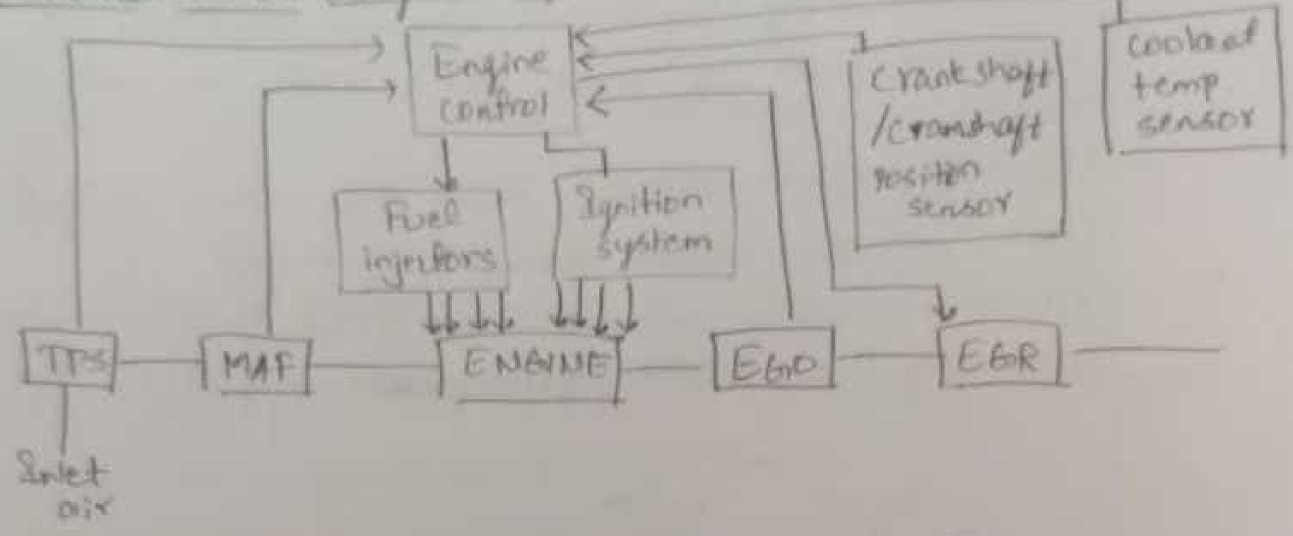
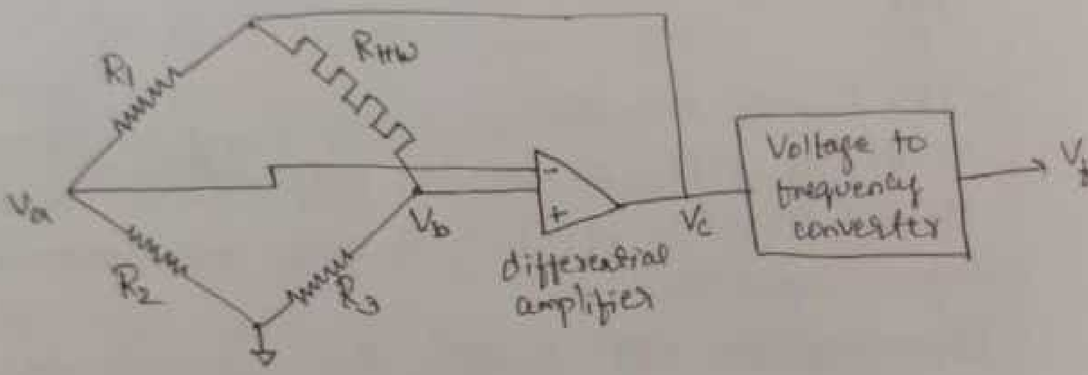
General block diagram of power train



- TPS & MAF are at inlet air manifold. These do, the quality of MAF is directly proportional to air flowing through throttle (TPS). Both will input data or pulse to engine control unit.
- Depending on MAF & TPS, the ECU will decide the amount of fuel injected by fuel injectors in engine cylinder.
- Width of pulse supplied to solenoid & is proportional to injectors open time
- Air & fuel mixture is compressed in engine cylinder with the help of spark advance i.e., ignition system.
- Among other all sensor remaining, crankshaft position senser is most important. It senses the position of camshaft/crankshaft in degrees of its rotation inside cylinder. Ideal position for spark ignition is 8-10° before the TDC.
- The data sent by crankshaft position sensor to ECU, this decides the position of piston before TDC & also ignition timing is produced.
- This ECU will gives pulse ignition system i.e., provides current to ignition coils that provides sparks to engine.

MAF sensor:

- An electrically controlled engine requires a measurement of mass flow rate in air (Rm) into engine.
- This requires a sensor that can sense air flow rate into the intake manifold of engine.
- It is normally mounted as part of air cleaner assembly (i.e., intake ~~manifold~~ manifold of the engine).



Wheat store

Here,

R_{HW} - sensing element

V_a & V_b - output of wheatstone ⟶ differential amplifier

output of differential amplifier ⟶ v ⟶ f converter.

- R_{HW} - heated filament resistor.

value of resistance changes as the filament temperature changes.

- As air flows across the hot filament, heat is carried away from the film by moving air.
- The amount of heat carried away varies in proportional to the mass flow rate of the air.
- The heat post ~~by~~ by the film to the air tends to cause the resistance of the film to vary, which unbalances the

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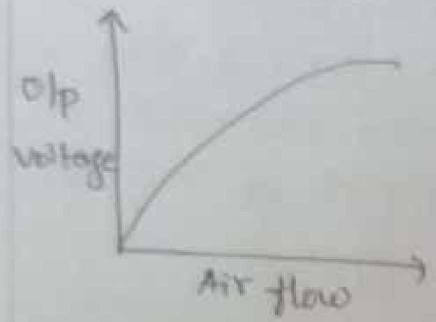
- This voltage to gives to voltage to frequency converter.

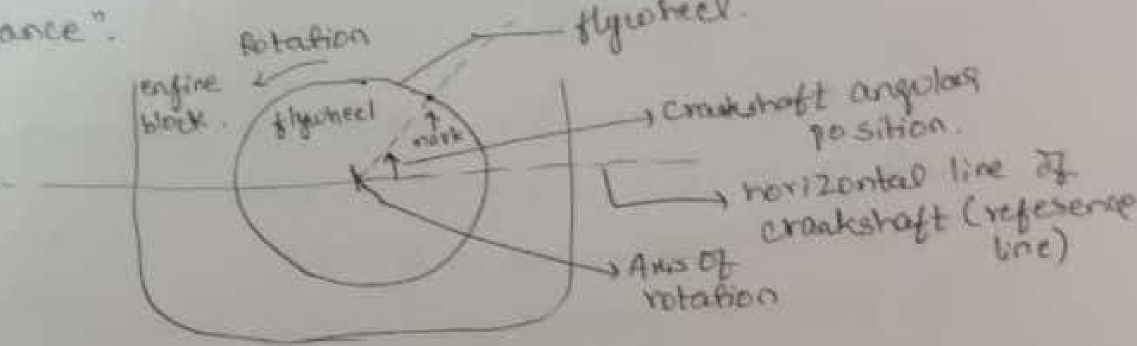


Here the graph is called calibration curve.

- The output from the voltage to frequency converter will go to ECU, which is in pulse
- Here, no linear curve is present.
- In particular zone it gives linear output
- The amount of fuel to be injected is decided by the air flow sensor [MAF] whose output is given in the pulse to the ECU. Finally proper air : fuel ratio should be maintained.

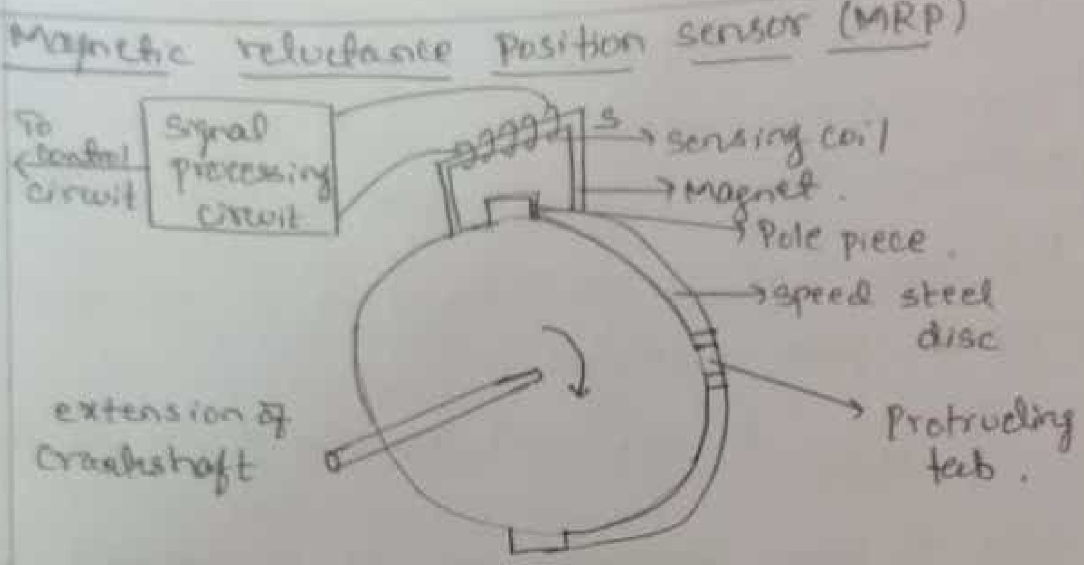
Engine crankshaft angular position sensor:

- In order to determine the spark timing, valve timing etc., the position of piston w.r.t TDC & BDC is necessary. Therefore we need a sensor to sense the same.
- This sensor works on the principle of "Magnetic reluctance".



- Flywheel - senses rotation of crankshaft which is integrated in engine block, 1 rotation is 360° of rotation.
- Piston moves from TDC to BDC, then crankshaft completes its half rotation i.e., 180°.
- 360° rotation - from TDC to BDC & again back.
- Considering intake of cylinder where piston is at TDC & if crankshaft rotates at 180° then piston moves from TDC to BDC. Again 180° to 360° is next (compression stroke BDC to TDC).
- In compression stroke, the ignites the spark. Ideal spark ignition is at 8 - 10° before TDC.
- This crankshaft position senses, it will measure the distance of piston from TDC or BDC in degrees of rotation of crankshaft
- Measurement of degrees is w.r.t to horizontal reference line. At 0° - piston at TDC. At 180° - piston at BDC. Again at initial point (360°) - from BDC to TDC.

Magnetic reluctance position sensor (MRP)



- One engine sensor configuration that measures crankshaft position directly (using magnetic sensor)
- This sensor consists of permanent magnet with a coil of wire wound around it.
- A steel disk that is counted on the crankshaft has tabs that pass between the pole pieces of this magnet.
- This sensor is of the magnetic reluctance type & is based on the concept of magnetic circuit.
- Reluctance, $R = \frac{L}{\mu_0 \mu_r}$, Area of cross-section of magnet.
- One noncontacting engine sensor configuration that measures crankshaft position directly (using magnetic phenomena).
- The sensor consists, in general, there are N tabs where N is determined during the design of the engine control system.
- The passage of each tab could correspond for eg, to TDC position of cylinder, although other reference positions are possible.

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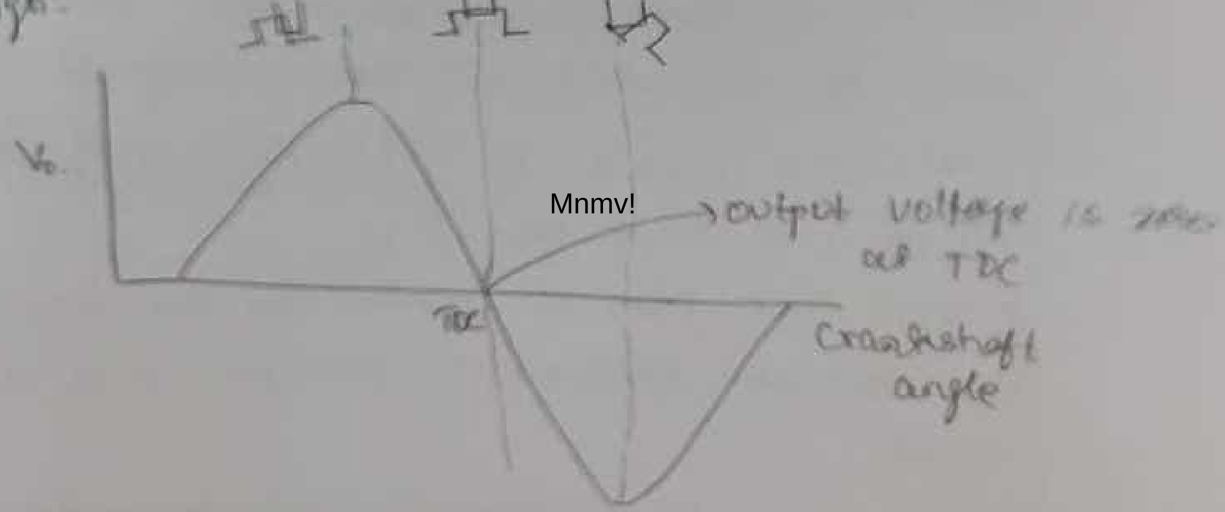
Changes in reluctance

i) Before tab approaches, air is present as dielectric medium. μ_r - relative permeability ($\mu_r = 1$ for air)

ii) tab comes between the circuit & it changes the magnetic path disturbs.

$R = \frac{l}{\mu_0 \mu_r} A$, μ_r won't remain 1, it changes

Here R drops drastically as μ_r of steel will be high.



- The rate of change of flux induces a voltage across the coil.
- A peak in voltage indicates tab crossing the pole piece as shown.

Throttle position sensor

- A variable that must be measured for electronic engine control in the throttle plate angular position.
- This is linked to accelerator pedal mechanically.
- When the driver depresses the accelerator pedal, this linkage causes the throttle plate angle to increase allowing air to enter the engine.
- The power generated by engine is directly proportional to air entering the engine.
- The throttle sensors are essentially potentiometers
- Speed can be controlled by this sensor.
- When the pedal is pressed, the throttle value which is called butterfly value will open & it increases air flow thus increasing speed of vehicle.

- TPS monitors, how much the value is open & how much accelerator pedal is depressed by driver.
- When value is widely open, more air flows. Thus fuel intake will be more, speed will be more
- When value is closed nearly, less air flows, fuel intake will be less, speed will automatically reduce. It is presented at accelerator pedal. TPS senses the value open to the ECU of engine.
- Thus variable speed is achieved
- The ECU decides the amount of fuel to be injected to the engine.

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Construction of 3 wired potentiometer

- 1st wire = 5 V, 2nd wired - grounded, 3rd wire connected to movable need.
- Other end of needle is input of ECU i.e., V(a)
- As throttle values changes its position, needle will also move accordingly.
- The circuit is closed as Va(a) is connected to ECU where continuous constant current will be flow through the circuit.
- The amount of current flowing through resistor is different in different parts. the current changes as the position of needle change. Therefore voltage variable which is input of ECU which decides the amount of fuel to be released for the engine.

- Based on construction, TPS are different like potentiometer or closed throttle position sensor which has switches in it.

- Disadvantage: the potentiometer for automotive applications is its analog output. But for digit engine, the voltage V(a) must be converted to digit format using an analog is digital converter.

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Sensor for feedback control: have exhaust gas recirculati-on (in order to reduce exhaust gas Discharged by cars.

- Exhaust gas oxygen sensor - propularly known as lambda sensor.
- The amount of oxygen present in exhaust gas is in turn used to measure the air: fuel ratio.
- As a result, one of the most significant automotive sensor in use today is exhaust gas oxygen [EGO] sensor.
- Also called lambda sensor,

$$\lambda = \frac{\text{air/fuel}}{\text{air/fuel at stoichiometry}}$$

with the help of λ value, we can know how much carboration is happening inside the engine.

- If λ is to flutuating, then there is no proper carborati-on taking place.
- Thus λ should be measured, which is done by EGO sensor
- If $\lambda > 1 \longrightarrow$ mixture is lean

  If $\lambda < 1 \longrightarrow$ mixture is rich

  If $\lambda = 1 \longrightarrow$ ideal.

stoichiometric air/fuel is 14.7 : 1.

- Actual air/fuel ratio is measured by air-MAF sensor.

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- Some part of λ sensor is placed inside the exhaust gas exhaust tub & some is at output of tube.
- Concentration of oxygen in tube is different from what the concentration of oxygen outside the tube.
- The difference in concentration of oxygen, this will create potential gradient at terminals (V_0)
- V_0 is the output voltage of the sensor.
- If $\lambda < 1$ (rich mixture) fuel quantity will be more the oxygen in the exhaust gas tube. This means the EGO will give more output i.e., V_0 will be more.
- If $\lambda > 1$, fuel is less & air is more, Concentration of oxygen is high. V_0 will be lower.
- Difference in concentration of oxygen of inside and outside the tube is less, so here V_0 will be less, vice versa.

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Temperature Sensor:

- Temperature sensor is an important parameter through-out the automotive system.
- In operation of an electronic fuel control system it is vital to know the temperature of the coolant, the temperature of inlet air & temperature of exhaust gas oxygen sensor.
- We can illustrate the basic operation of most of the temperature sensors by explaining the operation of types of coolant sensor.

- To keep the engine at optimum temperature.
- Measure the temperature of coolant present in the cooling system.
- We will get to know amount of heat generated by the engine by knowing coolant temperature
- Commonly known as ECT.
- The ECT resistance of ECT sensors will be converted to voltage signal which is further

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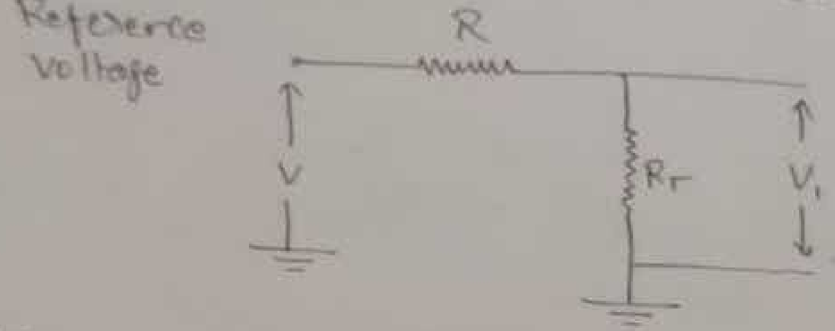
by ECU

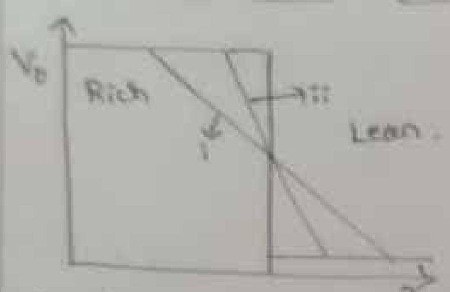
- It continuously monitor the temperature of coolant & make sure engine is running at optimum temperature
- $R \propto 1/temp$, for eg. consider 20° of engine. R will be 2kΩ or 3kΩ. When temperature increase like 90° these R will be low like 200 Ω to 300 Ω

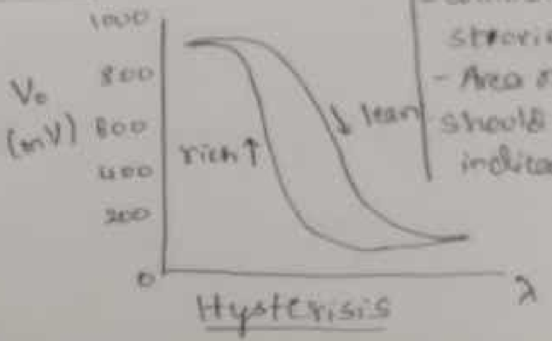


Electrical circuit of ECT sensor.

- Here,
  R_T - coolant temperature sensors resistance value
  R_T - Connect to fixed reference voltage through fixed resistance R.
- Sensors discussed before feedback control are open loop ECU sensors.
- Open ECU sensors - with exhaust gas recirculation
- $V_T = \frac{V R_T}{R + R_T}$
- Here V_T decreases as temperature sensed by R_T increases.

Desirable EGO characteristics:





- Commonly used for storing memory
- Area of hysterisis should be less, it indicates memory
$V_0 \times \lambda$ = memory of sensor

① Abrupt changes in voltage at stoichiometry - if $\lambda > 1$, $V_0 = 0.8$ $(V_0 > 1)$ where $\lambda = 1$, $V_0 = 0$, $\lambda < 1$, $V_0 = 1.2V$
Transitions from rich to lean or vice verse will cause V_0 change

② Rapid switching of V_0 in response to exhaust to exhaust gas O_2 changes - concentration of O_2 at exhaust gas will be changing fast at every stroke.

③ Large difference in sensor output voltage between rich & lean mixture conditions - V_0 should be having large difference at rich & lean. $(V_0)_{rich}$ & $(V_0)_{lean}$ should be differentiable.

④ Stable voltages w.r.t exhaust temperature.

i. In hysterisis graph, $\lambda = 0$ to 0.8 - V_0 - constant

ii. V_0 = more at $\lambda = 0.99$ we need to select it where is more like ideal are to get appropriate value of EGO.

- Choose sensor with lesser memory because less memory can be easily vanished & it is given appropriate output on present. With less hysterisis all desirable EGO characteristics will be satisfied.

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Engine Speed sensor:

① Wheel speed sensor: required for safety system, works on principle of proximity.

Signal - actual output from sensor

Disc has some producing tabs which is mounted on wheel, when producing tab is closed to sensor, then it is said close event

Notch → open time.

- The time difference of events (open & close) is directly proportional to the speed of wheel.
- difference is very less, rotation is high amount of rpm
- signal produces pulses, which in turn gives wheel speed
- Wheel speed sensor is integral part of ABS.

② Vehicle speed sensor: located at transaxle of transmission, kind of wheel speed or derivative

- Vehicle speed sensor is used by ECU to adjust ignition timing, air/fuel ratio, adjust spark timing or transmission shift times.

- fuel - we need to know rate of spray injection
- Amount of fuel = rate of spray injection x time of valve open to injection.

After combustion: EGO sensor is present at exhaust gas recirculation system. Based on concentration of oxygen which is in exhaust gas the type of mixture is determined.

- Most of sensors use Zirconium dioxide [ZrO_2] & titanium dioxide [TiO_2]
- ZrO_2 is most commonly used because it is very sensitive to the person of O_2.
- The resistance of ZrO_2 in the presence of O_2. Change rapidly with the change in onc of O_2 at the particular constant pressure & temperature.
- Thus by ZrO_2 variations in its resistance we can measure O_2 concentration at exhaust gas at constant pressure & temperature.

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Knock Sensor:

- Due to automobile aging there are some noices produced by parts. The noices produced by engine is called knock
- Noice is due to the sudden rise of pressure in engine cylinders
- Knocking will also occurs when burning of fuel is uneven, this uneven burning is because of faulty spark plugs.
- Aging of plugs leads to malfunctions & results in knock
- Engine performance & efficiency reduces due to the knocking so knocking should be detected & protected so as to minimize the engine & valves damage.
- knock sensor prevent knocks & it will help to vary spark advance to prevent.

① We can sense the knocking and we can retard or delay the ignition until knocking stops completely.

- It uses magnetostriction principle – it is a phenomenon in which the magnetic property of the material changes depending on stress.

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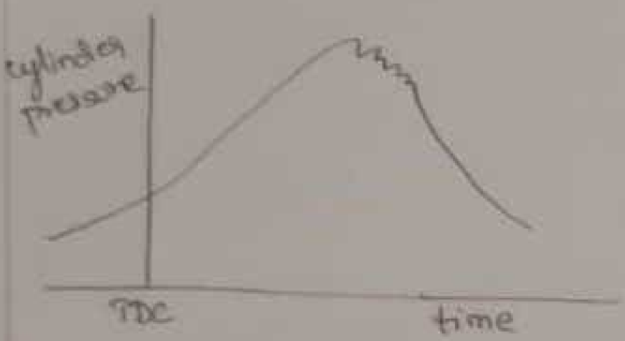
- Magnetostrictive rods are in coil
- magnet is inserted in the coil.
- In steady state condition, the magnetic flux linked with magnet to fixed & voltage level is induced in the coil is zero.
- Change in flux is required to generate the emf.
- When knock occurs, it exerts pressure on the engine walls, the magnetostric rods will get modified.
- This will change magnetic property of rods & emf will get induced.
- We will recieve pulses at terminal.



- Piston comes near TDC, cylinder pressure increasing gradually i.e. after combustion
- Deviations in curve represents knocking.

- Other sensors use piezoelectric crystals or the piezo-resistance of doped Si semiconductor.
- Knocking occuring in a cylinder alerts the sensor of its cylinder remaining wont range
- Here, the piston near TDC occurs, the cylinder pressure increases gradually after combustion.
- It also contains soft magnetic shell, insulator in the sensor.