MADE EASY

ELECTRICAL ENGINEERING

Control System

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- Theory
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

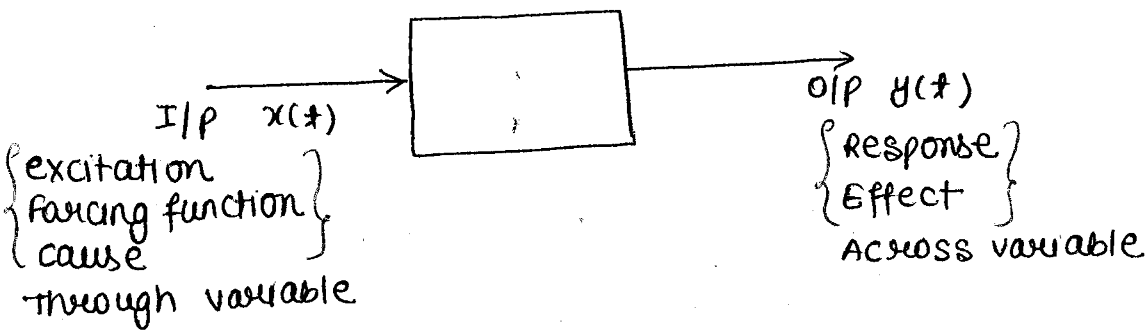
System :- The means of transforming a signal.

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 desire manner.

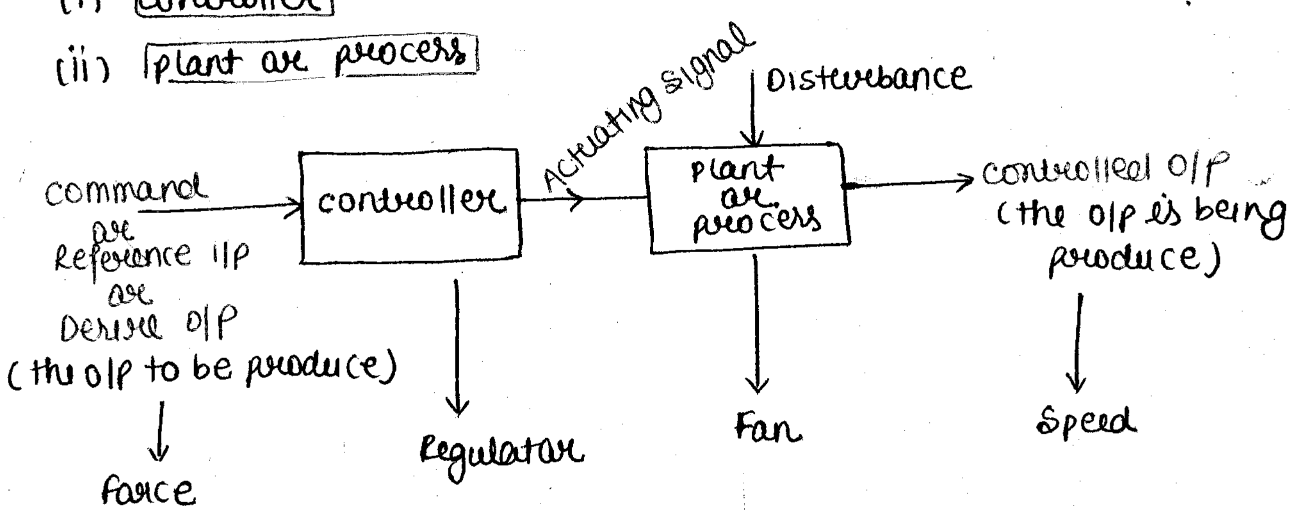
Ex-: system : J/K F/F

Master slave F/F : control system

To make control system we need basically two element -

(i) controller

(ii) plant or process



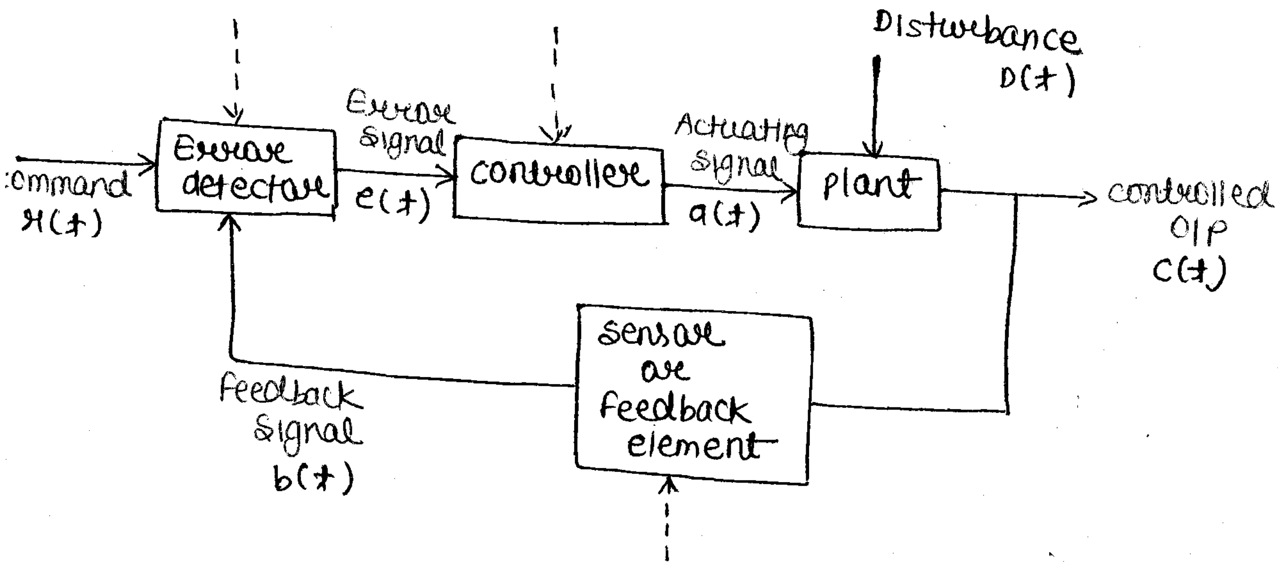
SISO :- MISO :-

MIMO :- Automobile SIMO :-

the objective of any control system is to ensure that controlled output become same as desire 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 :-



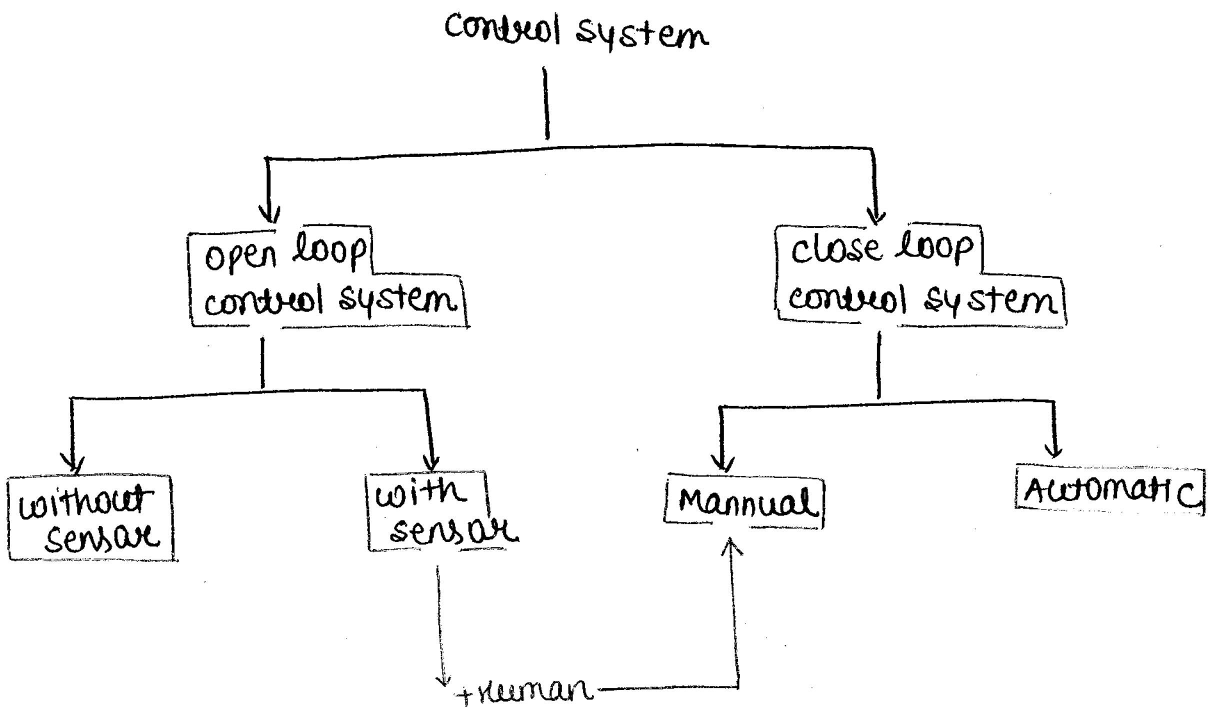
$C(t) = C_r(t) + C_D(t)$ [Linear combination because r(t) & D(t) both are independent to each other]

Disturbation = Distortion + Noise
↓ Internal disturbance
↓ External 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.

$+10 = 10\angle 0°$ → +ve feedback i.e; in phase

$-10\,V = 10\angle 180°$ → -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 OLTS does not change, though its output changes. Hence OLCS is not accurate	(i) The behaviour of close loop system if it output changes. Hence CLCS is accurate.
(ii) open loop system may or may not have sensor but it does not have complete sense.	(ii) Close loop system has complete sense either manually or Automatically.
(iii) Time constant of open loop system is larger, due to which transients takes large time to die out. Hence open loop system is slow.	(iii) Time constant of close loop system is smaller, due to which transients die out rapidly. Hence close loop system is faster.
(iv) Effect of external disturbance and internal parameter variation is more in OLCS i.e; OLCS is more sensitive.	(iv) Effect of external disturbance and internal parameter variation is less in close loop system. i.e; close loop system is less sensitive.
(v) The OLCS is generally stable but can be stabilize when it becoming unstable.	(v) Close loop system can become unstable but can be stablized.
(vi) OLCS is simple & economical	(vi) CLCS is complex & expensive.

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

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

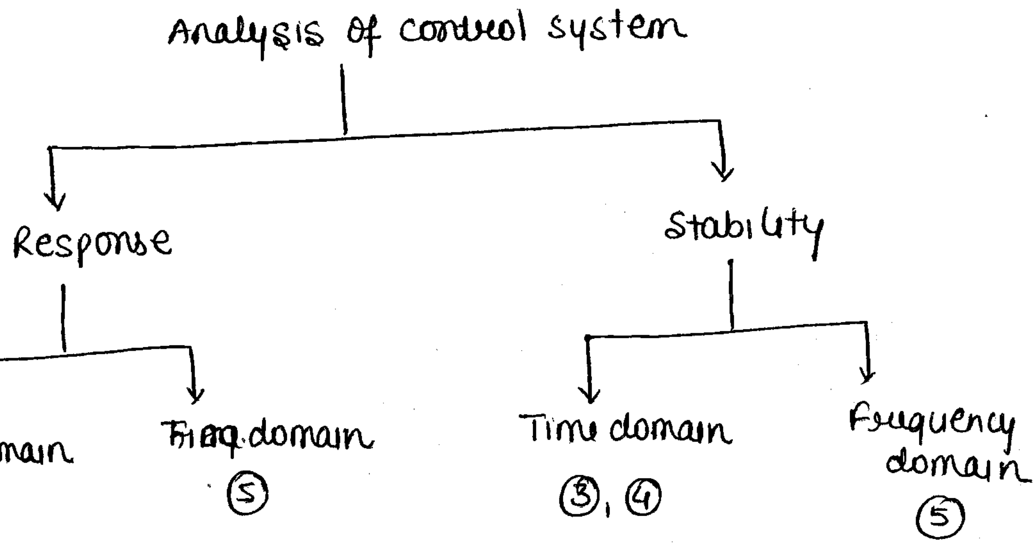
parameter	$1\angle 180°$ –ve F.B.	$1\angle 0°$ +ve F.B.
Gain	↓	↑
Bandwidth	↑	↓
Time constant	↓	↑
Speed	↑	↓
sensitivity	↓	↑
stability	↑	↓

Gain x Bandwidth = constant   Time constant x speed = constant

sensitivity x stability = constant

(i) study the system design }
(ii) Redesign } Mathematically

standard model :-
(i) T/F 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.

$$T.F. = \frac{L[O/P]}{L[I/P]}$$ initial condition = 0

Total response = ZIR + ZSR (ZIR → 0)

- ZIR: due to initial condition / state
- ZSR: due to i/p

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

ZSR - zero state response

$$Y = C + mx$$

mx → due to i/p because x is a part of it.

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

Zero state response

- Transient or Dynamic Response
- Steady state or Static Response

$$T.F. = \frac{L[O/P]}{L[I/P]} = \frac{L[IR]}{L[\delta(t)]} = \frac{L[SR]}{L[u(t)]} = \frac{L[RR]}{L[t\,u(t)]} = \frac{L[PR]}{L[\frac{t^2}{2}u(t)]}$$

$$T.F. = L[IR] = s\,L[SR] = s^2 L[RR] = s^3 L[PR]$$

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

Solution:- $T.F. = s\,L[SR]$

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

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

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

Now $IR = \delta(t) - 10\left[e^{-t}\delta(t) + u(t)\,e^{-t}(-1)\right]$

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

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

$T.F. = L[IR]$

$= -9(1) + \frac{10}{s+1} = \frac{1-9s}{s+1}$ i.e; Transfer functi is unique functic

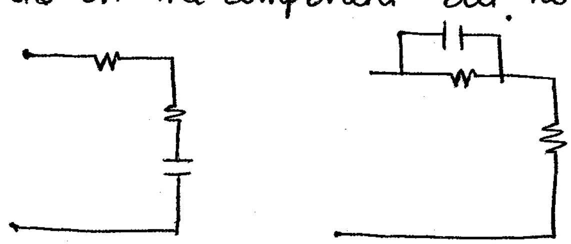
$SR = (1-10e^{-t})\,u(t)$

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

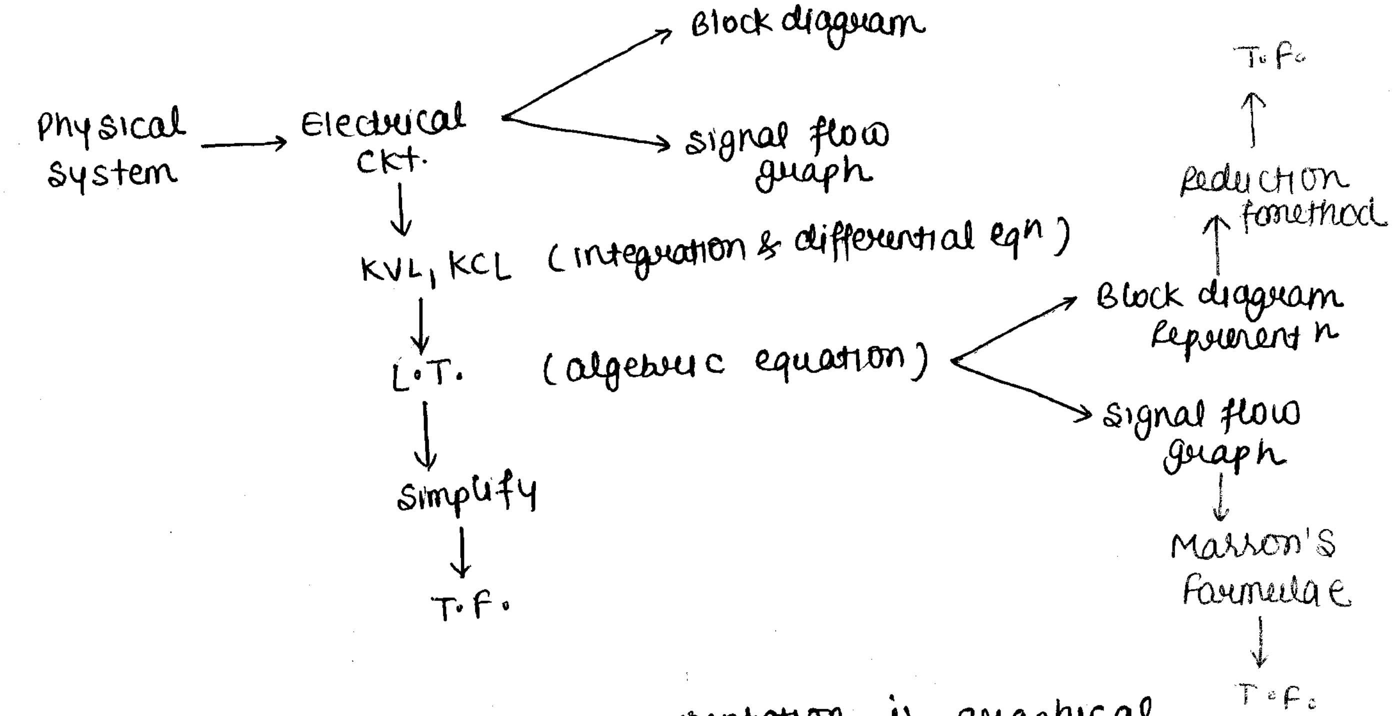
$SR\big|_{t=0} = (1-10e^{-t})\big|_{@\,t=0} = -9 \neq 0$ i.e; it contains initial condition due to which it is not relaxed

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.



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



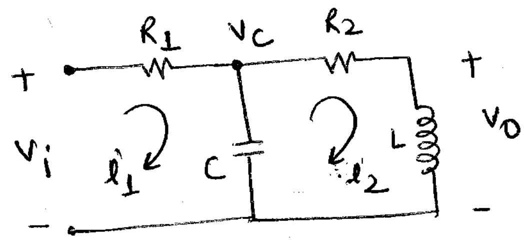
BDR, SFG : BDR or SFG representation is graphical representation of mathematical relation between the variables of a system described in the form of set of linear algebric equation in cause effect form.

Linear : $y = mx$ ⟶ BDR | SFG ⟶ T.F.

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

$q = cv$

$i = c\frac{dv}{dt}$



$-V_i + i_1R_1 + \int(i_1 - i_2)\cdot dt \cdot \frac{1}{C} = 0$.

$-V_c + R_2 i_2 + V_0 = 0$

not in cause effect form ⟸ ~~$V_i = i_1R_1 + \frac{1}{C}\int(i_1 - i_2)\,dt$~~

$V_0 = (sL)\,i_2$

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

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