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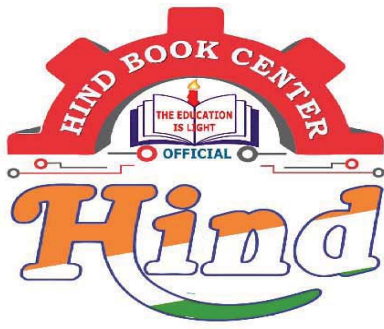
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System :- The means of transforming a signal.

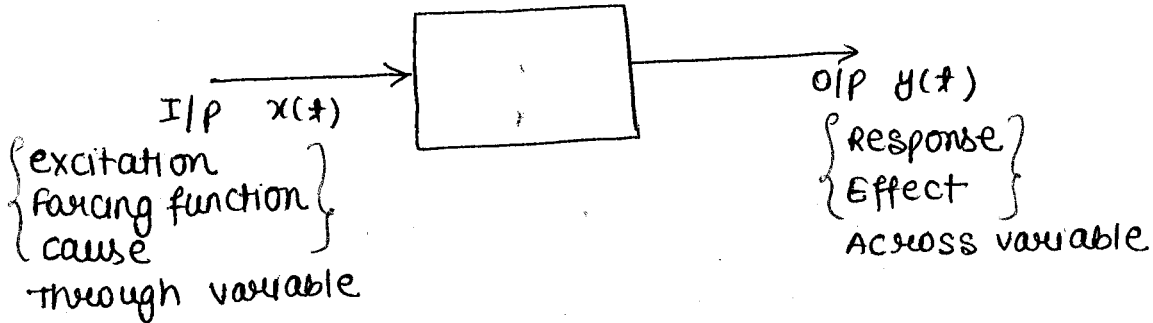
Signal is a form of energy that contains information of some phenomenon. Mathematically, signal can be defined as one or more number of independent variables.

ex-: speech =  $f(t)$

Room temperature =  $f(x, y, h, t)$

Image =  $f(x, y)$

video =  $f(x, y, t)$



$$y(t) = T[x(t)]$$

Control system :- Control system is that means by which any quantity of interest is maintained or altered according to a desired manner.

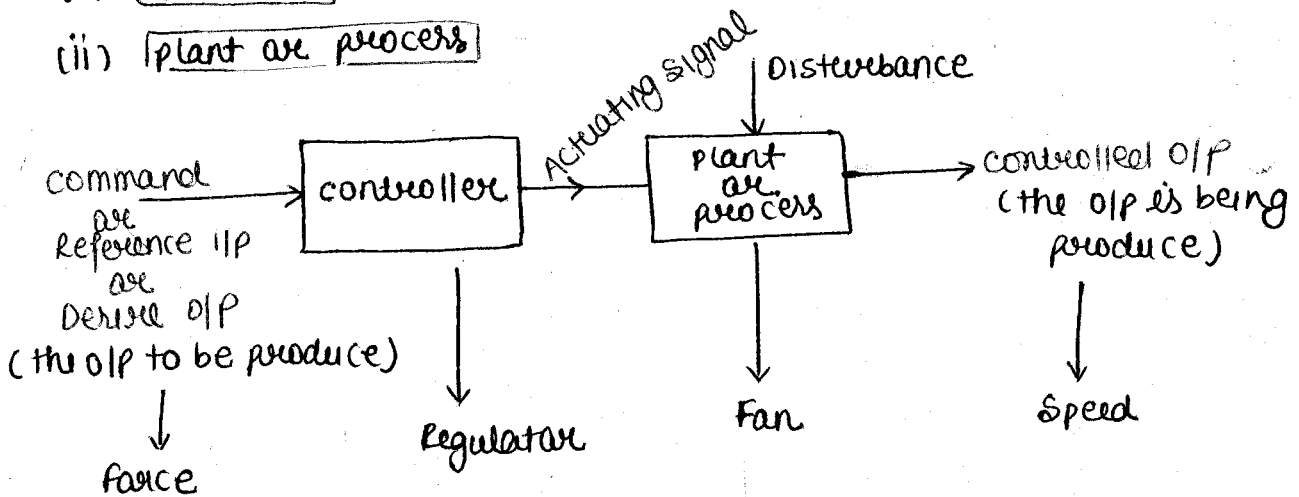
ex-: system : J/K F/F

Master slave F/F : control system

To make control system we need basically two element -

(i) controller

(ii) plant or process



SISO :-

MISO :-

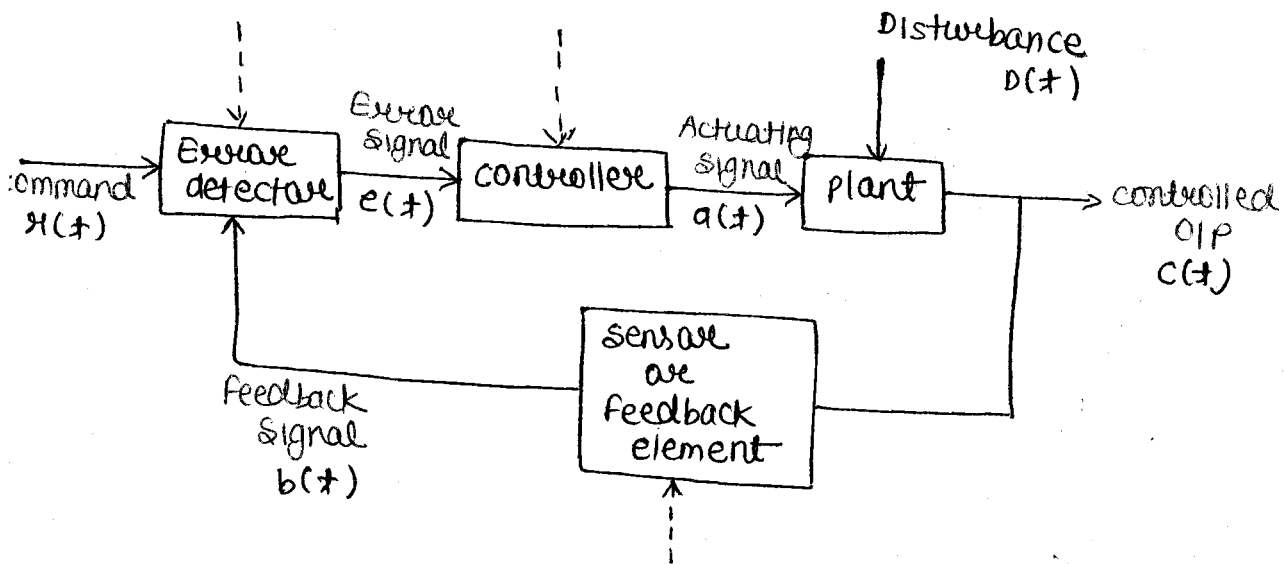
MIMO :- Automobile

SIMO :-

The objective of any control system is to ensure that controlled output become same as desired o/p. This state of the system is called steady state.

without disturbance, control system is Ideal. but in practical system, there will be disturbance along with it.

practical control system :-



$$C(t) = C_r(t) + C_D(t) \quad [\text{linear combination because } r(t) \text{ \& } D(t)]$$

both are independent to each other]

$$\text{Disturbation} = \text{Distraction} + \text{Noise}$$

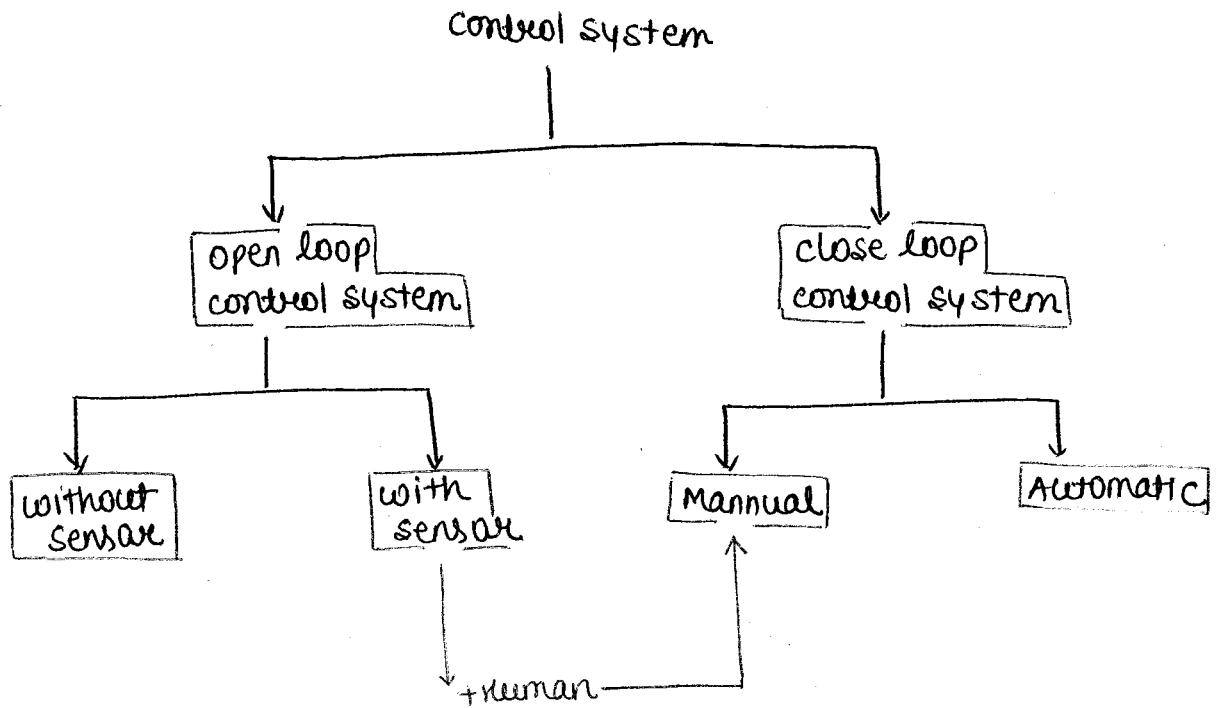
↓                      ↓  
 Internal            External  
 disturbance        disturbance

Above system can overcome, the effect of disturbance associated only with the plant whereas the other disturbances still continues. Hence a system can attain steady state but not with 100% output within finite time.

+10 = 10∠0° → +ve feedback i.e; in phase

-10∠ = 10∠180° → -ve feedback i.e; out of phase

control system is classified into two categories -



Differences between open loop and close loop system :-

open loop control system	close loop control system
(i) The behaviour of OLCs does not change, though its output changes. Hence <u>OLCS</u> is <u>not accurate</u> .	(i) The behaviour of close loop system if its output changes. Hence <u>CLCS</u> is <u>accurate</u> .
(ii) open loop system <u>may or may not</u> have <u>sensors</u> but it does <u>not</u> have <u>complete sense</u> .	(ii) close loop system has <u>complete sense</u> either <u>manually</u> or <u>Automatically</u> .
(iii) Time constant of open loop system is larger, due to which transients take large time to die out. Hence <u>open loop system</u> is <u>slow</u> .	(iii) Time constant of close loop system is smaller, due to which transients die out rapidly. Hence <u>close loop system</u> is <u>faster</u> .
(iv) Effect of external disturbance and internal parameter variation is more in OLCs i.e; <u>OLCS</u> is <u>more sensitive</u> .	(iv) Effect of external disturbance and internal parameter variation is less in close loop system. i.e; <u>close loop system</u> is <u>less sensitive</u> .
(v) The OLCs is generally stable but can be stabilize when it becomes unstable.	(v) close loop system <u>can become unstable</u> but <u>can be stabilized</u> .
(vi) OLCs is <u>simple</u> & <u>economical</u>	(vi) CLCS is <u>complex</u> & <u>expensive</u> .

NOTE: (i) The transient in system are due to stored energy / change in i/p / change in load condition

(ii) sequence of step to stabilize a system -

step 1 :- Apply feedback, preferably negative feedback.

step 2 :- Adjust system parameters preferably open loop gain.

step 3 :- Insert a controller / compensator preferably P+D controller / lead compensator.

ste

(iii) A system can be stable or unstable or marginally stable with any feedback, but a system is always more stable with a negative feedback compared to positive feedback.

(iv) In spite of having negative feedback, control system can still become unstable due to high open loop gain / high type number / high sensitivity / High transport delay or lag phase.

By default we have to consider — will be close loop control system.

parameter	180° -ve F.B.	0° +ve F.B.
Gain	↓	↑
Bandwidth	↑	↓
Time constant	↓	↑
speed	↑	↓
sensitivity	↓	↑
stability	↑	↓

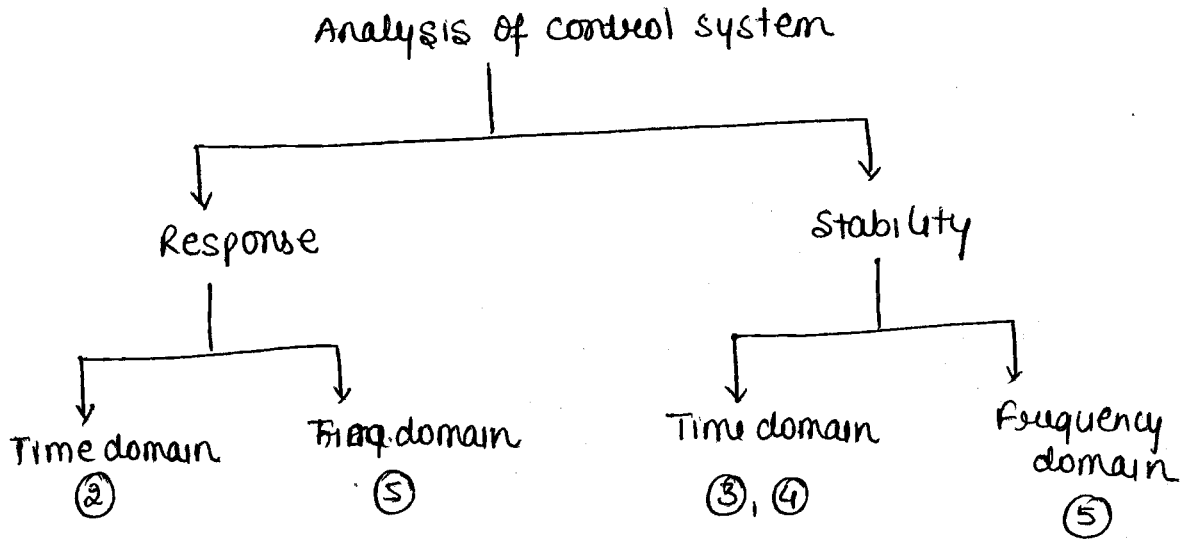
Gain × Bandwidth = constant      Time constant × speed = constant

sensitivity × stability = constant

- (i) study the system design } mathematically
- (ii) Redesign

standard model :-

- (i) TIF model (only for LTI)
- (ii) state model (Any system)



Redesign — 6

state model — 7

	T.D.	F.D.
C.T. System	L.T.	F.T.
D.T. System	Z.T.	D.T.F.T.

L.T. :- Laplace transform

F.T. :- Fourier transform

Z.T. :- Z-transform

DTFT :- Discrete time Fourier transform.

$$\boxed{\text{T.F.} = \frac{L[\text{OIP}]}{L[\text{IIP}]}} \quad \text{initial condition} = 0$$

$$\boxed{\text{Total response} = \text{ZIR} + \text{ZSR}}$$

due to initial condition / state  $\leftarrow$

$\leftarrow$  due to i/p

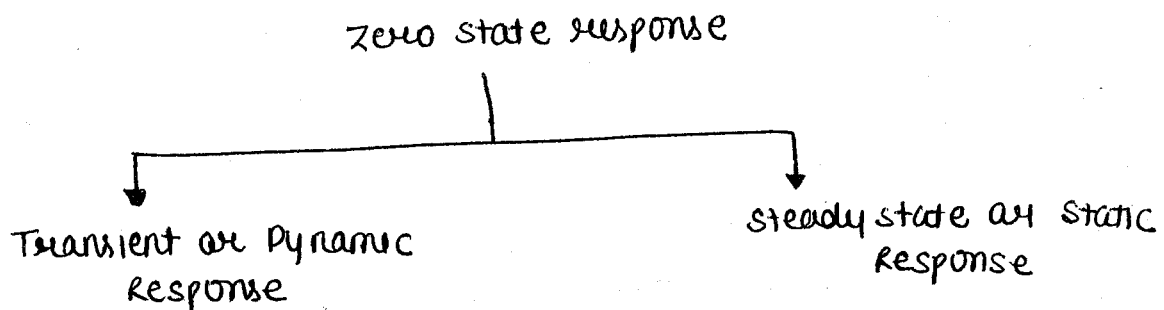
ZIR - zero i/p response  
i.e., i/p = 0

ZSR - zero state response

$$y = c + \frac{mx}{\quad}$$

$\leftarrow$  due to i/p because x is a part of it.

NOTE:- ZIR is consider then analysis will be done in state model only.



$$\boxed{\text{T.F.} = \frac{L[\text{OIP}]}{L[\text{IIP}]} = \frac{L[\text{IR}]}{L[\delta(t)]} = \frac{L[\text{SR}]}{L[u(t)]} = \frac{L[\text{RR}]}{L[1+u(t)]} = \frac{L[\text{PR}]}{L\left[\frac{t^2}{2}u(t)\right]}}$$

$$\boxed{\text{T.F.} = L[\text{IR}] = sL[\text{SR}] = s^2L[\text{RR}] = s^3L[\text{PR}]}$$

Q.N:- SR =  $1 - 10e^{-t}$  then T.F. = ?

Solution:- T.F. =  $sL[\text{SR}]$

$$= s \left[ \frac{1}{s} - \frac{10}{s+1} \right] = s \left[ \frac{s+1-10}{s(s+1)} \right] = \frac{1-9s}{s+1}$$



$$SR = (1 - 10e^{-t})u(t)$$

$$\frac{d}{dt}(SR) = IR$$

$$\text{NOW } IR = \delta(t) - 10[e^{-t}\delta(t) + u(t)e^{-t}(-1)]$$

$$= \delta(t) - 10\delta(t) + 10e^{-t}u(t)$$

$$= -9\delta(t) + 10e^{-t}u(t)$$

$$\text{T.F.} = L[IR]$$

$$= -9(1) + \frac{10}{s+1} = \frac{1-9s}{s+1} \quad \text{i.e., Transfer function is unique function}$$

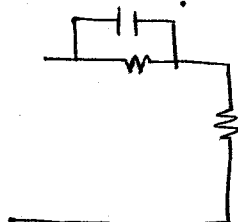
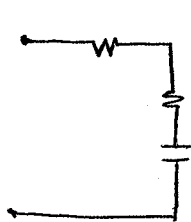
$$SR = (1 - 10e^{-t})u(t)$$

$$RR = \int_0^t (SR) dt = \int_0^t (1 - 10e^{-t})u(t) dt =$$

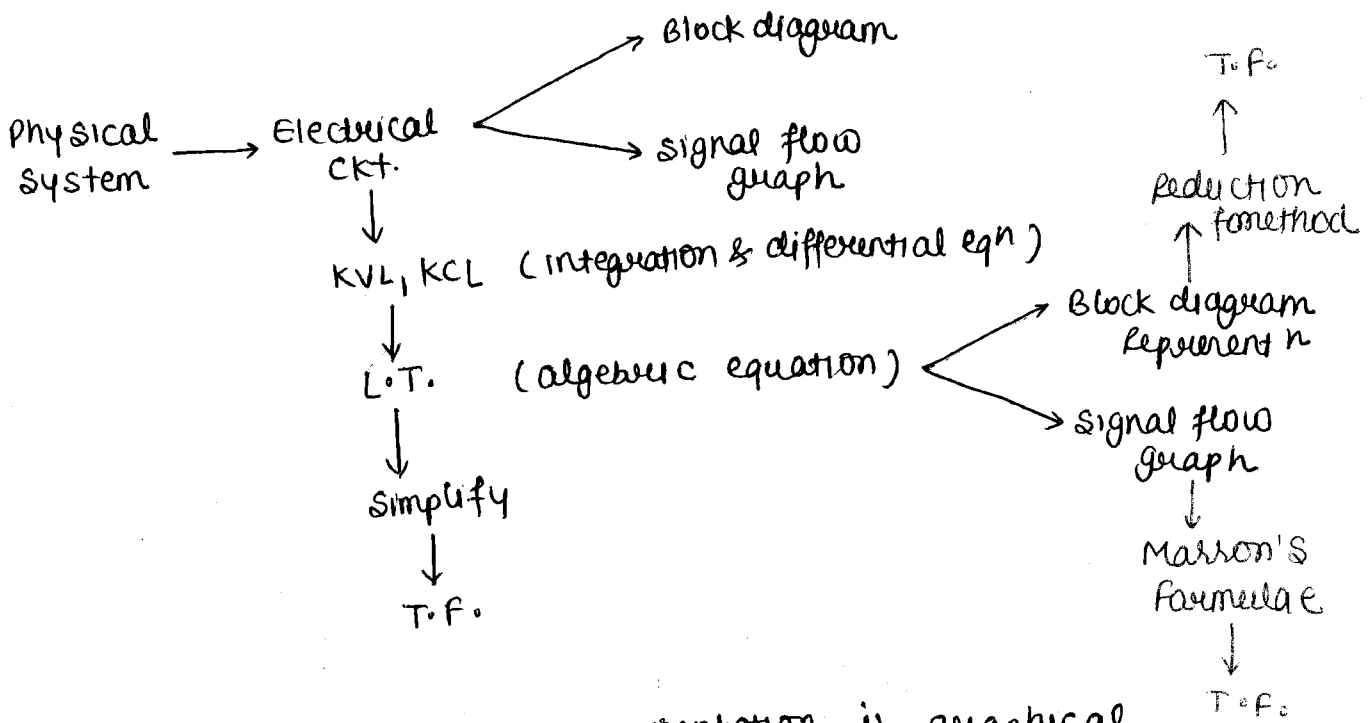
$$SR \Big|_{t=0} = (1 - 10e^{-t}) \Big|_{@ t=0} = -9 \neq 0 \quad \text{i.e., it contains initial condition due to which it is not relaxed}$$

if initial condition is zero then L [Impulse response] = T.F.

Transfer function of a system is unique i.e., one system can not have two transfer function but two or more number of different system may have the same transfer function. because transfer function depends on the component but not their configuration.



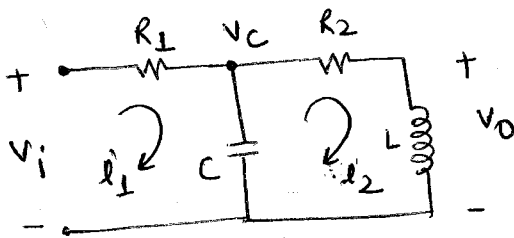
$$\frac{s+a}{s+b}$$



BDR, SFG: BDR or SFG representation is graphical representation of mathematical relation between the variables of a system described in the form of set of linear algebraic equation in cause effect form.

Linear:  $y = mx \rightarrow$  BDR/SFG  $\rightarrow$  T.F.

Non linear:  $y = mx + c \rightarrow$  state diagram  $\rightarrow$  state model



$$q = CV$$

$$i = C \frac{dV}{dt}$$

$$-V_i + i_1 R_1 + \int (i_1 - i_2) \cdot dt \cdot \frac{1}{C} = 0$$

$$-V_c + R_2 i_2 + V_o = 0$$

not in cause effect form  $\Leftarrow$   ~~$V_i = i_1 R_1 + \frac{1}{C} \int (i_1 - i_2) dt$~~

$$V_o = (sL) i_2$$

$$\frac{V_i}{s} = R_1 \frac{i_1(s)}{s} + \frac{1}{Cs} (i_1 - i_2)$$

$$\frac{V_i}{s} = \frac{R_1 i_1}{s} + \frac{i_1}{Cs} - \frac{i_2}{Cs}$$