Unit -V
Engine Management System (EMS)

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❖ **Syllabus:**

- Layout and working (open loop and closed loop control), SI Engine Management System: group and sequential injection techniques(TBI, PFI, MPFI),fuel system components, cold and warm start system, idle speed control, acceleration / deceleration and full load enrichment and fuel cut-off and spark timing control. Diesel Engine (CI) Management System: Fuel quantity (Spill control), Injection timing control, Idle speed control, CRDI, fuel control MAPs.

❖ Engine Mapping:

- The development of any control system comes from knowledge of the plant, or system to be controlled.
- In the case of the automobile engine, this knowledge of the plant (the engine) comes primarily from a process called ***engine mapping***.
- For engine mapping, the engine is connected to a **dynamometer** and **operated throughout its entire speed and load range**.
- Measurements are made of the **important engine variables** while quantities, such as the air/fuel ratio and the spark control, are varied in a known and systematic manner.

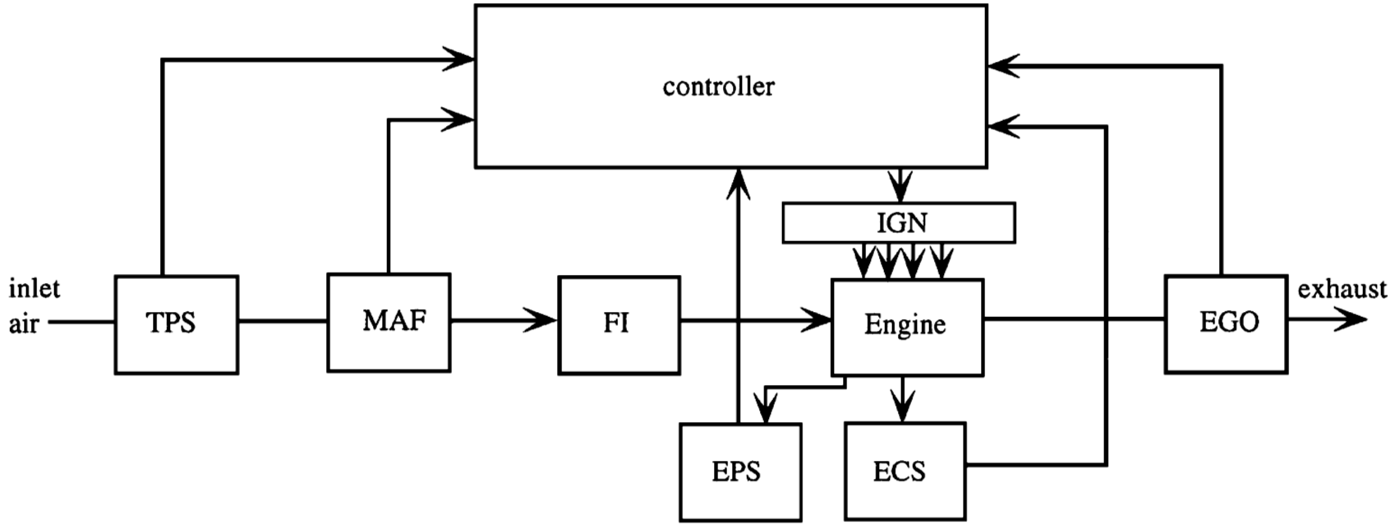
- Such engine mapping is done in engine test cells that have engine dynamometers and complex instrumentation that collects data under computer control.
- From this mapping, a mathematical model is developed that explains the influence of every **measurable variable and parameter** on engine performance.
- The control system designer must select a control configuration, control variables, and control strategy that will satisfy all performance requirements (including stability) as computed from this model and that are within the other design limits such as cost, quality, and reliability.

❖ ELECTRONIC FUEL CONTROL SYSTEM

- For an understanding of the configuration of an electronic fuel control system, refer to the block diagram of Figure below.
- The primary function of this fuel control system is to accurately determine the mass air flow rate into the engine.
- Then the control system precisely regulates fuel delivery such that the ratio of the mass of air to the mass of fuel in each cylinder is as close as possible to stoichiometry (i.e., 14.7).
- The components of this block diagram are as follows:

1. Throttle position sensor (TPS)
2. Mass air flow sensor (MAF)
3. Fuel injectors (FI)
4. Ignition systems (IGN)
5. Exhaust gas oxygen sensor (EGO)
6. Engine coolant sensor (ECS)
7. Engine position sensor (EPS)

- The EPS has the capability of measuring crankshaft angular speed (RPM) as well as crankshaft angular position when it is used in conjunction with a stable and precise electronic clock (in the controller).
- The signals from the various sensors enable the controller to determine the correct fuel flow in relation to the air flow to obtain the stoichiometric mixture. From this calculation the correct fuel delivery is regulated via fuel injectors.
- In addition, optimum ignition timing is determined and appropriate timing pulses are sent to the ignition control module (IGN).



❖ 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.
- 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).

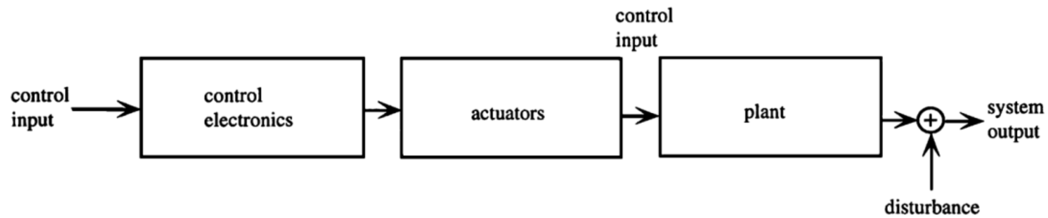
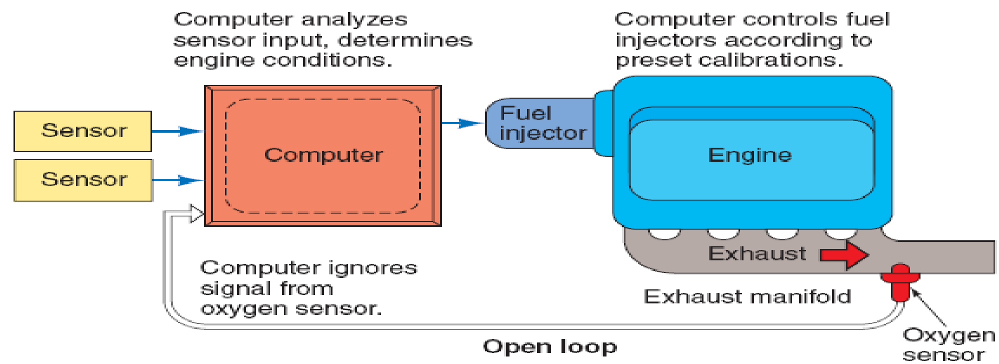


Figure. A



- 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.

❖ 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.

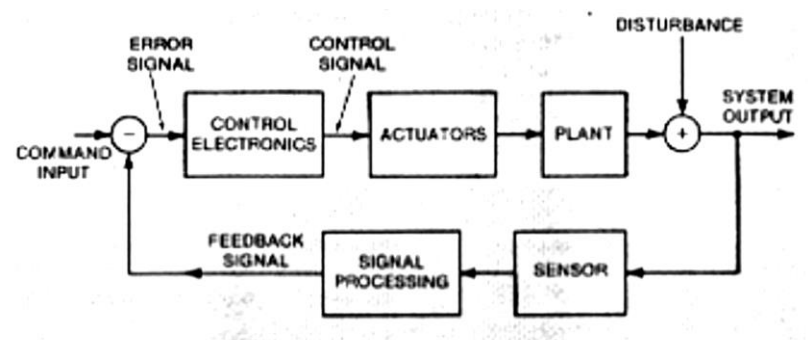
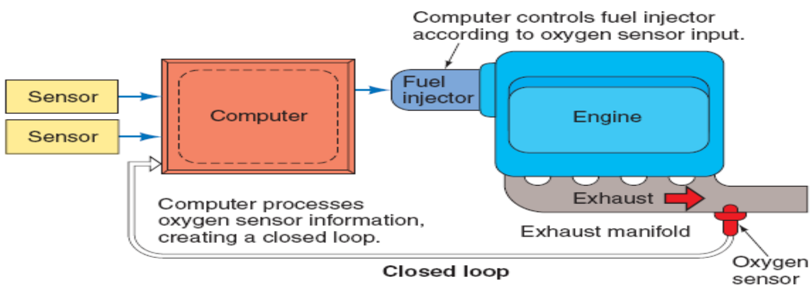


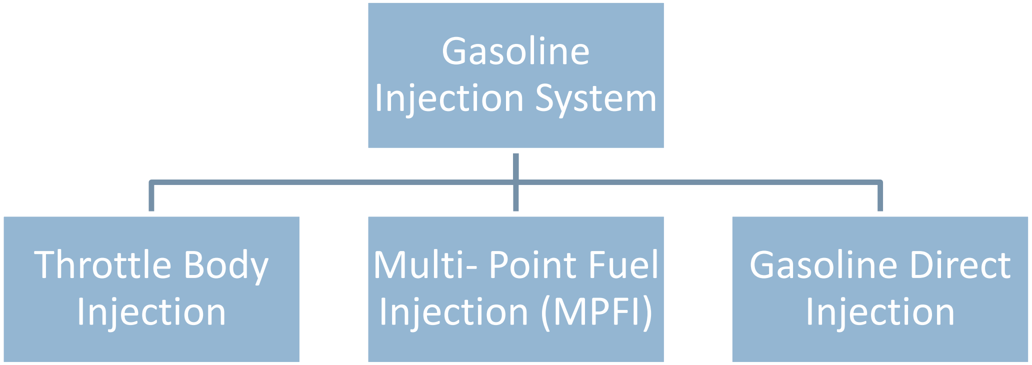
Fig. B



- 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.
- 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.

❖ SI Engine Management System:

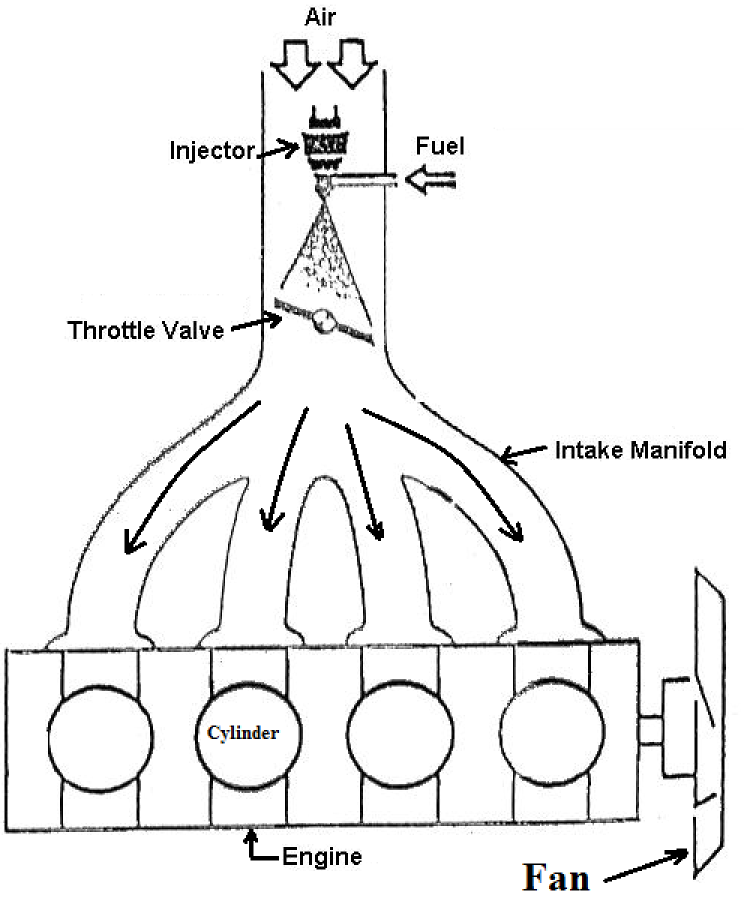
- The types of gasoline injection systems are mentioned below in Fig



❖ Throttle Body Injection

- The throttle body injection is also known as single point injection. The Fig. below shows the simplified sketch of throttle body injection. This system can be used in single cylinder engines and multi-cylinder engines.
- This injection system was firstly introduced for aircraft engines (in 1940). Later in 1980, the TBI system was employed in automotive 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.

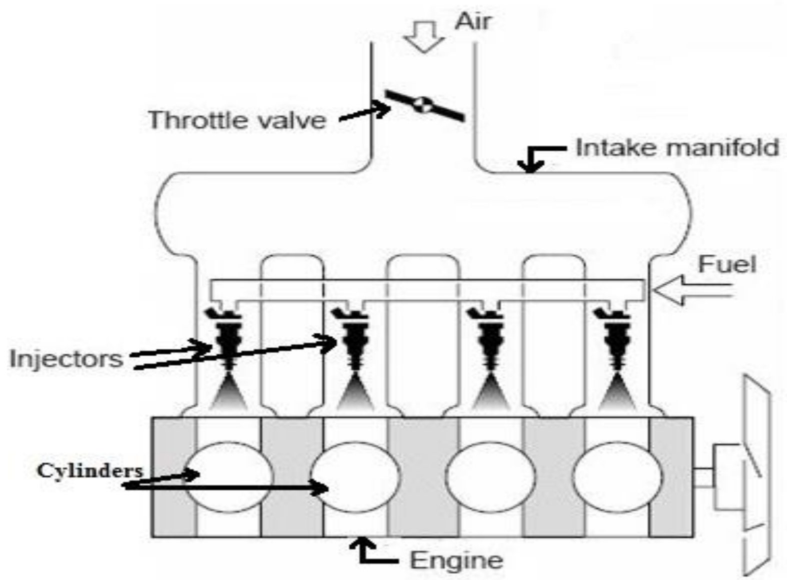
- As mentioned earlier, TBI is a single point fuel injection, but in case of V-engines (having 8 to 16 cylinders), two such TBI systems would be used because V-engines have two intake manifolds.
- There are two injection strategies viz., Continuous injection and Timed or Sequential Injection. These are discussed in later sections.
- The Mono-Jetronic is trade name of Robert Bosch Gmbh. Germany. It is an example of single point throttle body injection (TBI) system.



❖ 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.
- 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.

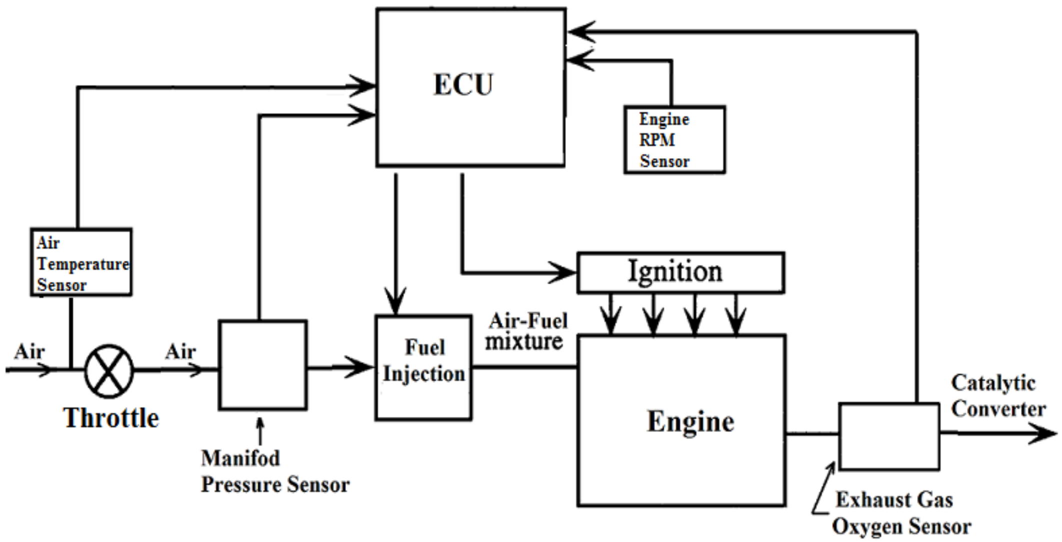
- The heat conducted from the engine cylinder assists the fuel evaporation, which improves the homogeneity of the mixture.
- There are two types of MPFI systems, these are listed below.
  - **D- MPFI**
  - **L- MPFI**
- The Robert Bosch Gmbh, Germany has developed many MPFI systems, they are known by the trade name Jetronic like L-Jetronic, K-Jetronic, KE-Jetronic etc.



❖ 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.

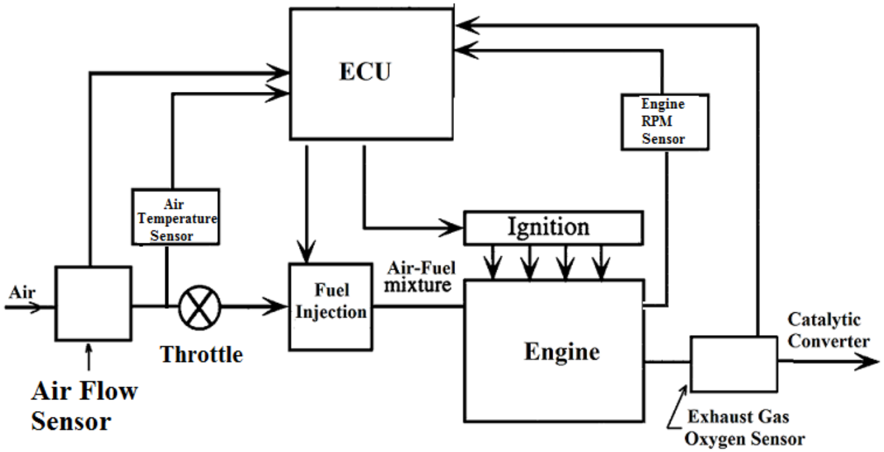
- The exhaust gas oxygen (EGO) sensor detects the amount of oxygen retained in exhaust gas. This is because the 3 way catalytic converter gives better conversion efficiency at stoichiometric air-fuel ratio



❖ 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.
- This system is also known as L-Jetronic (Robert Bosch Corporation, Germany)

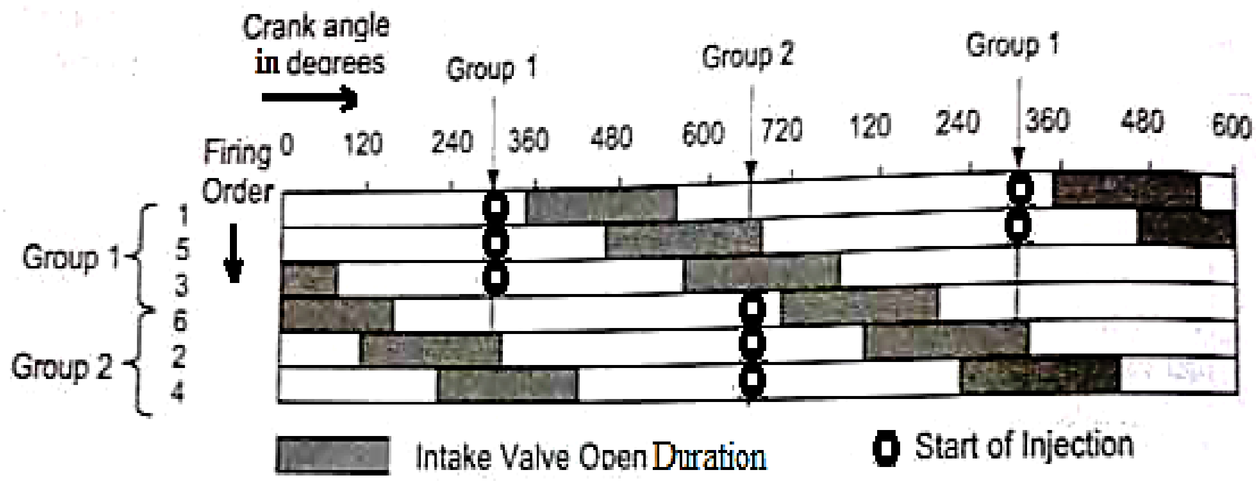
- The modern automotive engine is also equipped with sensors like, coolant temperature sensor, Throttle position sensor, manifold absolute pressure sensor, crankshaft position sensor, camshaft position sensor etc.
- These sensor helps for close control of engine which in turn gives good performance, 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 equipments for servicing them.



❖ Injection Strategy (or Techniques)

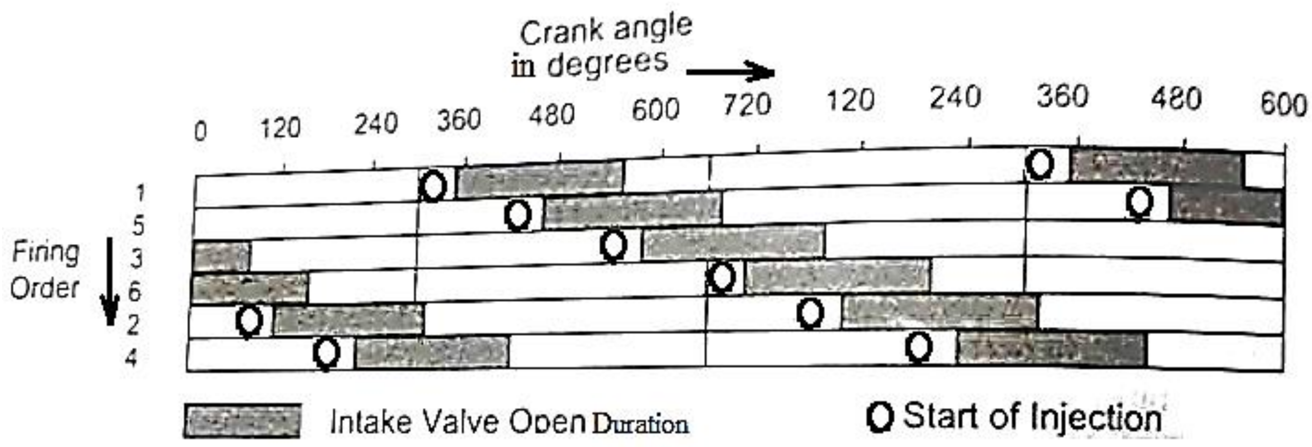
1. Continuous or Grouped Injection

- 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.
- In multicylinder engine, the injection may be grouped depending on the number of cylinders as shown in Fig.below.

- As shown in 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.
- Most of Jetronic Systems (Robert Bosch Gmbh, Germany) use continuous injection strategy.
- 

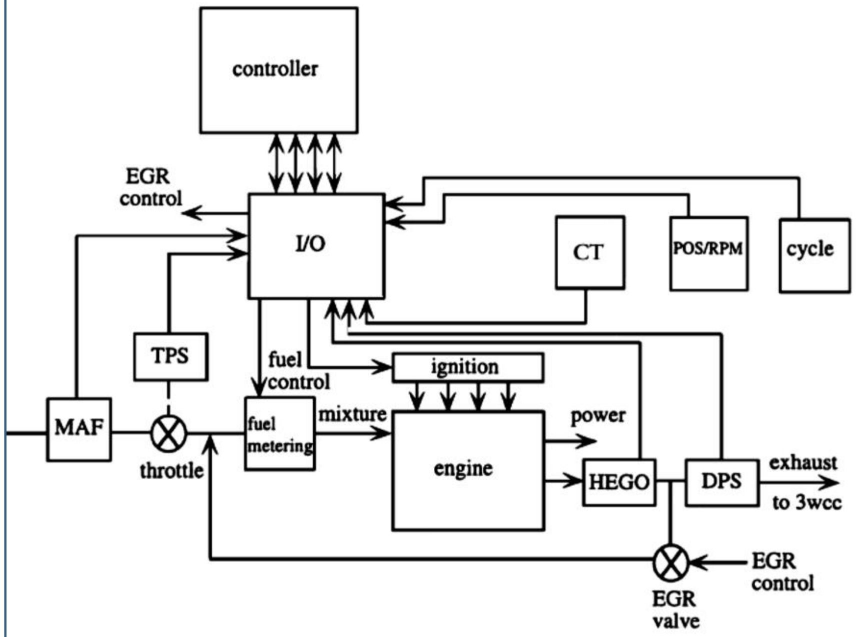
2. **Timed or Sequential Injection**

- 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.



❖ 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: **engine crank, engine warm-up, open-loop control, closed-loop control, hard acceleration, deceleration, and idle**.
- The program for mode control logic determines the engine operating mode from sensor data and timers.
- In the earliest versions of electronic fuel control systems, the fuel metering actuator typically consisted of one or two fuel injectors mounted near the throttle plate so as to deliver fuel into the throttle body.
- These throttle body fuel injectors (TBFI) were in effect an electromechanical replacement for the carburetor.

- Requirements for the TBFI were such that **they only had to deliver fuel at the correct average flow rate for any given mass air flow**. Mixing of the fuel and air, as well as distribution to the individual cylinders, took place in the intake manifold system.
- The more stringent exhaust emissions regulations of the late 1980s and the 1990s have demanded more precise fuel delivery than can normally be achieved by TBFI.
- These regulations and the need for improved performance have led to timed sequential port fuel injection (TSPFI).
- In such a system there is a fuel injector for each cylinder that is mounted so as to spray fuel directly into the intake of the associated cylinder.
- Fuel delivery is timed to occur during the intake stroke for that cylinder.

- When the ignition key is switched on initially, the mode control logic automatically selects an engine start control scheme that provides the low air/ fuel ratio (rich mixture) required for starting the engine.
- Once the engine RPM rises above the cranking value, the controller identifies the "engine started" mode and passes control to the program for the engine warm-up mode.
- This operating mode keeps the air/fuel ratio low (rich mixture) to prevent engine stall during cool weather until the engine coolant temperature rises above some minimum value.
- The particular value for the **minimum coolant temperature is specific to any given engine** and, in particular, to the fuel metering system. (Alternatively, the low air/fuel ratio may be maintained for a fixed time interval following start, depending on startup engine temperature.)

- When the coolant temperature rises sufficiently, the mode control logic directs the system to operate in the open-loop control mode until the **EGO sensor warms up enough to provide accurate readings.**
- This condition is detected by monitoring the EGO sensor's output for voltage readings above a certain minimum rich air/fuel mixture voltage set point.
- When the **EGO sensor has indicated rich mixture at least once** and after the engine has been in open loop for a specific time, the control mode selection logic selects the closed-loop mode for the system. (Note: other criteria may also be used.)
- The engine remains in the closed-loop mode until either the EGO sensor cools and fails to read a rich mixture for a certain length of time or a hard acceleration or deceleration occurs. If the sensor cools, the control mode logic selects the open-loop mode again.

- During hard acceleration or heavy engine load, the control mode selection logic chooses a scheme that provides a rich air/fuel mixture for the duration of the acceleration or heavy load.
- This scheme provides maximum torque but relatively poor emissions control and poor fuel economy regulation as compared with a stoichiometric air/fuel ratio.
- After the need for enrichment has passed, control is returned to either open-loop or closed-loop mode, depending on the control mode logic selection conditions that exist at that time.

- During periods of deceleration, the air/fuel ratio (Lean mixture) is increased to reduce emissions of HC and CO due to unburned excess fuel.
- When idle conditions are present, control mode logic passes system control to the idle speed control mode.
- In this mode, the engine speed is controlled to reduce engine roughness and stalling that might occur because the idle load has changed due to air conditioner compressor operation, alternator operation, or gearshift positioning from park/neutral to drive, although stoichiometric mixture is used if the engine is warm.

❖ Components of a fuel injection system

- Figure 9.20 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.

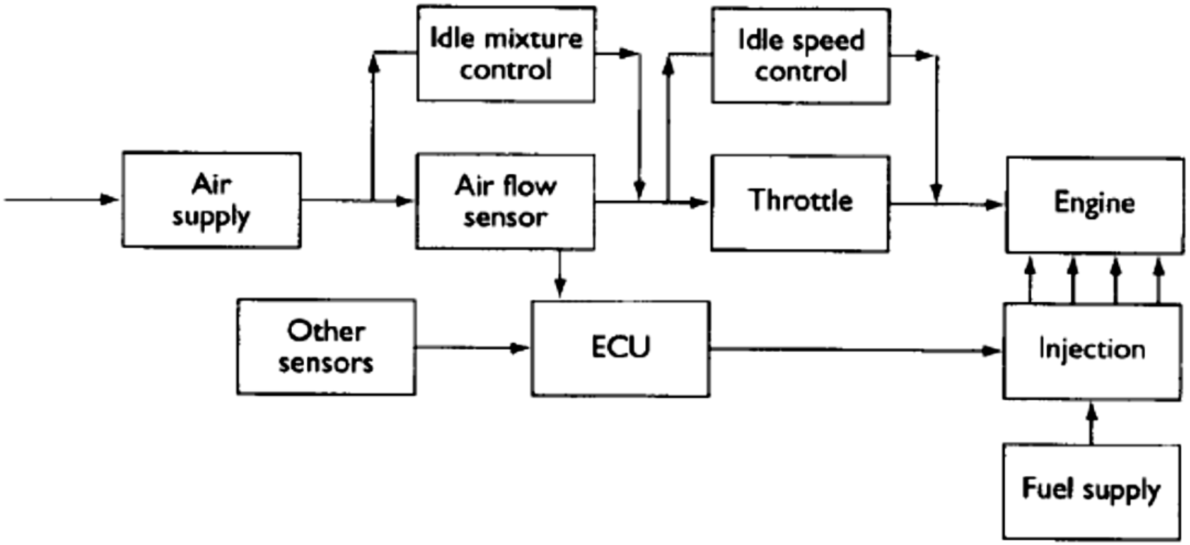


Figure 9.20 Typical control layout for a fuel injection system

- Figure 9.21 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.
- A three-dimensional cartographic map, shown in Figure 9.22, is used to represent how the information on an engine's fuelling requirements is stored.
- This information forms part of a read only memory (ROM) chip in the ECU.

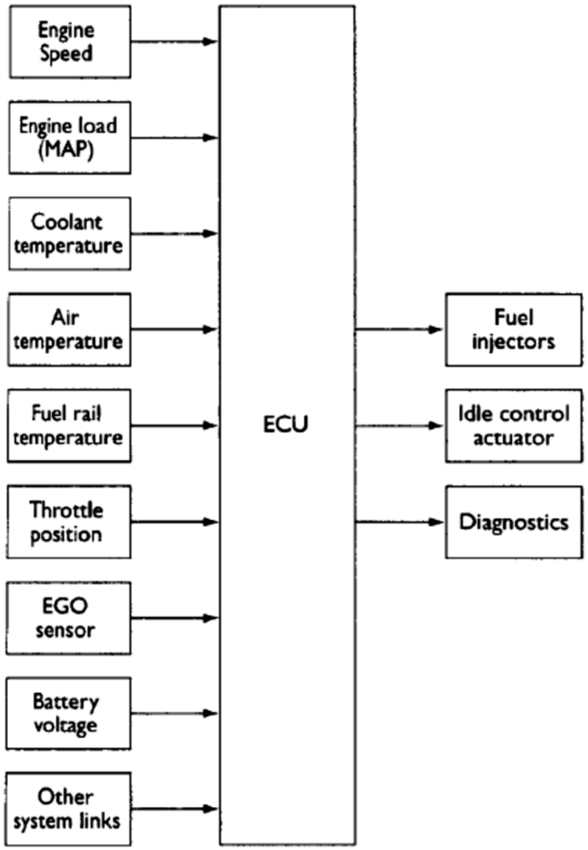


Figure 9.21 Block diagram of inputs and outputs common to most fuel injection systems

- 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.

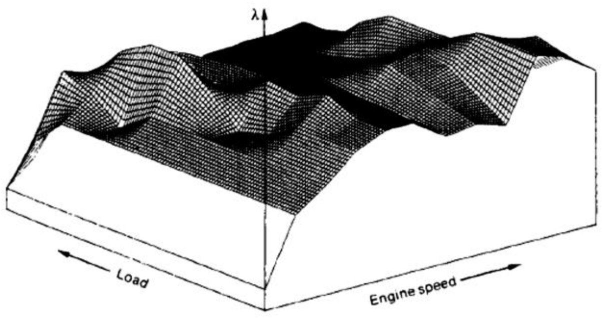


Figure 9.22 Cartographic map used to represent how the information on an engine's fuelling requirements are stored

- 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.

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. Cold start injector and thermo time switch

- An extra injector was used on earlier systems as a form of choke. This worked in conjunction with the thermo-time switch to control the amount of cold enrichment. Both engine temperature and a heating winding heat it. This technique has been replaced on newer systems, which enrich the mixture by increasing the number of injector pulses or the pulse length.

11. 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. This will only allow the fuel pump to operate when the engine is being cranked or is running.

12. Electronic control unit

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

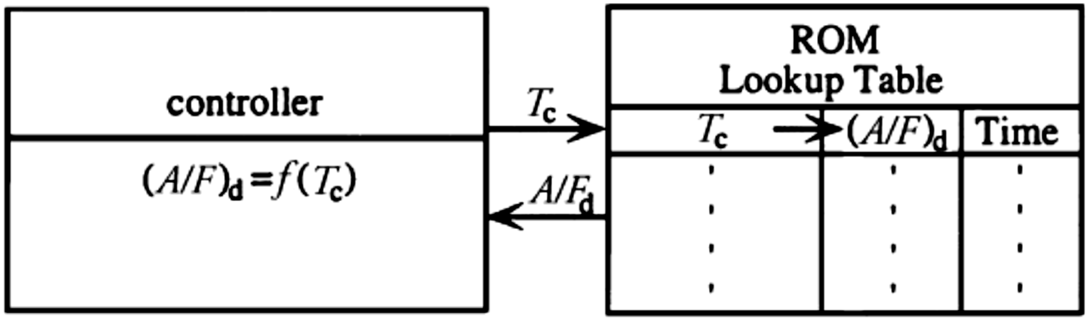
❑ Engine Crank

- While the engine is being cranked, the fuel control system must provide an intake air/fuel ratio of anywhere **from 2:1 to 12:1,** depending on engine temperature. The correct air/fuel ratio (i.e., [*A*/*F*]d) is selected from a ROM lookup table as a function of **coolant temperature.**
- Low temperatures affect the ability of the fuel metering system to atomize or mix the incoming air and fuel. At low temperatures, the fuel tends to form into large droplets in the air, which do not burn as efficiently as tiny droplets.
- The larger fuel droplets tend to increase the apparent air/fuel ratio, because the amount of usable fuel (on the surface of the droplets) in the air is reduced; therefore, the fuel metering system must provide a decreased air/fuel ratio to provide the engine with a more combustible air/fuel mixture.
- During engine crank the primary issue is to achieve engine start as rapidly as possible. Once the engine is started the controller switches to an **engine warm-up mode.**

❑ Engine Warm-Up (Cold and Warm Start System)

- While the engine is warming up, an enriched air/fuel ratio is still needed to keep it running smoothly, but the required air/fuel ratio changes as the temperature increases.
- Therefore, the fuel control system stays in the open-loop mode, but the air/fuel ratio commands continue to be altered due to the temperature changes.
- The emphasis in this control mode is on rapid and smooth engine warm-up. Fuel economy and emission control are still a secondary concern.

- A diagram illustrating the lookup table selection of desired air/fuel ratios is shown in Figure 7.3. Essentially, the measured coolant temperature (*CT*) is converted to an address for the lookup table.
- This address is supplied to the ROM table via the system address bus (A/B). The data stored at this address in the ROM is the desired air/fuel ratio (*A*/*F*)d for that temperature. This data is sent to the controller via the system data bus (D/B)



- There is always the possibility of a coolant temperature failure. Such a failure could result in excessively rich or lean mixtures, which can seriously degrade the performance of both the engine and the three-way catalytic converter (3wcc).
- One scheme that can circumvent a temperature sensor failure involves having a time function to limit the duration of the engine warm-up mode. The nominal time to warm the engine from cold soak at various temperatures is known.
- The controller is configured to switch from engine warm-up mode to an open-loop (warmed-up engine) mode after a sufficient time by means of an internal timer.

Acceleration Enrichment

- During periods of heavy engine load such as during hard acceleration, fuel control is adjusted to provide an enriched air/fuel ratio to maximize engine torque and neglect fuel economy and emissions.
- This condition of enrichment is permitted within the regulations of the EPA as it is only a temporary condition. It is well recognized that hard acceleration is occasionally required for maneuvering in certain situations and is, in fact, related at times to safety.
- The computer detects this condition by **reading the throttle angle sensor voltage**. High throttle angle corresponds to heavy engine load and is an indication that heavy acceleration is called for by the driver.

- In some vehicles a switch is provided to detect wide open throttle. The fuel system controller responds by increasing the pulse duration of the fuel injector signal for the duration of the heavy load.
- This enrichment enables the engine to operate with a torque greater than that allowed when emissions and fuel economy are controlled. Enrichment of the air/fuel ratio to about 12:1 is sometimes used.

Deceleration Leaning

- During periods of light engine load and high RPM such as during coasting or hard deceleration, the engine operates with a very lean air/fuel ratio to reduce excess emissions of HC and CO.
- Deceleration is indicated by a **sudden decrease in throttle angle** or by closure of a switch when the throttle is closed (depending on the particular vehicle configuration).
- When these conditions are detected by the control computer, it computes a decrease in the pulse duration of the fuel injector signal. The fuel may even be turned off completely for very heavy deceleration.

Overrun fuel cut-off

- This is an economy and emissions measure. The injectors do not operate at all during this condition. This situation will only occur with a warm engine, throttle in the closed position and the engine speed above a set level.
- If the throttle is pressed or the engine falls below the threshold speed the fuel is reinstated gradually to ensure smooth take up.

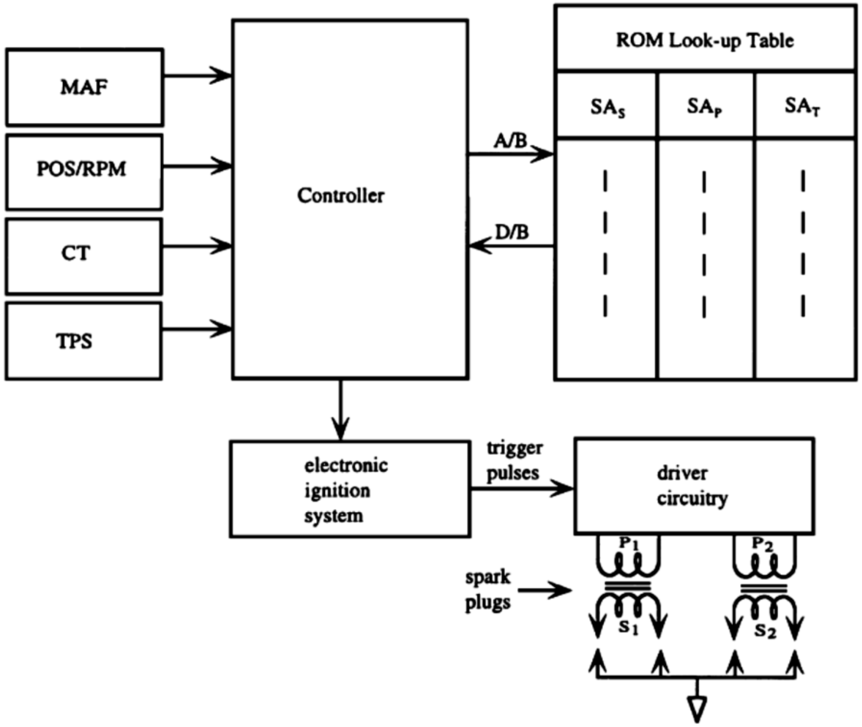
Overspeed fuel cut-off

- To prevent the engine from being damaged by excess speed, the ECU can switch off the injectors above a set speed. The injectors are reinstated once engine speed falls below the threshold figure. Hot-wire fuel injection is a very adaptable system and will remain current in various forms for some time.

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.)



- Figure above 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.

- 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 chosen 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 performance as measured on an engine dynamometer.

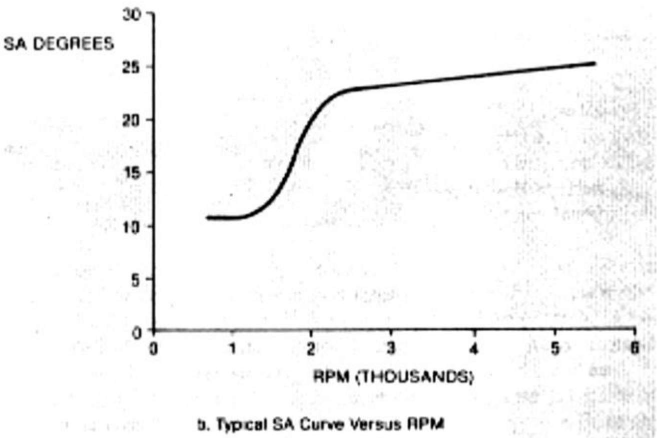


Figure 7.9b Distributorless Ignition System

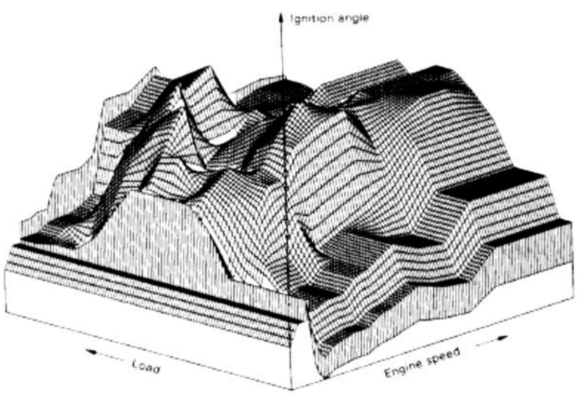
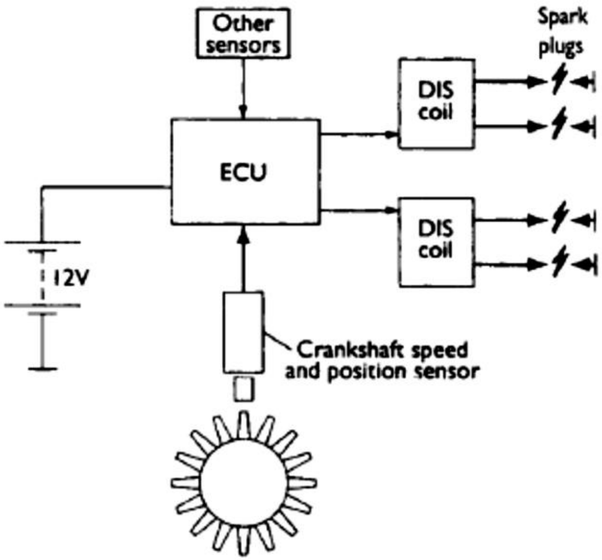


Figure 8.21 Cartographic map representing how ignition timing is stored in the ECU

- 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. For example, the variation of spark advance (SA) with RPM for a representative engine is shown in Figure 7.9b.
- 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 *distributorless ignition system* (DIS) since it uses no distributor.
- There are a number of older car models on the road that utilize a distributor. However, the electronic ignition system is the same as that shown in Figure, up to the coil packs.
- 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.
- Each engine configuration has its own spark advance characteristic, which is normally a compromise between a number of conflicting factors (the details of which are beyond the scope of this book).

- 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.

Introduction to diesel fuel injection

- The basic principle of the four-stroke diesel engine is very similar to the petrol system. The main difference is that the mixture formation takes place in the cylinder combustion chamber as the fuel is injected under very high pressure.
- The timing and quantity of the fuel injected is important from the usual viewpoints of performance, economy and emissions.
- Fuel is metered into the combustion chamber by way of a high pressure pump connected to injectors via heavy duty pipes.
- When the fuel is injected it mixes with the air in the cylinder and will selfignite at about 800 °C. The mixture formation in the cylinder is influenced by the following factors.

❑ Start of delivery and start of injection (timing)

- The timing of a diesel fuel injection pump to an engine is usually done using start of delivery as the reference mark.
- The actual start of injection, in other words when fuel starts to leave the injector, is slightly later than start of delivery, as this is influenced by the **compression ratio of the engine, the compressibility of the fuel and the length of the delivery pipes**.
- This timing increases the production of carbon particles (soot) if too early, and increases the hydrocarbon emissions if too late.

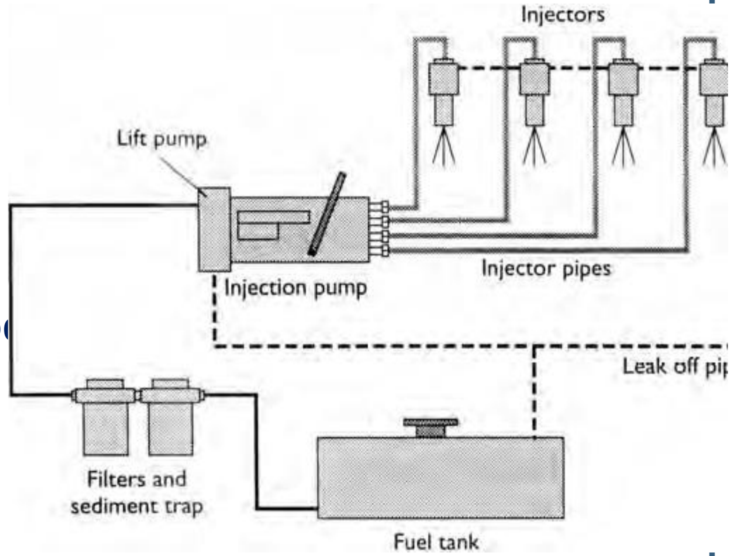
Spray duration and rate of discharge (fuel quantity)

- The duration of the injection is expressed in degrees of crankshaft rotation in milliseconds.
- This clearly influences fuel quantity but the rate of discharge is also important.
- This rate is not constant due to the mechanical characteristics of the injection pump.

- **Injection pressure**
  - Pressure of injection will affect the quantity of fuel, but the most important issue here is the effect on atomization.
  - At higher pressures, the fuel will atomize into smaller droplets with a corresponding improvement in the burn quality. Indirect injection systems use pressures up to about 350 bar, while direct injection systems can be up to about 1000 bar.
  - Emissions of soot are greatly reduced by higher pressure injection.
- **Injection direction and number of jets**
  - The direction of injection must match very closely the swirl and combustion chamber design. Deviations of only 2 ° from the ideal can greatly increase particulate emissions.

❑ Diesel Engine (CI) 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.
  - ➢ Idle speed control.
  - ➢ Control of exhaust gas recirculation.
  - ➢ Drive by wire system (potentiometer on throttle p
  - ➢ An anti-surge function.
  - ➢ Output to data acquisition systems etc.
  - ➢ Temperature compensation.
  - ➢ Cruise control.



- Figure 9.39 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.

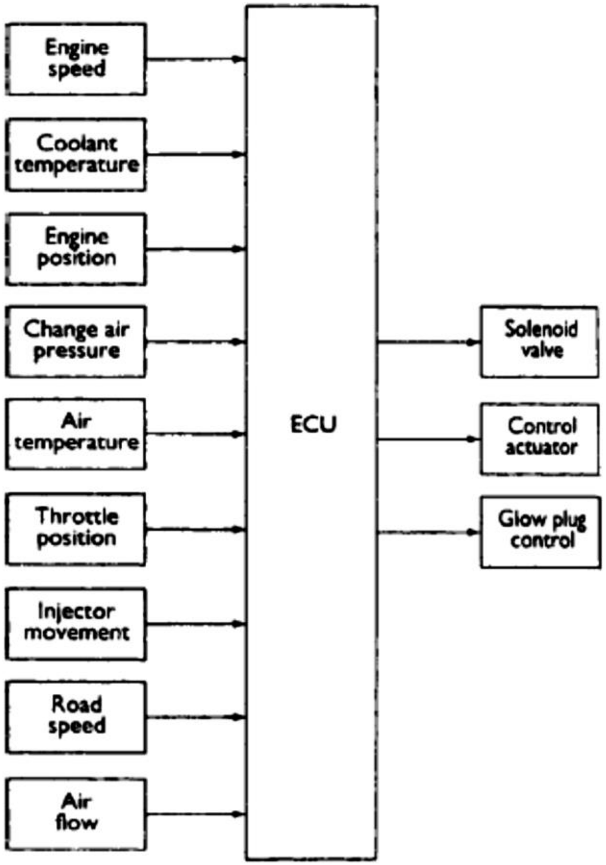


Figure 9.39 Block diagram of typical electronic diesel control system

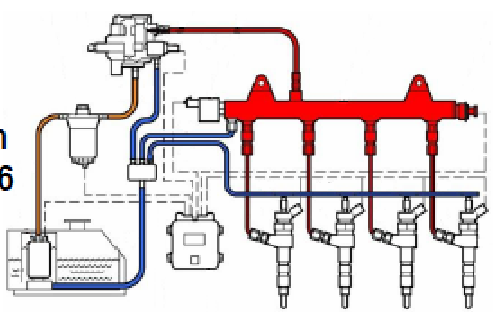
Common Rail Diesel Fuel Systems

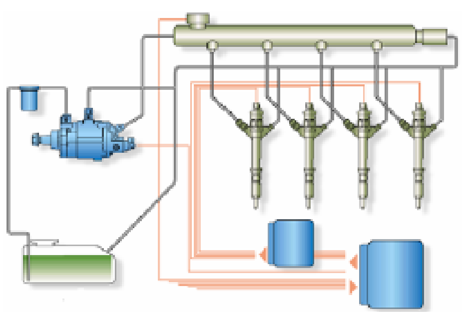
Examples of typical common rail system maximum fuel pressures:

- **Bosch:** Generation 1: up to 1350 Bar (19845 psi). Unijet
  Generation 2: up to 1600 Bar (23520 psi) EDC 16
  Generation 3: up to 2000 Bar + (29400 psi)
- **Denso:** 1st generation: up to 1450 Bar (21315 psi) ECD-U2P
  2nd generation: 1800 Bar + (26460 psi) HP3/HP4
- **Delphi** Multec: up to 2000 Bar
  Direct acting diesel common rail system: up to 2000 Bar

Various systems differ in design, components layout and specific functions. However, all operate in a similar way.

Bosch EDC16

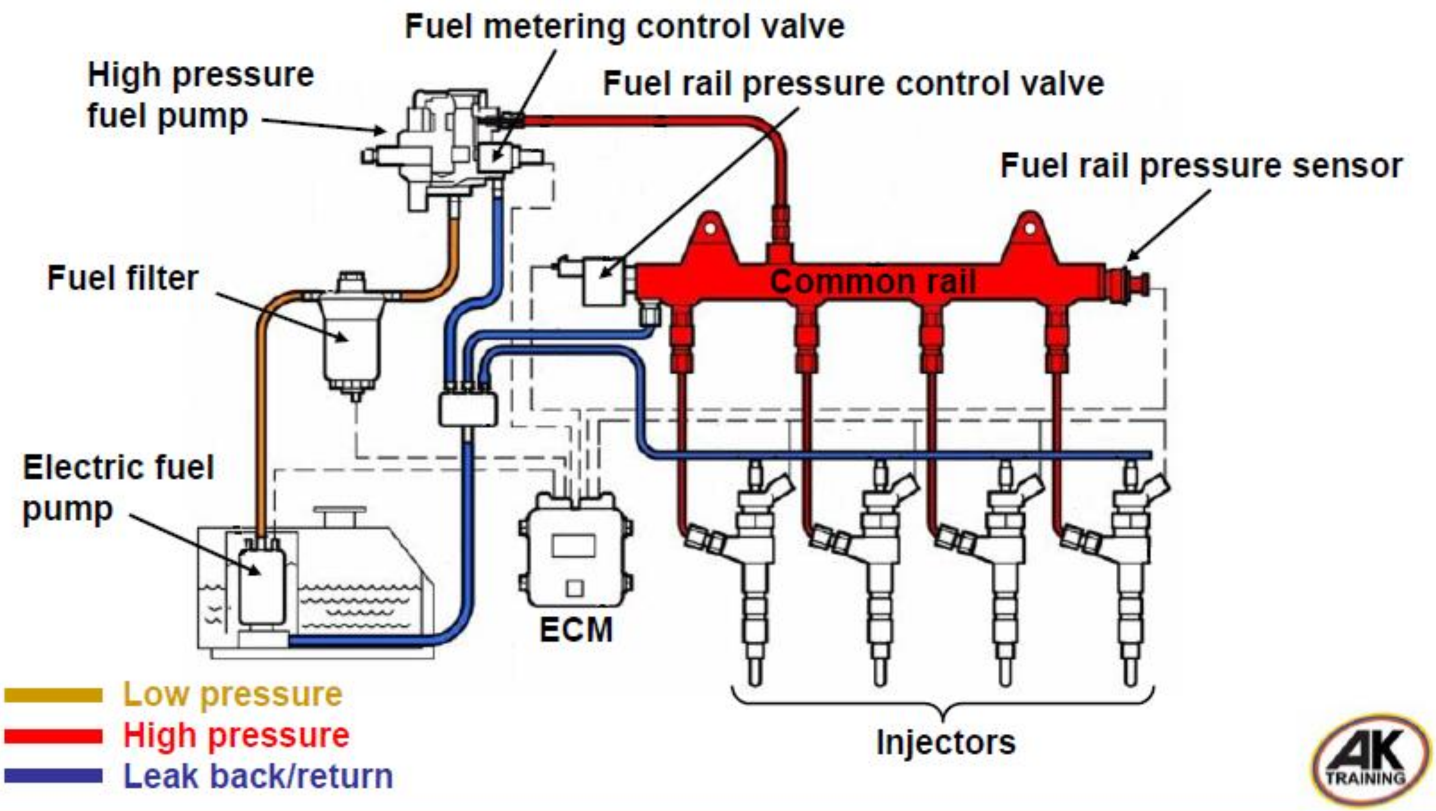




Denso ECD-U2P

Common Rail Diesel Fuel Systems

Components overview (example: Bosch EDC 16)



Common Rail Diesel Fuel Systems

Advantages of common rail:

- Fuel pressure available on demand.....
- Higher injection pressures and finer atomization of fuel.....
- Injection pressure created independent of engine speed.....
- Multiple injections per cylinder combustion are possible.

Benefits of common rail:

- Reduction of overall exhaust emissions.....
- Reduction of particulate emissions.....
- Reduction of noise emissions.....
- Improved fuel efficiency.....
- Higher performance.