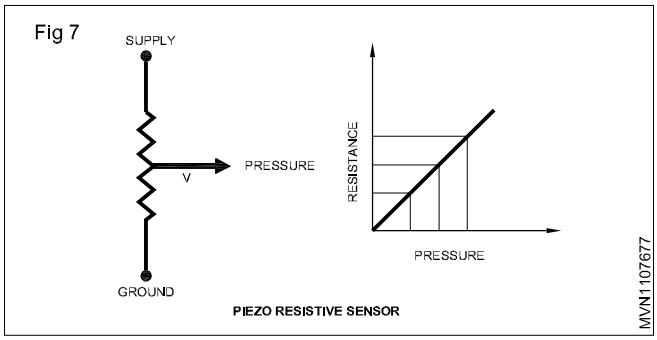
Fig 6



4 Piezo resistive sensor (Fig 7)

Piezo resistive sensors are those whose resistance changes die to change in pressure. They are subjected to external pressure which causes change in resistance. Constant voltage is supplied & out put voltage changes due to change in pressure which is interpreted by control unit to decide the pressure value.

Fig 7



5 Current generating sensor

Certain sensors generate the voltage when subjected to change is physical phenomenon such as pressure, position etc. They are mainly classified as follows.

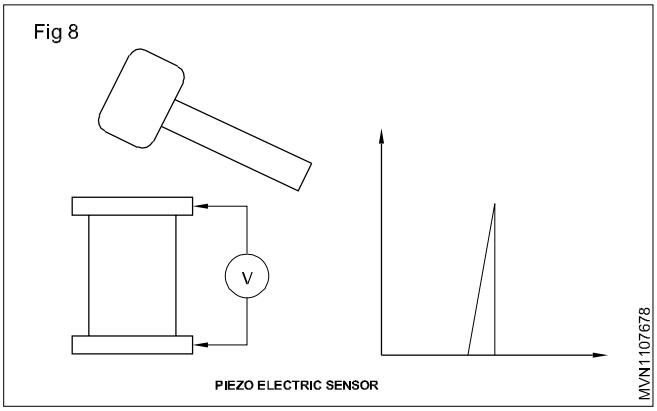
1 Piezo electric sensor

2 Magnetic induction sensor

6 Piezo electric sensor (Fig 8)

Certain crystal such as quartz when subjected to a pressure generate potential difference on its surface. The phenomenon is reversible.

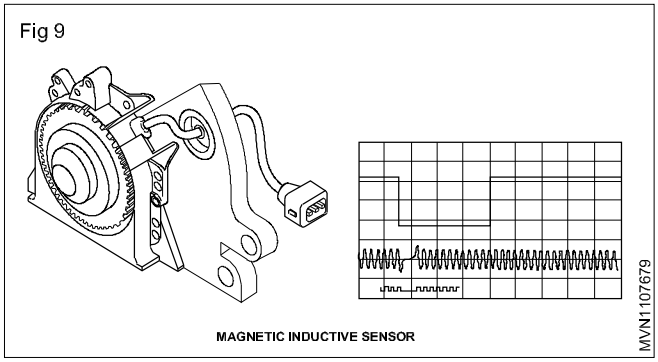
Fig 8



7 Magnetic inductive sensor (Fig 9)

This kind of sensor are consist of coil whould around the permanent magnet. When the magnetic filed is disturb by external means current is generated inside the coil terminals. The pattern of current obtained is depends on the kind of disturbance produce.

Fig 9

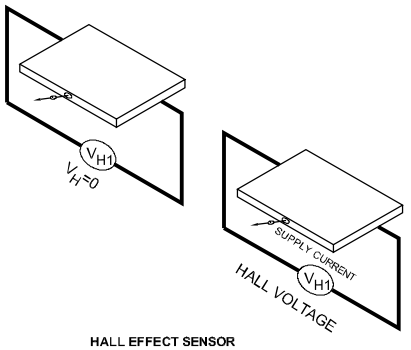


8 Hall effect sensor (Fig 10)

When a current passes through the semiconductor plate there is no current develop at right angles to the direction of current. However when this plate is subjected to a magnetic filed, voltage is developed at right angles to the

direction of current. The magnitude of this voltage is proportionate to the magnetic field through the semiconductor.

Fig 10



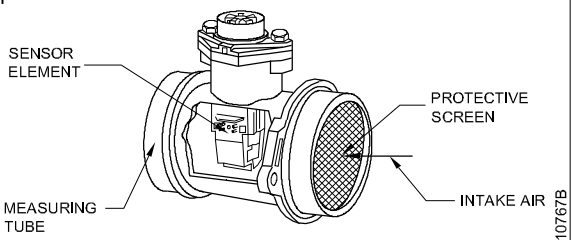
HALL EFFECT SENSOR

MVN110767A

9 Hot film air mass meter (Fig 11)

This sensor is used to measure the air flow in engine management system. It consist of measuring tube & sensor electronic with sensor element. The sensor element consist of heating resistors, two thermistor R1 & R2, & intake air temperature sensor.

Fig 11



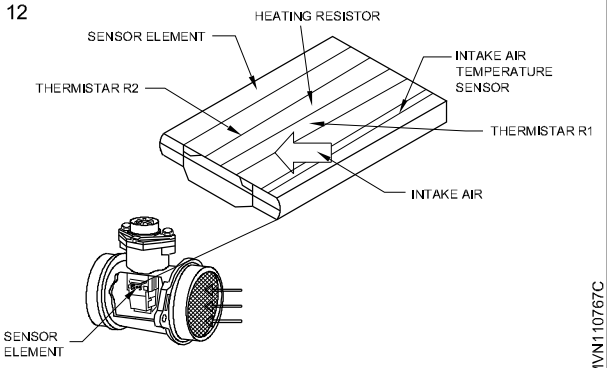
HOT FILM AIR MASS METER

MVN110767B

10 Sensors & actuators (Fig 12)

Sensors element is heated at constant temperature appr. 120°C above intake air temperature. Due to air flow there is a temperature difference at R1 & R2. This difference is recognized by electronic module & the intake air mass is calculated. This also decide the direction of air flow.

Fig 12

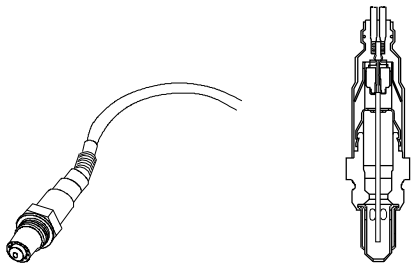


MVN110767C

11 Lambda (oxygen) sensor (Fig 13)

This sensor is normally used in petrol engine to decide the oxygen content in exhaust gas. Based on the input from this sensor the ECU do minor correction to the amount of fuel being metered.

Fig 13

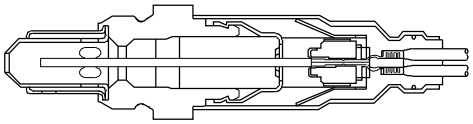


LAMBDA (OXYGEN) SENSOR

MVN110767D

12 Lambda (oxygen) sensor (Fig 14)

Fig 14



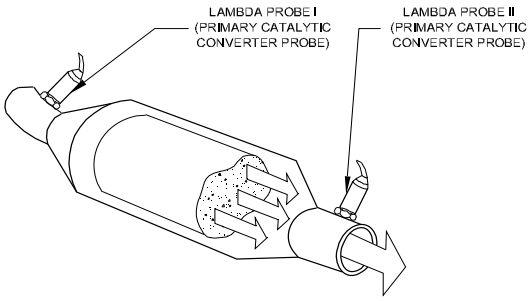
LAMBDA (OXYGEN) SENSOR

MVN110767E

The difference in oxygen content between the exhaust gas & ambient air causes a change in the electrical voltage within the probe. A change in the composition of the air fuel mixture produces a sudden voltage change by which $\lambda = 1$ can be identified.

13 Sensors & actuators (Fig 15)

Fig 15



MVN110767F

In connection with OBD II, second lambda sensor is connected after catalytic converter. It test correct functioning of the catalytic converter.

Actuators

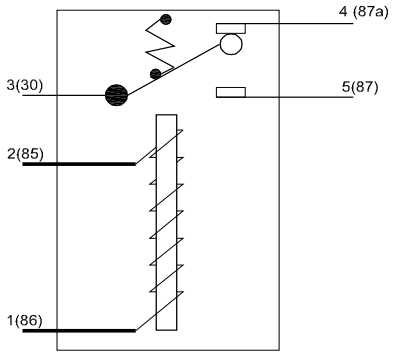
1 Injectors
2 Power windows
3 Wiper motors
4 Relays etc

Number of actuators depends upon the devices to be operated.

14 Relay (Fig 16)

A relay is an electrically operated switch. many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used.

Fig 16

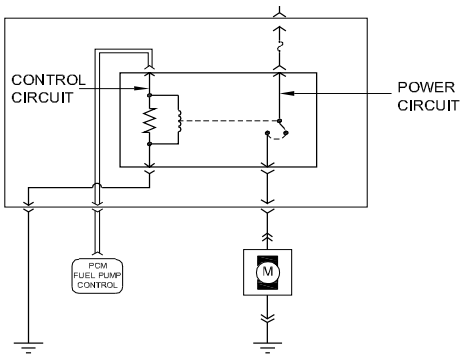


RELAY

Relays are used where it is necessary to control a circuit by a low-power signal (with compete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.

1 **Control circuit:** Control the operation which are activated by control unit or switch. It required very less power to activate. (Fig 17)

Fig 17

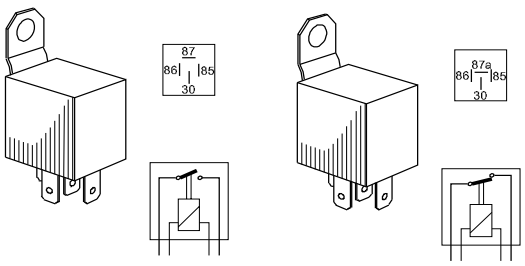


2 **Power circuit:** Connected to the load. Main current flows through this circuit. (Fig 17)

1 **Normally open relay [NO]: (Fig 18)** Power circuit is in open position. Circuit closes when control circuit is activated.

2 **Normally close relay [NC]: (Fig 18)** Power circuit is in close position. Circuit opens when control circuit is activated.

Fig 18



NORMALLY OPEN RELAY **NORMALLY CLOSE RELAY**

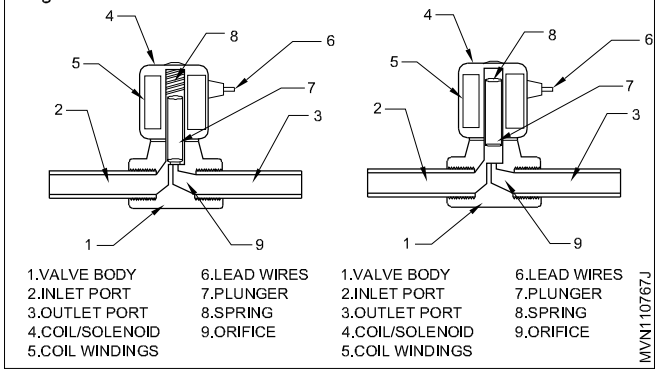
Working principles of acturators

DC Motors

Solenoid (Fig 19)

A solenoid is an electromechanical switch/ valve that is controlled by an electric current. The electric current runs through a solenoid, which is a wire coil wrapped around a metallic core. A solenoid creates a controlled magnetic field when an electrical current is passed through it. This magnetic field affects the state of the solenoid valve, causing the valve to open or close.

Fig 19



Stepper motor (Fig 20)

Stepper motors provide a means for precise positioning and speed control without the use of feedback sensors. The basic operation of a stepper motor allows the shaft to move a precise number of degrees each time a pulse of electricity is sent to the motor. Since the shaft of the motor moves only the number of degrees that it was designed for when each pulse is delivered, you can control the pulses that are sent and control the positioning and speed. The rotor of the motor produces torque from the interaction between the magnetic field in the stator and rotor. The strength of the magnetic fields is proportional to the amount of current send to the stator and the number of turns in the windings.

Fig 20