Chapter 1:

CRDI → Common Rail Engine

Automotive electronics: Automotive electronics are the electronics used in automobiles either to replace the existing mechanical component or/and control.

Ex: × by wire s/m.
× may be drive, break.

Motivatn:
→ Semiconductor era & Regulations by govt.

→ i.3s — idual start stop s/m
→ hill-hold s/m
→ start-stop s/m (stand-still + neutral gear) ECU's.
→ ~~Adaptive~~ adaptive cruise control
→ ESP & ABS
→ Alert s/m.

→ ~~st~~ Vehicles were designed to reduce the pollutn (Fuel economy & emission)

IQ) Why we need electronics in automotive.

→ Fuel efficiency
→ Exhaust particle
→ Control the temp inside engine — ECM
→ High power
→ Higher torque
→ Control knocking

[Power train: Power generation & transmission unit.]

→ vehicle slip control
→ over steering control
→ under " "
→ Vehicle roll over control
→ Reduce stopping distance
→ Brake distribution

ABS, TCS & ESP.

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→ Vehicle interior lighting
→ Vehicle exterior "
→ Automatic Door lock
→ Power windows
→ Remote key

} BCM (Body control Model)

Safety domain:
→ Belt pretensioners
→ Automatic roll over bar
→ Supplementary restrain systems

} Air bag control unit

ABS → active saftey s/m ∵ comes before or prior to
Air bag s/m → passive " " ∵ comes after

Additionally other electronic s/m ACC, Power steering s/m, Air conditioning s/m &

ADAS : Advance driver assistance s/m

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Overview of Automotive industry and Design Process, Technologies.

Terminologies used in Automotive

→ OEM's : Original Equipment Manufacturer's.

→ Honda is OEM's. In simple whoever puts their logo on car is OEM's.
→ Maruti, Ford.

Bosch, KPIT, Continental → Suppliers :- they put their logo on product like ECU

Tier 1

0.5 Tier 1

→ Tier 1 → Suppliers.

→ Tier 2 → TCS, Wipro, KPIT → service provider

→ Suppliers

→ Customers → For Robert Bosch India, Robert Bosch Germany is customer.

→ End customers.

Automotive Industry size:

It has manufacturing companies whose 1° activity is

→ Development

→ Manufacturing

Product Categories.

SUV → Sports utility vehicle

MUV → Multi utility vehicle.

Segments of Auto Industry:

→ 4 sub-segments.

(1) OEM's : The makers of cars, light trucks, & motor bikes

(2) Heavy equipment

(3) Suppliers

(4) Dealers

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Major revenue / profit is taken by dealers (Used car & New car dealers)

Automotive Value chain:

Raw material suppliers → Suppliers Tier "n" / Tier I → Original Equipment manufacturer → Dealers

↓

After market & services — Finance Insurance

Bata shoes → African shoes

Market drivers for Auto Industry:

(1) Government : → ~~TREAD~~ Act → Disposal / → reconciliation
→ Safety & environmental legislations

(2) Competition
→ Competing on cost / features. → Globalised

(3) Customer → Technology adoption differs → Variety

(4) International trade
→ Exchange rate → Trade acts / tariff

(5) OEM
→ Distributed operation → High FG inventory

(6) Suppliers
→ Global presence → Emerge of flow cost destination
→ Increasing Tiers

(7) Technology : → Telematics → Hybrid fuel → Collaborative design

(8) Market : → Sluggish growth
→ Weak ~~autom~~ economic outlook
→ Globalisation

Evolution of Automotive Electronics:

→ 1970's : Introduction of electronics for engine controls.
→ 1980's : ABS (Bosch 1st introduced in Benz).
→ Early 1990's : Airbags become standard.
→ Late 1990's : Rapid expansion of body electronics – seat motors, instrument panel lighting, auto locking door & keyless entry.

→

→ Late 2000's : steer-by-wire, wireless connectivity
→ By 2020's : Connected cars & Autonomous cars.

⇒ "Earlier s/m were more of Auto Electrical s/m than Electronics."
⇒ More than 61 ECU's are used in Automotive Electronics Today
∴ if 1 s/m fails it should not affect others.
⇒ 11,136 electrical parts.
⇒ external diagnosis for 31 ECUs via serial communication
⇒ Optical bus for high bus infotainment data

Evolution of Safety S/m:

active safety
→ collision-avoidance
→ automatic braking

safety
→ Pedestrian object recognition
→ PreCrash
→ accident warning

Passive saftey

active

vehicle guidance
→ active parking ass
→ ACC Stop + go

→ Active safety : Before accident
→ Passive safety : After accident

Sensors:
→ Radar > 180 m
→ camera
→ ultrasonic for parking
→ GPS
→ laser cameras

Electronics controls used in various car s/m today
(1) Powertrain (Power generation & transmission unit) largest and most trending domain
→ engine control
→ transmission control
→ starter / alternator

(2) Body & convenience :
→ lighting, light control
→ wipers
(3) Safety : → ABS
→ Active & Passive
(4) Infotainment : navigation

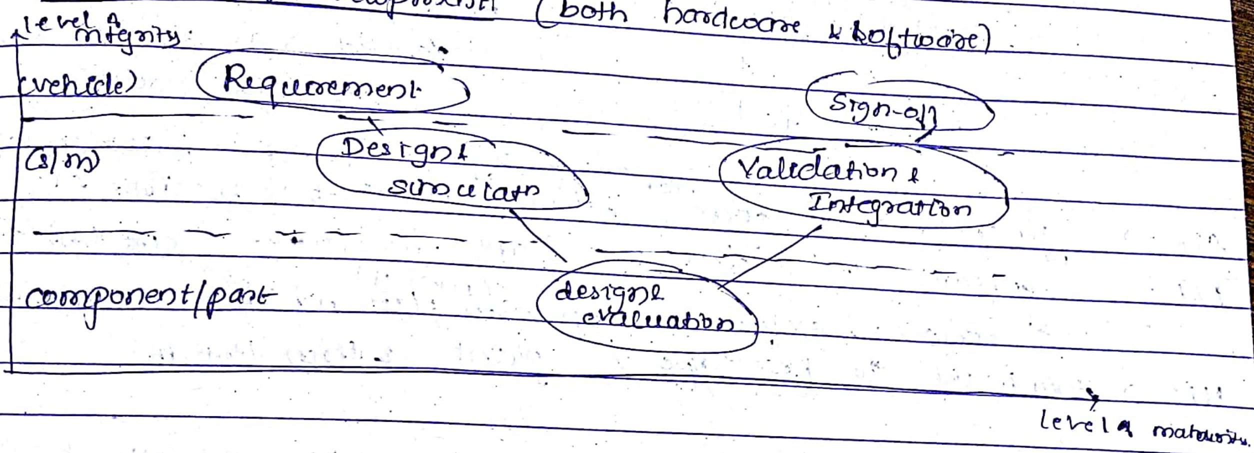
4 domains

⇒ Automobiles had changed from machinery to s/m of E/E s/m
∵ (1) Cars have upto 2500 software controlled s/m & 10 million lines of ~~cold~~ code

⇒ Automotive Electrical & Electronic s/m are divided into clusters of related functions — so called vehicle domains.
(1) Infotainment : GPS, entertainment like audio, video
(2) Body electronics : seat belt adjustment
(3) Chassis & driver assistance : suspension s/m, ABS, ESP, Automatic ~~brake~~ control, lane change assistance, lane departure
(4) Powertrain : Engine & transmission
(5) Safety s/m : seat belt, ABS

→ S/m Engineer approach.

→ V-model of Development (both hardware & software)



→ Documentation & Validation:

→ Ex("DOORS" from Telelogic/IBM.) → IT tools that support requirements, management also and for mapping the requirements

Component Development Process:

(1) Microcontroller : software for hardware : functional comp. built on one chip

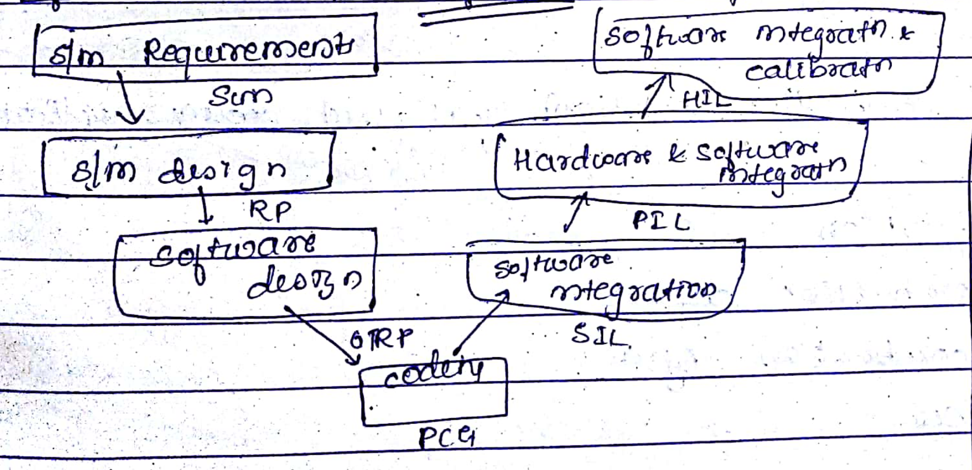
(2) ECU basic software: not a applicatn software Ex: OSEX / ISO has OS,

(3) Applicatn software: controls & executes the required fun (tools like MATLAB/SIMULink) Ex: temp. sensor

(4) Middleware : applicatn prog. to use a common API Ex: AUTOSAR RTE etc

(5) Physical elements: PCB, housing, shielding, terminal sockets.

~~Soft~~ Embedded S/m Software Development Process



Sim : Simulato

RP : Rapid prototyping

OTRP : On-target Rapid Prototyping

PCG - Productn code Generatn

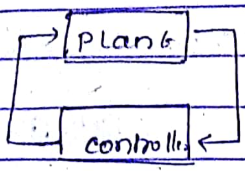
SIL - Software in the loop testing

PIL = Processor-in the loop testing

HIL = Hardware in loop testing

MIL - Model in loop

MIL → Model in loop testing



both plant & controller are tested using models like simulink model.

SIL → generate a 'C' code for the controller & then ~~test it~~ it is connected to plant in loop this becomes SIL

PIL → software ie 'C' code & a plant - hardware (model). are tested
'C' code → hexfile in loop with plant which is still a model

HIL → they make the prototype of plant & then test it

dSPACE simulator: Simulates all functionalities of diff vehicles

Fundamental Components of Vehicles
- → Engine
- → Transmission unit
- → Braking unit
- → Steering unit
- → Differential gear
- → Suspension unit

Engines
→ converts some energy to mechanical motion.

Types of engines
Classified Based on combustion (ignition), fuel used, cooling, application, construction.

(1) Based on combustion
- → External combustion engine
- → Internal combustion engine

(2) Based on fuel used
- → Disel engines
- → Petrol
- → CNG
- → LPG

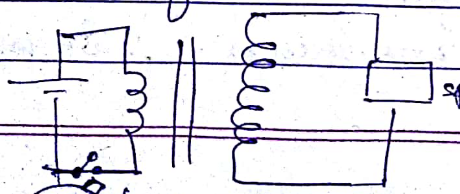
controller are
models like
model.
plant in loop
becomes STL
are tested
is still a model
it
diff vehicles
applications

1) Based on cooling s/m
→ Air cooled &
→ Liquid cooled
2) Based on application
→ Stationary engine
→ Rocket
→ Automobile
3) Based on construction
→ Inline
→ Opposed
→ Rotary
→ V- engine

Most commonly used
→ Internal combustion
→ piston -type
→ 4 stroke /cycle
→ gasoline fueled
→ spark-ignited
→ liquid cooled

Camshaft: controls the inlet & outlet valve at right time
& also help to provide spark to light cylinder
→ When we accelerate, air is controlled. thru throttle → throttle
ideal air fuel ratio : 14.7 : 1 (stoichiometric)

→ Voltage required to ignite ie spark plug = 22000 V
→ Spark or ignite the mixture at right time is taken care by camshaft
→ We have 12V battery but we need 22000 V, this is achieved using transformer.



2 electrodes
(1) Ground
(2) central.

4 corners, 4 cylinders

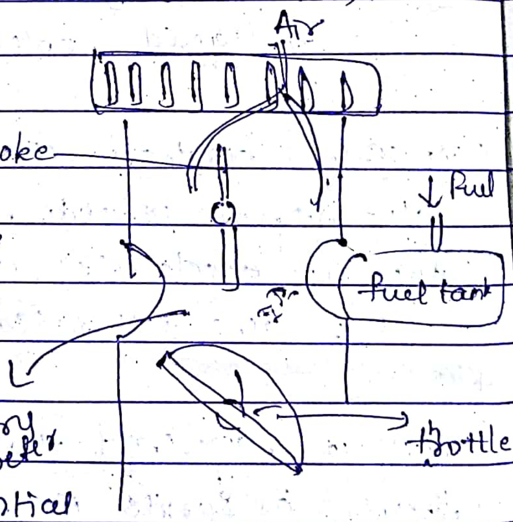
(as there is sudden interuption high voltage across 2° coil)

Electronics in automative:
→ Safety
→ Infotainment
→ Fuel efficiency

HHC → Hill-hold control.
I3S → Ideal start stop s/m
ACC → Automatic cruise control.

Parts of engine:
(1) Camshaft: Spark should appear at JBTDC (Just before Top Dead Centre) at 8 to 10°.
(2) Crankshaft: linear motion to rotational motion.
(3) Piston:
Modern vehicles have engines without camshaft i.e conventional vehicles. Here spark is provided by distributor.

(5) Carburetor: → To mix the air & fuel mixture in proper ratio.
→ Mainly appears in 2-wheel vehicles. (2 wheelers)
" → i.e Conventional vehicle
→ Bernoulli's principle
Ideal mixture: 14:1



drawback
(Consumes more fuel)
→ restricts the air intake

Venturi meter.
Creates differential pressure which helps to suck the fuel).

→ rich mixture: more fuel than air
→ ↳ needed during winter season ∴ we pull the choke.

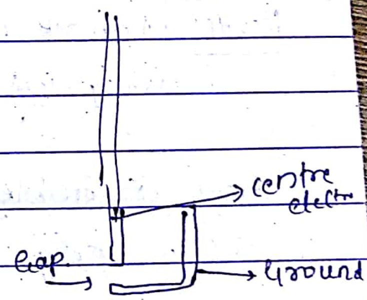
[Eventhough we won't accelerate the vehicle ie we start the vehicle but won't accelerate then also engine starts i.e. of idoling
→ bypass valve

Fuel ignition: (How fuel is ignited?)
→ 12V is used to step up to 20000 V.
→ ~~thru~~ spark plug.

Altemator:
→ charges the battery

→ Even if the battery is not there in 2-wheeler engine starts ~~btt~~ i.e. of alternator & destributor

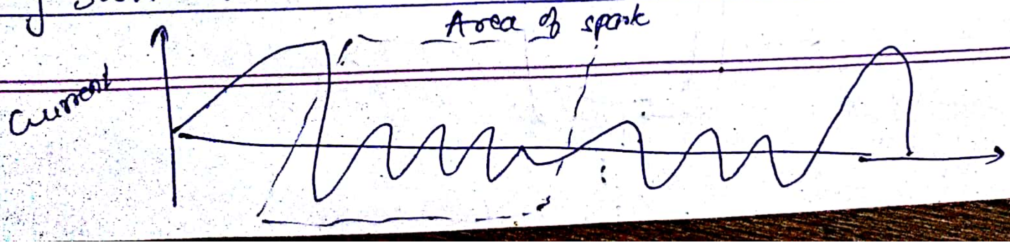
Ignition s/m:
Components:
→ Spark Plug
→ High voltage Circuit & distribution
→ Spark ~~plug~~ pulse generation



Spark plug:
Gap → 0.6 mm (0.025 inch) to 1 mm

High voltage Circuit & Distribution:
→ ~~Distributor provides spark to spark~~

Spark Pulse generation:
→ The actual generation of the high-voltage pulse is accomplished by switching the current thru the 'C' ckt



→ Number of flat surfaces on cam equal to no. of cylinders

Ignition timing
→ Ignition occurs some time before top dead centr (BTDC) during compression cycle

Breaking S/m
→ Disk brake (Front wheels ∵ they r costlier)
→ Drum brake (Rear " ∵ they r easy to activate but high maintainability).

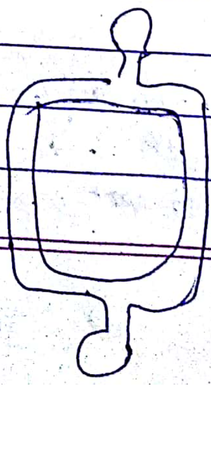
Differential gear:
→ helps during turns
→ ie lesser wheel (inner wheel) has to move ~~to~~ with lesser speed than the outer wheels. This gear helps in achieving it
→ It directs the torque

Suspension s/m
Parts: (1) Shock absorber/struct (main part)
(2) Spring

wheel assembly is called as unspring mass
car body " " " spring mass.

Electronic Suspension s/m can change (vary) the damping coefficient
(st. road) ride → low damping coefficient
(handling) corner → high " "
} convention s/m has constant damping coefficient whereas electronic suspension s/m can vary.

rides – how will ur vehicle respond to the road levels when u r driving straight



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Steering s/m:

Components:

→ Steering wheel

→ Steering column

→ Rack & pinion

→ Tie rod

→ Kingpin.

→ Modern s/ms use rack & pinion (convention s/m)

high compression ratio: disel → 25:1 gasoline → 10:1

1st step in disel engine: compression

Disel engines are autoignited.

On cold days → disel engines use glow plugs to ignite

disel fuel evaporates slower → ∵ disel is heavier.

Transmission s/m:

→ technique of providing different gear ratio / drive ratio b/w engine and ~~ge~~ wheels.

Types:

→ Manual transmission → Manual gear lever.

→ semi-automatic " → clutch is absent

→ Automatic

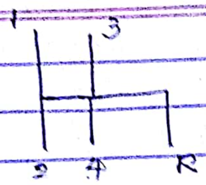
→ Automatic manual transmission

gear lever is not connected directly to transmission & gear is not present ie handled thru sensors.

2-wheelers:

→ Continuous Variable Transmission. (CVT)

standard gear box.



Smaller gear (1) → high torque
Large gear (4) → small "

Role of Technology:

Regulatory Requirements:

→ approval apply to technical specifications within the following area. (ARAI → Automotive Research Association India).

(1) Active safety (accident prevention)
(2) Passive safety

ARAI → certify all vehicles
ICAT → International Centre for

Types of the power Train — Based on Drive:

(1) RWD (Rear wheel Drive)
(2) FWD (Front " ")
(3) AWD (All " ")

Emission Norms in India:

→ BS-IV+ (Bharat Stage IV+) norms in India now

(1) India 2000
(2) Bharat stage II
(3) BS-III
(4) BS IV
(5) BS V (not implemented ∵ the fuel available in India)
(6) BS VI

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REVOLO : (product of kpit).

→ an intelligent plug in hybrid technology

→

BMS → Battery Management s/m

ECU → Electronic Control Unit.

Components:

→ EEPROM / Flash memory

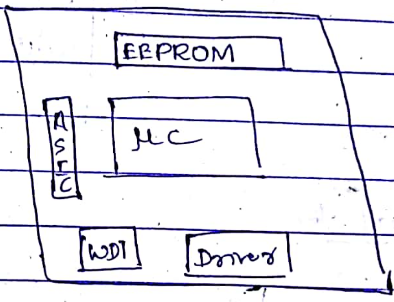
→ μC

→ Watch Dog Timer

→ ASIC

→ Driver

→ Analog & digital I/O wires



EEPROM : ~~needed~~ is used to store all the faults related to ECU. Present out side.

μC : ~~stores~~ has memory and stores only program code.

WDT : keeps the track of μC. , basically it is a counter.

ASIC : Application Specific Integrated Chip

→ to perform rel actions.

→ Power drive interface / control

→ More than 80 ECU's in modern vehicle.

Different Types of ECU:

Software types in ECU:

→ Application software : Ex: ABS,

→ Communicatn software :

→ Basic software (includes hardware monitoring software)

ie mainly: (1) Applicatn software/layer.

(2) Middle-ware

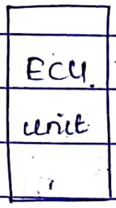
(3) Basic-software : (μC, drivers, I/O drivers, communicatn drivers).

REVOLO → technology developed by KPIT.

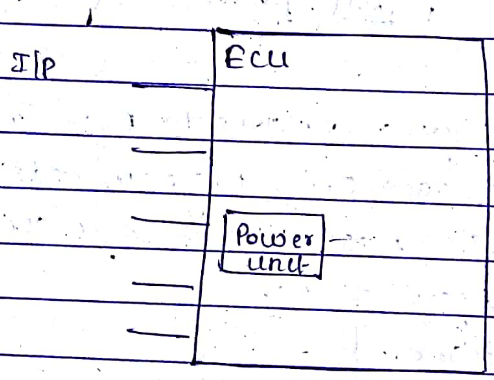
~~At~~ V-cycle development (software, hardware * - - . . .)

Components of ECU:

Inputs ⟶ Process ⟶ O/P.



ECU Internal ckt:



Functions and ECU's per vehicle:

EBD → Electronics Brake Distribution. (In convention equal amount of weight is applied)

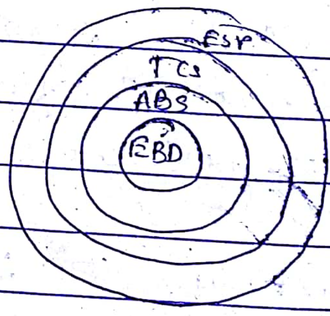
↳ based on situation it distributes the brake force

ie whenever brake is applied the ~~bod~~ weight of vehicle falls on front axel. ∴ large amount of brake is applied to the rare vehicle.

ABS →

↳ to reduce skidding

↳ to give space



TCS → Tracking control s/m

↳ applies brake when there is friction

↳ avoids spinning.

↳ brake the individual ~~value~~ wheel.

ESP → Electronic stability program
↳ to maintain stability of vehicle
ESP ++

ie ECU's are exploding ∵ they using same component but perform diff functions.

Life cycle of vehicles: ← 3 year → development ← 7 year → Production ← 10–15 yrs →

Units & Components

Electronic chassis s/m include:

- ABS (calculates speed of vehicle with the help of wheel speed sensors).
- ESP

Distributed & Networked Electronic s/m (Required to interface / provide network b/w diff ECU's)

Cruise control:

The vehicle moves with constant speed and doesn't detect any obstacle and driver has to be alert.

Adaptive Cruise control:

Here Obstacle is also detected.

It requires

- throttle control (to control speed).
- braking s/m.

Dashboard ECU: (to provide warning msg)

(5&7) Ribbons.

Chapter 2:

Need for electronics:

→ To control engine
→ " braking s/m
→ " suspension
→ " steering

Engine expectation:

→ pick-up ie, high power
→ Light-weight → high torque
→ Milage → Less fuel consumption
→ Less weight
→ Low emission
→ smooth running performance

We cannot achieve all these with conventional s/m. & also in Electronic control s/m (ECM) but we can go for optimised soln with help of ECM.

What is that u can control in engine via electronics.

→ temp (needed ∵ vehicle may explode or catch fire Ex Nano).
→ air & fuel intake ie valve control
→ Vibrations (knocks → unwanted vibrations) ↳ electronic term.

Knocks:

→ Occurs when combustion occurs much before TDC.
→ controlled by taking care of pistons.

By controlling knocks and emissions we can have impact on fuel consumption.

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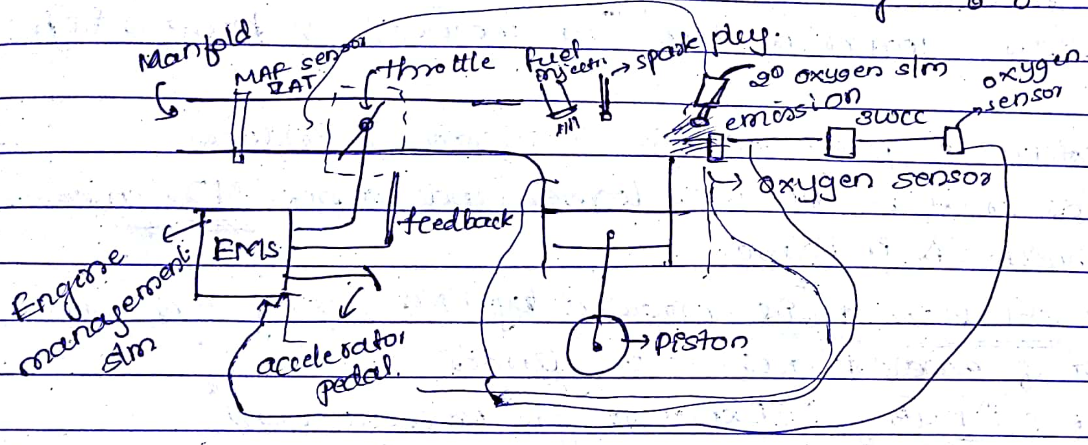
air & fuel = 14.7 : 1 (stoichiometric ratio).
↓ air ↓ fuel

best is = 16 : 1 → maximum benifit
→ economy is high



Conventional : throttle is directly connected to accelerator pedal
modern : sensor decides.

feedback: to know whether the throttle is attained its position

throttle : not only actuator but also sensor

rich mixture : fuel content more ∴ more emission
↓ needed in cold & hill station.

HC (hydrocarbon), CO, NOx (Nitrogen oxide)

MAF → sensor to check the air.

oxygen sensor: If oxygen content in emission is more then fuel was less. & if " " " is less then fuel content was more

∴ & this info is feedback to EMS. which controls the fuel injection period

3 way catalytic converter: (3WCC) (exhausts particles converter)
↳ converts $HC \longrightarrow H_2O$
$CO \longrightarrow CO_2$
$NO_x \longrightarrow N$

MAF (Mass Air Flow) sensor.

O_2
2nd oxygen sensor → provides information or effeciency of 3WC.

(modern engine)
→ Injector & throttle is used instead of carburettor ∵ air:fuel ratio remains same in carburettor.

In Rajastan: leaner mixture ⇒ more air ∵ temp is high

→ lean mixture is preferred ∵ it increases milage
but as mixture becomes leaner and leaner NOx emission ↑ by which Δ increases.

∴ a solution to it is provided by EMS by putting some amount of exhaust gass to cylinder.

It is "EGR (Exhaust gas Recirculation)."

→ IAT → Intake air temperature sensor (to see whether it is cold).
→ MAP → Manifold air pressure "
→ cranking: ~~Starting~~ Starting an engine → rich mixture needed.

→ 2° air injection s/m: needed ∵ in morning while starting vehicle (rich mixture) 3WCC ~~doesn't~~ ~~to~~ is not that efficient ∴ it needs extra oxygen, this oxygen is provided by 2° air injection s/m is needed
→ It is ~~also~~ at ~~intake~~ exhaust valve → to maintain temp.
→ It is driven by battery
→ EVAP → evaporate s/m.

Idle Air:

Idle air controllers

If vehicle is idling (engine is ON but not moving) & u switch ON the electrical components (like AC) then more load is found then idle air is used/managed.

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3WCC:

→ 3 phase

(1) Reduction (∵ o/p is O_2 which is used to oxidise the HC & CO)

(2) Oxidatn

(3)

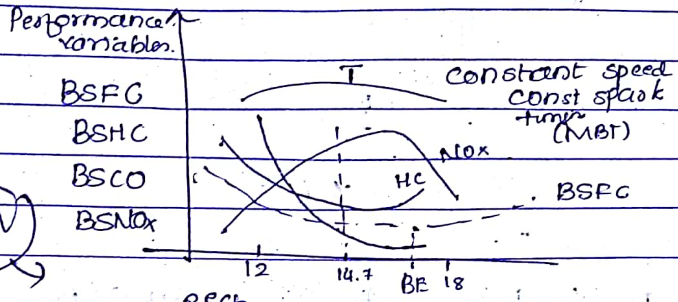
→ 3 elts: used

(1) Platinum

(2) Rhodium

(3) Paladium

GM

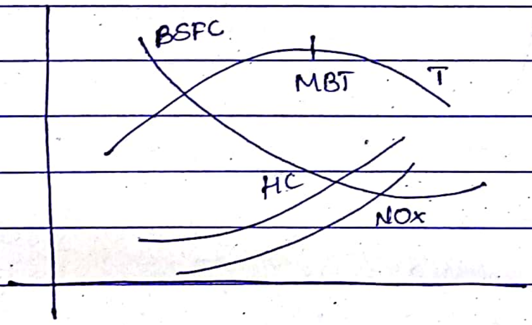


Mufflers to reduce the sound waves

From graph we observe as fuel mixture becomes leaner & leaner NOx ~~was~~ rises

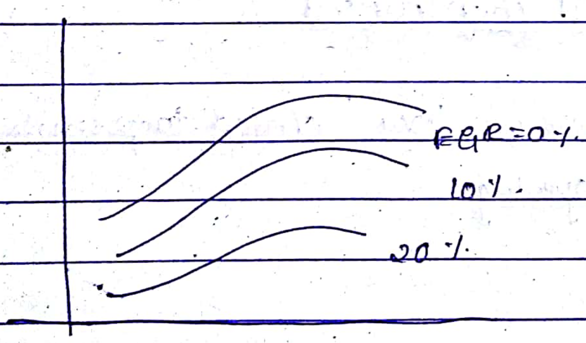
Typical variatn of performance with spark timing

** imp:



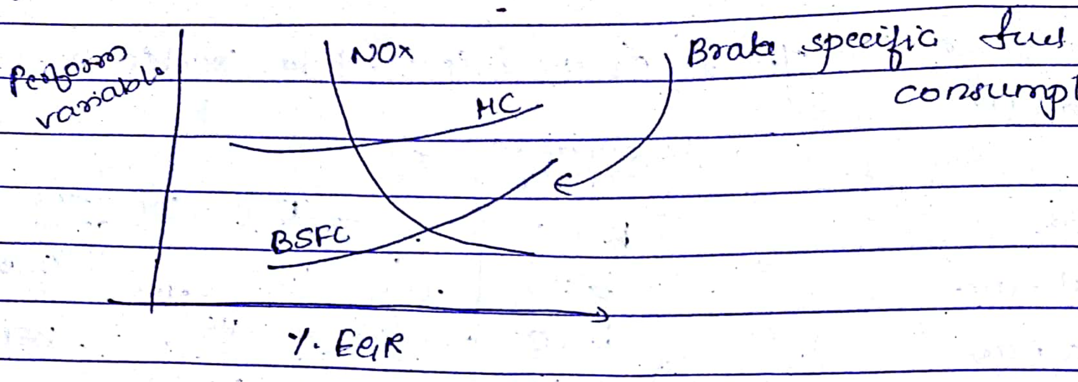
NOx Emission as a fun of EGR at various Air/Fuel Ratios.

~~imp~~



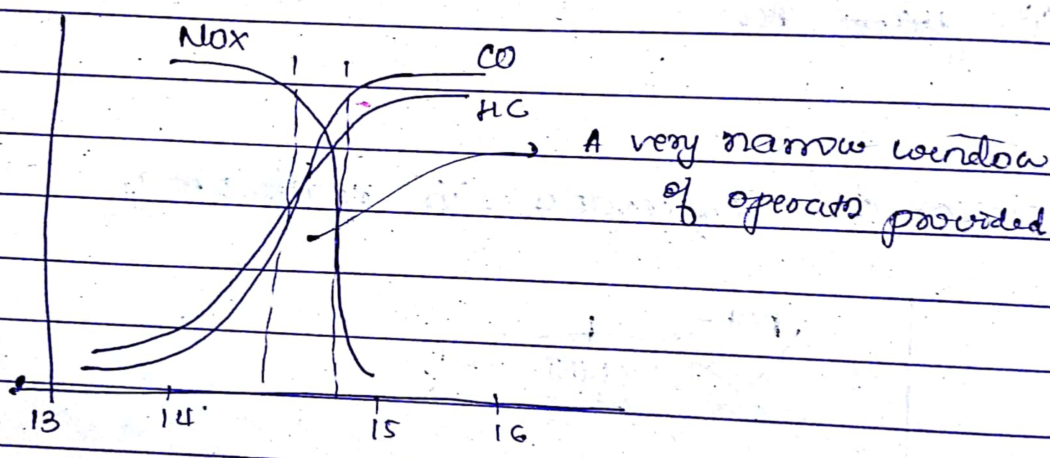
Greater EGR, lower NOx

→ Engine Performance with EGR.



as % EGR ↑ it is replacing O_2 contents ∴ mixture becomes rich.

→ Conversion efficiency of TWC.



HC 0.31 g/mi
CO 4.20 g/mi

Open loop control & closed loop control → based on feedback
→ 14:1 (ratio).
→ when oxygen sensor is low, closed loop control becomes openloop.

Engine Control Sequence:

$$\lambda = \frac{\text{actual air fuel ratio}}{\text{ideal " " (14.7:1)}}$$

$\lambda > 1$ → lean mixture.

< 1 → rich "

→ rich mixture ie mixture is set rich by amount depending on engine temperature (obtained by engine coolant temp).

→ Once the EGO sensor has reached . .

Open-loop Control

Inputs: (1) MAF (Ma)

(2) Accelerator pedal position sensor

(3) RPM

(4) Coolant temperature.

O/P: from controller:

Fuel injectn quantity (Mf).

$$M_f = \gamma_{fa} M_a.$$

where γ_{fa} = desired ratio of fuel to air.

M_a = Mass of air

** for a fully warmed up engine, this ratio is 1/14.7 fuel to air

for a very cold engine, the mixture ratio can go as low as 2 fuel to air

Numericals

Closed-loop

Inputs:

(1)

(2)

(3)

(4)

(5) O/P from EGO.

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Measuring Air Mass:

→ 2 methods of determining the mass flow rate of air

(1) using MAF sensor.

(2) MAPS (Manifold Absolute Pressure Sensor)

↳ speed-density method

↳ when MAF fails.

For a given volume of air (V).

6M

$$d_a = \frac{M_a}{V}$$

$$M_a = d_a V.$$

air is assumed to be moving thru a uniform tube

$$\boxed{R_m = R_v d_a}$$

R_m = mass flow rate

R_v = volume flow rate

d_a = air density in the intake manifold

$$d_a = d_o \times \left(\frac{P}{P_o}\right) \times \frac{T_o}{T_i}$$

d_o = standard density

P_o = Standard Press.

T_o = " temp

$$\boxed{R_v = \left(\frac{RPM}{60}\right)\left(\frac{D}{2}\right) \eta_v}$$

D = displacement

η_v = volumetric efficiency

Including EGR

$$\boxed{R_a = R_v - R_{EGR}}$$

$$\boxed{R_a = \left[\left(\frac{RPM}{60}\right)\left(\frac{D}{2}\right) \eta_v\right] - R_{EGR}}$$

Electronic

Engine Position Sensor

P_b

P_b = pow

MA =

= C

→ Power:

brak

→ actu

power

→ BFSC

→ Thermal

→ Calibrate

→ BSHC =

→ BSCO

→ BSNox

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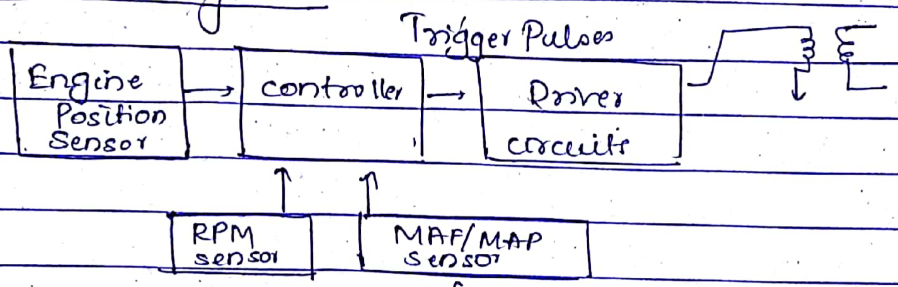
Electronic Ignition



↳ to reduce knock →

$$P_b = K M_A$$

P_b = Power from engine (hp or kw)

M_A = Mass of air.

K = constant relating power to air

→ Power: → delivered by engine to the dyanamometer is called the brake power (P_b)

→ actually developed in the engine is called indicated power (P_i)

$$P_b = P_i - \text{friction + other losses.}$$

→ BFSC

→ Thermal efficiency: only 20% energy is being used to drive the wheels

→ Calibration: setting the air/fuel ratio

→ $BSHC = \frac{r_{HC}}{P_b}$

→ $BSCO = \frac{r_{CO}}{P_b}$

→ $BSNO_x = \frac{r_{NO_x}}{P_b}$

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