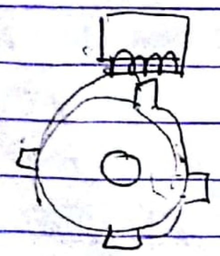
Sensors & Actuators

Air flow rate sensor:-

Engine speed sensor

1. An engine speed sensor is needed to provide an input for electronic controller for several function. position sensor is also used to measure engine speed.
2. If we consider the magnetic reluctance sensor. We notice that the 4 tabs will pass through sensing coil once for each crankshaft revolution. Therefore if we count the voltage pulse from the sensing coil per minute & divide by 4. Then engine speed in revolution per minute RPM will be known.
3. This can be obtained by using the timing circuit same as used in the clock. this will start the counter circuit that will count pulse until timing circuit stops.
4. The counter can have divide by 4 · or separate may be used. & In many cars separate RPM sensor disk will be mounted near the flywheel & has more than 4 tabs.



Thursday Friday Saturday Sunday Monday

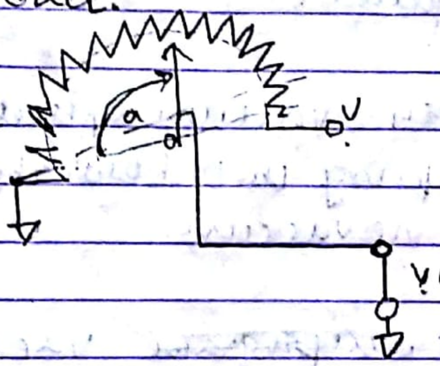
Throttle position sensor

Another important variable to measure the throttle plate angular position.

→ The throttle plate is linked to the Accelator mechanically. When the Accelator pedal is depressed this linkage causes throttle plate angle to increases allowing more air to enter the engine that in turn increases the power of engine

→ Most throttle angle sensor will be potentiometer

→ A potentiometer consists of resistor with movable contact.



$V(\alpha) = k\alpha$

→ A section of resistance material is placed in an arc form along the pivot & axis for the movable contact.

→ One end of the resistor is connected to ground & other end is connected to a fixed voltage.

→ Voltage at the contact point of the movable contact is proportional to the angle α from the ground contact to the movable contact.

$V(\alpha) = k\alpha$

→ This potentiometer is used to measure the any angular position especially the throttle angle.

→ But the only disadvantage is its analog o/p

→ engine has to convert it to digital before use

Exhaust Gas Recirculation Actuator.

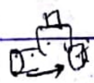
→ EGR is utilized to reduce the NOx emi

→ The amount of EGR is regulated by the controller.

When the correct amount of EGR is determined by the controller based on the measurements of various sensors, the controller then sends the ~~....~~ electrical signal to the EGR actuator.

→ This EGR actuator is variable position valve that regulates EGR, based on intake manifold & exhaust gas pressure.

→ This actuator is vacuum operated diaphragm valve with a spring that hold the valve closed if there is no vaccum.



The ~~vacuum to diaphragm~~ vaccum that operates the diaphragm is supplied by the pressure of intake manifold & is controlled by solenoid operated valve. This solenoid valve is controlled by the control s/m

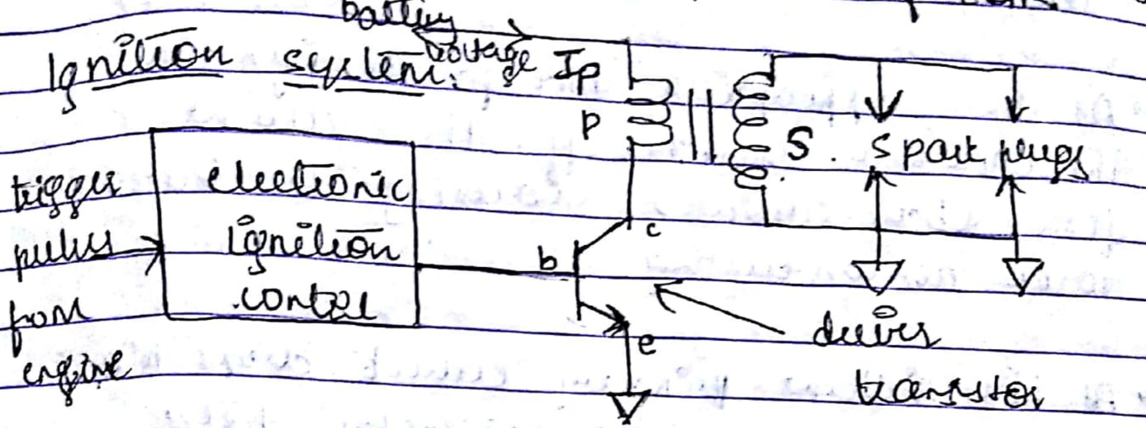
→ Whenever the solenoid is energised the EGR valve is opened by the applied vaccum.

→ The amount of valve opening is determined by the average pressure on the vaccum side of the diaphragm.

→ This pressure is regulated by variable duty cycle pulse applied to solenoid.

The duty cycle fixes of this pulsing current controls the power pressure in the chamber that affects the diaphragm deflection. thereby regulating the amount of pressure of EGR.

Ignition system:



→ The equivalent actuator for the ignition s/m on an engine is the combination of the spark plugs, ignition coil, & the electronic driver circuit

→ This subs/m receives the electrical signal from the engine controller & delivers its output, the spark that ignites the mixture during the end of the compression stroke.

→ From the above block diagram. The primary circuit of the coil depicted as P is connected to the battery & through power transistor it is grounded.

→ The secondary circuit of the coil is connected to the one or more spark plugs

→ The base current to the power transistor is supplied by the electronic controller making the transistor conductive which will act as closed switch

Relatively large current denoted by I_p flows through the primary winding & thereby creating relatively very large magnetic field that is linked to the secondary coil.

→ At the appropriate time for the ignition the controller switches off the current flow (base current), causing the transistor to be nonconducting.

→ At this instant primary current drops to 0 quickly, causing the magnetic field strength to drop rapidly, also

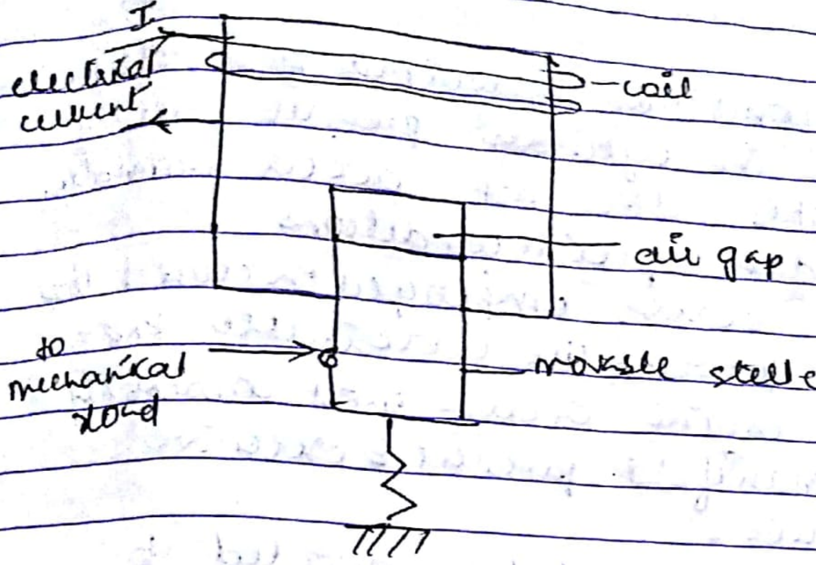
→ The very rapid drop in the magnetic field will generate very high voltage (30k to 80kV) which in turn creates the spark across the spark plug electrodes igniting the mixture.

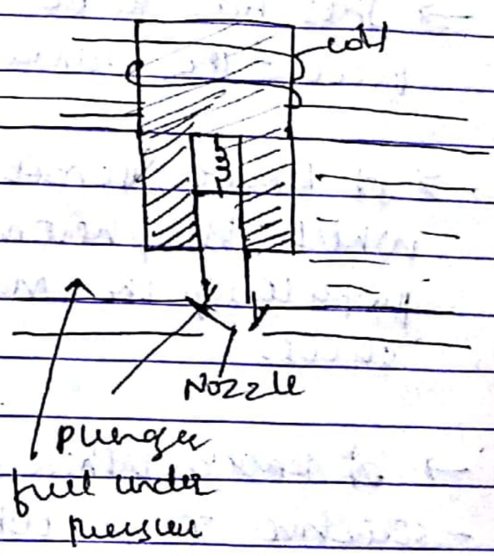
Automotive Engine control Actuator.

Actuator is a device that receives an electrical input & produces the mechanic or thermal action. e.g. solenoid, piezoelectric force generator.

Solenoid Operation

Fuel injection





A fuel injector is solenoid operated valve.
The valve opens or closes to permit or block fuel flow to the engine.

Valve is attached to the movable element of solenoid & is switched by solenoid actuation.

no current flowing in the coil = solenoid element is held down → fuel is blocked

flow of current in coil = solenoid element moved upward → fuel is permitted to flow

fuel flow rate = constant for given regulated fuel pressure & nozzle geometry

Quantity of fuel flow = time the valve is open.

Knock sensor

→ Knock is a condition described generally as rapid rise in cylinder pressure during combustion. This does not occur normally but only under special conditions.

→ & There is sensor employed in closed loop timing to prevent the undesirable knock.

→ Knocking of engine occurs most commonly with high manifold pressure & excessive spark advance.

→ This has to be detected & avoided to prevent the damage to engine.

→ A knock sensor uses magnetostriction technique which is phenomenon whereby the magnetic properties of the material changes depends upon stress.

→ A knock when sensing knock, the magneto-striction rods which are in magnetic field change the flux field in the coil due to knock induced forces. This change in the flux field produces voltage change in the coil. This voltage is used to sense excessive knocking.

→ which will form a closed loop s/m that retard the ignition to reduce the knock detected @ the cylinder.

→ Other knock sensors may be piezoelectric crystals or the piezoresistance of doped Si

Communication Protocals

CAN
LIN
Flexray
MOST

communication in a vehicle is needed
- to reduce the cost
- to reduce size
- to reduce the complexity
- to improve performance

CAN : Controller Area network:-

1. CAN is a serial bus system that is used to communicate with several embedded 8 bit or 16 bit S/ws. It was originally designed for automotive industry only but used for other applications too
2. It is asynchronous serial transmission protocal
3. highest Baud rate of 1Mbits/sec (8 bits in a frame)
4. uses message oriented tx protocals
5. There is no defined addresses, only defined messages.
6. Non destructive arbitration with CSMA CD
7. Multi master / Broadcasting concept
8. sophisticated error detection & handling s/m
9. Prioritization of messages
10. Fault confinement, Bit stuffing, NRZ format
11. Plug in/out protocal
12. ISO-OSI compliant
13. event trigged protocals

→ Hardware implementation of this protocol can be done by combination of error handling & fault confinement with high to

→ Twisted pair cable is usually used as tx media

→ There is built in feature to prevent the faulty node to block sm by fault confinement technique

CAN only standardizes the 2 layers
1. Data link layer
2. Physical layer

→ Application layer
All other high level protocols are used in Application layer

ISO-OSI Reference model [CAN layers]

Application layer
Data link layer - Logical link control sublayer - Medium Access control sublayer
Physical layer

The operations of Data link layer are sus. divided into 2 sublayers
1. Logical link control
2. Medium Access control

Scanned by CamScanner

Logical link control sublayer performs
- Acceptance filtering
- Overload notification
- Recovery management

Medium Access controller (MAC) sublayer performs
- Data encapsulation / Decapsulation
- Medium Access management
- Error Detection
- Error signalling
- Serialization / Deserialization

Physical layer performs
- Bit encoding decoding
- Bit timing bus failure
- synchronization management

CAN protocols
→ There 4 types of ~~data~~ frames
1. Data Frame
2. Remote frame
3. Overload frame
4. Error frame

Data frame:→

Idle	SOF	identifier	RTR	IDE	r0	DLC	Data	CRC	ACK	EOF	IFS	Id

SOF → start of Frame
Identifier : this field tells about data & its ID

RTR : Remote Transmission Request
IDE : Identifier extension [distinguishes b/w CAN std, 11 Bit & CAN extended 29 bit
r0 : reserved
DLC : Data Length Code
Data : 8 bytes of data
CRC : cyclic Redundancy check, that checks & detects & corrects the data bit errors by performing XOR operations
ACK : This is to acknowledge the Reception of the message
EOF : End of frame, to detect the end

CAN messages

→ Messages are distinguished by its identifier. This identifier defines the content & the priority of the message & the message identifier is unique to its network.

→ Messages over the CAN Bus have got its priority, the identifier with the lowest Binary value has the highest priority.
→ & The one who has highest priority wins & gets access to the bus.

→ The priority are specified during s/m design & cannot be changed dynamically

→ When all the nodes try to send the messages at the same time, conflicts occurs on Bus which can be resolved using "wired" mechanism where the dominate state overwrites recessive state

→ The nodes which doesn't get access tries to send message continuously unless the Bus gets free / available until then they automatically becomes receiver

→ If one or more errors are detected then the transmission is aborted. This prevents all other nodes to receive the message

→ Retransmission is automatic. Once there is continuous error occurance then all the Receivers will switch it off by itself from being tied up to bus

→ These errors detection is done on 2 levels
- Message level
- Bit level

Vehicle motion control

Cruise control system

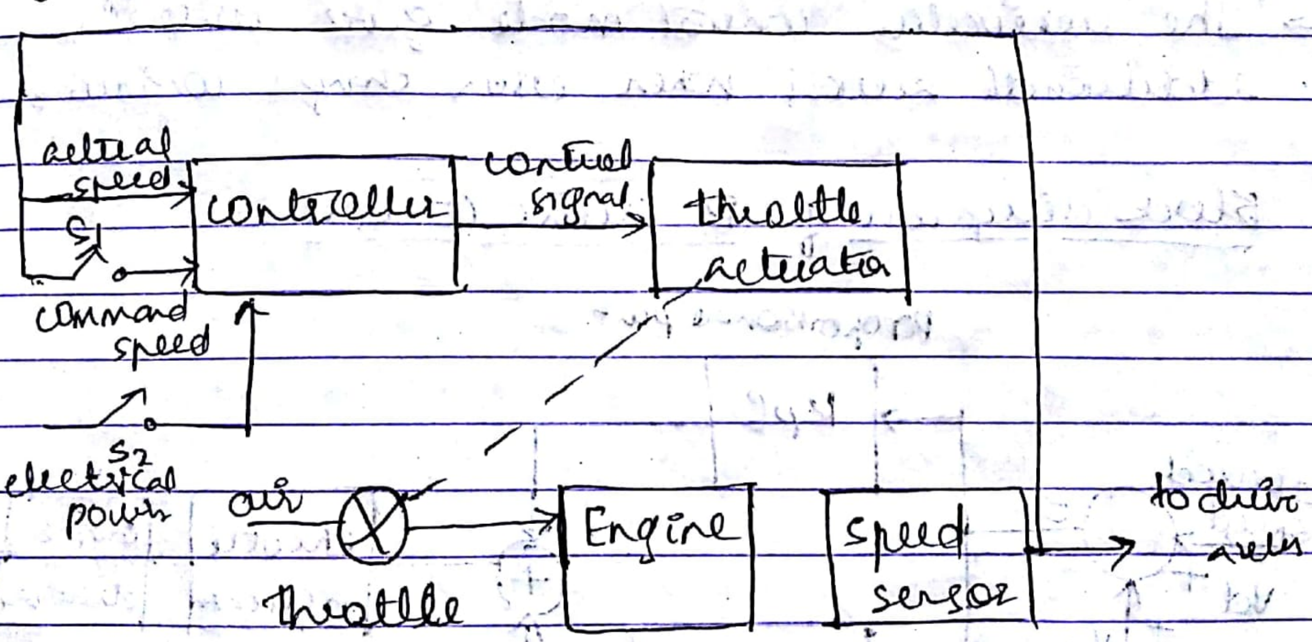
→ Cruise control is a system that automatically controls the speed of a vehicle.
→ The system takes over the throttle of the car to maintain a steady speed as set by the driver
→ The main problem regarding the normal cruise control technology is that it is not aware of other vehicle movement
→ The driver need be always aware, Hence possibilities of mistakes
→ possibility of collision with the leading car if not manually slowed down

Operation

→ In the case of cruise control, the variable being regulated is the vehicle speed. The driver manually sets the desired speed via accelerator pedal.
→ Upon reaching the desired speed, the driver then activates the momentary contact switch (S_1) that sets the speed as the command input to the control s/m
→ From that point onwards the cruise control s/m maintains the desired speed automatically by operating the throttle via throttle actuator.
→ There is a disable switch S_2 which disengages the cruise control s/m completely from power supply such that throttle control reverts back to the accelerator pedal. It is safety feature
→ The disable function can be activated in variety of ways. A brake pedal that disable cruise anytime when brake is pressed

→ Throttle Actuator operates the throttle based on the error b/w the desired & actual speed.
→ Whenever actual speed is less than the desired speed the actuator opens the throttle still more & increases the vehicle speed until error is zero & viceversa.

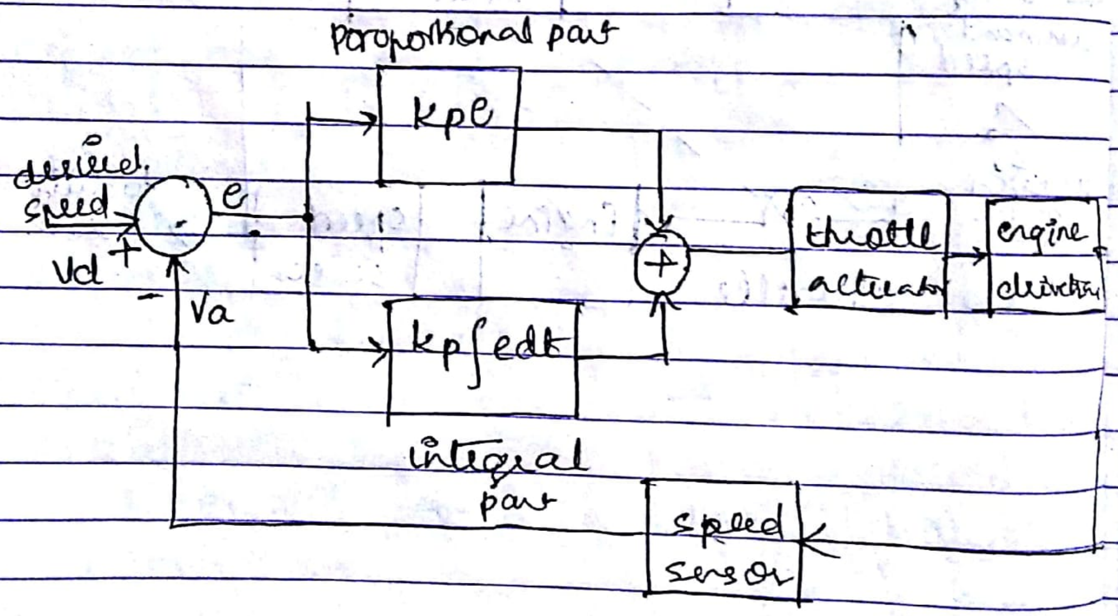
Block diagram of cruise control



PID - proportional integral differential CC

→ The proportional term produces an o/p value that is proportional to the current error.
→ The contribution from the integral term is proportional to both the magnitude of the error & the duration of error
→ The derivative control is predicting the future error based on the current slope of error
→ The derivative control mode gives controller additional action when error changes continuously

Block diagram of PI cruise controller



→ A block diagram of cruise control s/m is shown. Proportional integral strategy has been assumed. This reduces speed errors due to disturbances
→ An Error e is formed by subtracting the actual speed Va from the desired speed Vd.

$$e = Va - Vd$$

→ The controller then sends an actuation signal by combining a term proportional to the error (Kpe) & term proportional to the integral of the error ($K_i \int e\,dt$). The actuator signal u is combination of these 2 terms

$$u = K_p e + K_i \int e\,dt$$

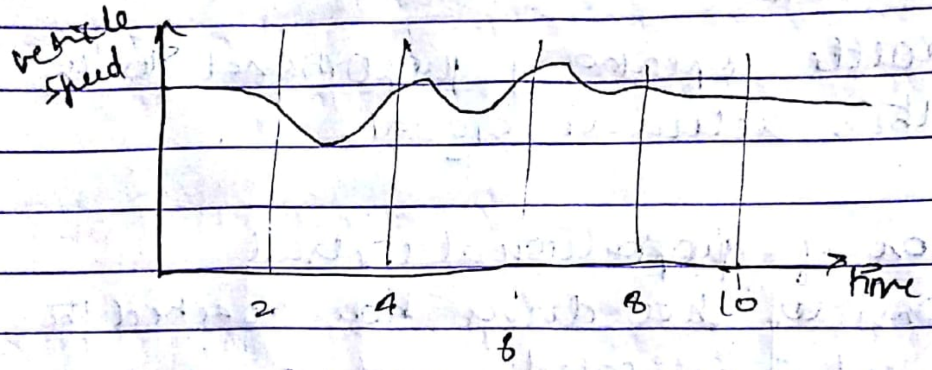
→ The throttle opening is proportional to the value of this actuator signal

→ Operation of proportional control
If we consider that driver has reached the desired speed & activated speed set.
- If car is travelling on a level road, then error is zero & throttle remains @ fixed position
- If car were to enter hill the slope @ the current position, engine will produce less power hill represents disturbance to s/m. & vehicle speed will decrease introducing error. This in turn will increase the actuator signal causing increase in engine power in turn increasing the speed & keep it balance

Operation of Proportional integral control
→ The steady error when integrated produces an ever increasing output from the integrator. This causes the actuator to increase further with resulting speed increase.
→ In this case the actuator o/p will increase until the error is reduced to zero

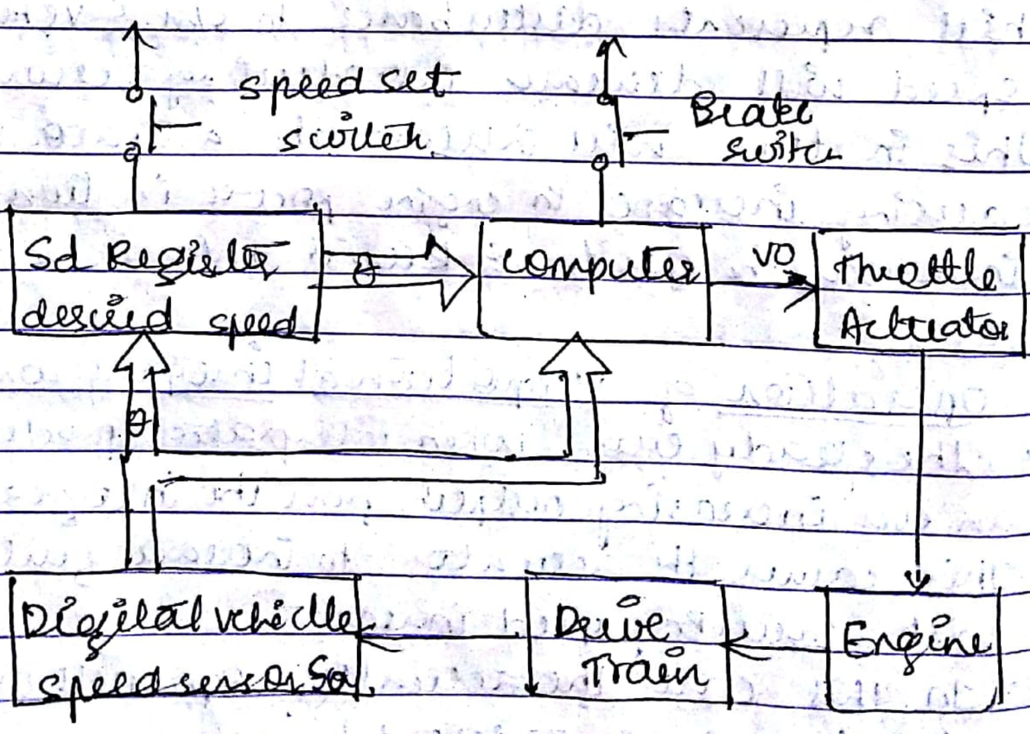
Response characteristics of PI controller strongly depends on the choice of gain parameters Kp & KI.

→ It is possible to select values of gain in order to increase the speed of the s/m in response to disturbance



Digital cruise control.

Block diagram



→ Cruise control system is now digitally implemented using microprocessor based computer.

→ For such s/m proportional, integral control computation are performed numerically in computer.

→ block diagram for typical digital cruise control is shown.

The vehicle speed sensor used is digital.

→ When the car reaches desired speed S_d the driver activates the speed set switch.

→ At this time the output of vehicle speed is transferred to a storage register.

→ The computer continuously reads the actual speed S_a & generates an error e_n at the sample time, t_n

$$e_n = S_d - S_a \Big|_{at\ t_n}$$

→ A control signal d, is computed that has the following form

$$d = K_p e_n + K_I \sum_{m=1}^{M} e_{n-m}$$

→ Where Σ → that adds the M previously ~~previous~~ calculated errors to the present error

→ This sum is multiplied by the integral gain K_I & added to the most recent error multiplied by the proportional gain K_p to form the control signal.

→ This control signal is actually the duty cycle that is applied to the throttle ~~sensor~~ actuator. The throttle opening increases or decreases as 'd' increases or decreases due to the action of the throttle actuator

Adaptive cruise control

Due to the drawbacks of cruise control we go for Adaptive cruise control.
Drawbacks are
→ The main problem regarding the normal cruise control technology is that it is not aware of other vehicle movement
→ Possibility of collision with the leading car if not manually slowed down.

I Introduced

→ With the introduction of Adaptive cruise control speed would be automatically adjusted for safe inter-distance that is longitudinal control of vehicle.

→ Once the safe inter-distance is reached the speed would return to the desired speed set by the driver

→ Adaptive cruise control s/m is constitute of buttons on the steering wheel taken as input, brake, clutch, gas pedal & feedback of
→ processor
→ Output : throttle position.

Operation
→ With ACC we can accelerate or decelerate the car by 1mph with the tap of button
→ Hitting the ON button tell the ECU to switch ON ACC viceversa

The set/accel button tells the car to maintain the speed, currently driving in. Holding down the set/accel button will make the car accelerate & on this car tapping it once will make the car go 1 mph faster

→ Holding down the coast button will cause the car to decelerate, just as if taking foot off completely from gas pedal.

→ The brake pedal & clutch pedal each have a switch that disengages the cruise control as soon as the pedal is pressed & cruise control s/m is shut off with a light tap on the brake or the clutch

→ Main functions of ACC are
1. it Presets & maintain the car speed
2. Measures the distance to the preceding car & relative speed.
3. Adjust the car speed accordingly
4. Maximum deceleration = 3.5 m/sq

→ Types of ACC
1. Radar Based s/m
   → 3 overlapping radar beams (76-77 kHz
   → Detects moving object upto 120m
   → works in poor weather conditions
2. Laser Based s/m (Lidar)
   → less expensive & easier package

→ Sensors used in ACC S/M are
1. wheel speed sensor
2. Throttle position sensor
3. Brake pressure sensor
4. Radar/lidar sensor