Control Systems

Gate ⇒ (8M to 10M) IES → 100M ⇒ [30M + 70M]

Gate ⇒ ① Control System Engineering ⟶ NISE

② Control System Engineering ⟶ Nagrath & Gopal

ESE ③ Automatic Control Systems ⟶ B.C.KUO.

④ Control Systems: Principle & Design ⟶ M. Gopal.

⑤ Modern Control Systems ⟶ Ogata

⇒ TF, Block Diagrams, Signal flow Graphs — 1M or 2M

⇒ Time Domain Analysis → Transient Analysis, Steady state Analysis → 2M

⇒ Stability
- → Time Domain tech → RH Criteria & Root locus → 4M
- → frequency Domain tech ⇒ Bode Plot & Nyquist Plot

⇒ compensators & controllers → ESE

⇒ State space Analysis → 2M

⇒ Mechanical Systems [Gate]

Objective of CS :- To get desired or Accurate o/p.

⇒ Why we don't get desired o/p?

⇒ prob Noise signal → It is a unwanted signal which effects the performance of the system.

⇒ High frequency noise signal effects system performance badly.

⇒ (Noise amplitude) ∝ BW ↑

⇒ High frequency noise signal should be eliminate to get the desired o/p.

⇒ High frequency noise signal eliminated by Low pass filters.

⇒ control systems are designed as <u>LOW PASS FILTERS</u>

⇒ A FAN without Blades ⟶ Not a system ⟶ No proper o/p [No air flow]

⇒ A FAN without Regulator ⟶ System ⟶ proper o/p ⟶ air flow

May (or) May not be desired.

⇒ A FAN with Regulator ⟶ control system ⟶ Desired o/p

System :- It is a group of physical components arranged in such a way that it should gives proper o/p.

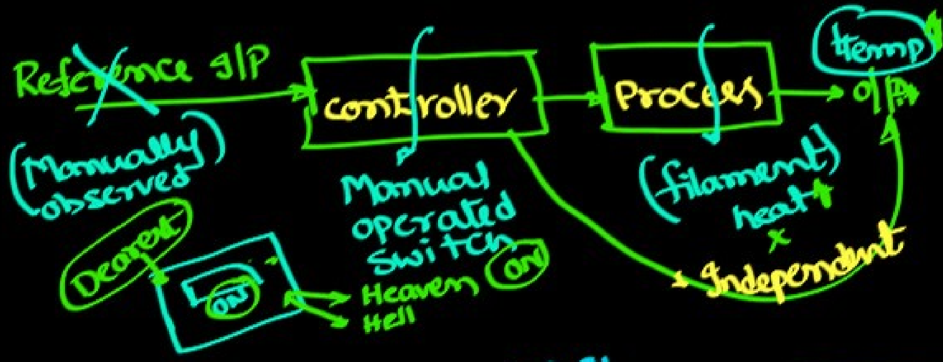
⇒ proper o/p is may (or) may not be desired o/p.

control systems :- It is a group of physical components arranged in a such a way that it gives the desired o/p by using controller (or) Regulator to the given i/p.

⇒ control systems are classified into two ways based on controller action.

1. open loop control systems [OLCS]
2. closed loop control systems [CLCS]

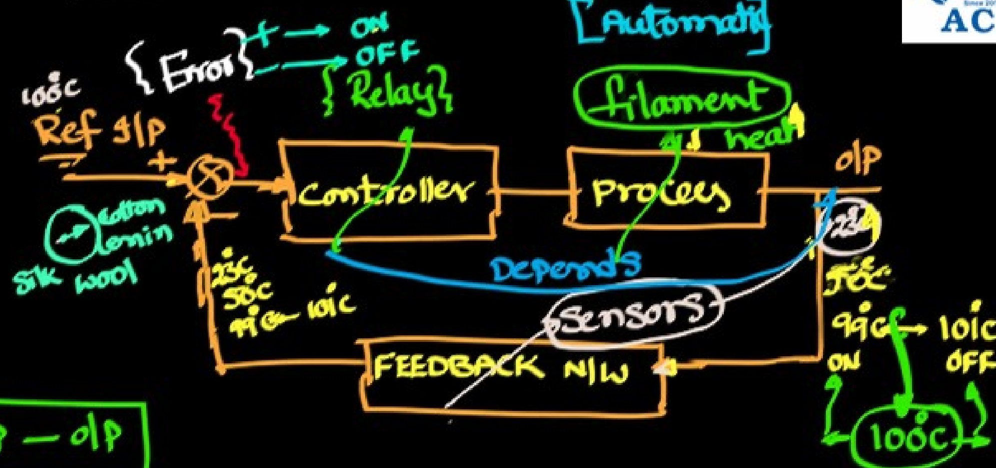
open loop control systems [Manual]



Ex → Iron BOX → OL, CL

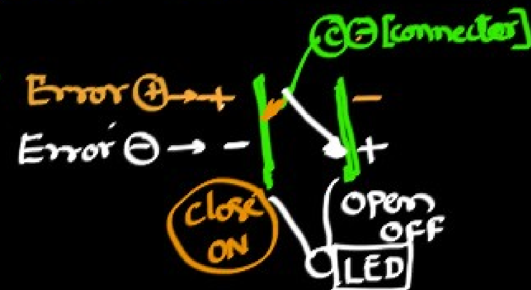
$\boxed{\text{error} \Rightarrow i/p - o/p}$

Closed loop control system [Automatic]



Reference input :- what we required from the system [Desired o/p]

Relay → Automatic Switch →



Ex :- Traffic control signal

→ Traffic control signal lights duration is not changed according to exist Traffic

→ $\boxed{\text{OLCS}}$

<u>open loop control system</u> :- A system in which the controller action is independent of the o/p is called OLCS.

Ex :- FAN, air cooler, Light, Traffic light, washing machine ....

any system which is not having sensors and not having provision to select reference i/p.

Closed loop control system :- A system in which the controller action depends on the output is called closed loop control system.

Ex :- AC, refrigirators, Human being, Automatic iron box ....
any system which is having sensors and having provison to select the reference i/p.

Feedback network :- It is a property of closed loop control system, which brings output to input and compare with reference input. Hence Error is generated.

→ The controller action takes place such that, the error becomes zero.

⇒ Error is zero means ⇒ The system gives desired o/p and system is stable. [Bounded i/p]

→ The feedback network consists the sensors and passive elements

⇒ The maximum gain of feedback network ratio is 1.

→ The best feedback is unity negative feed back.

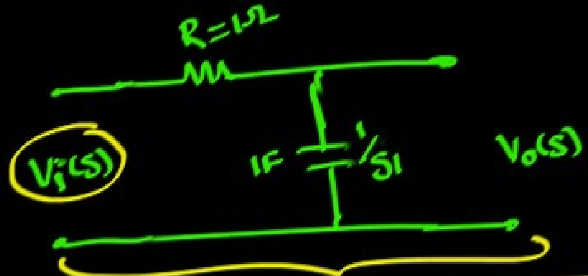
→ Negative feedback improves the relative stability [Loop Gain GH>0]

⇒ Steady state errors are valid for only unity feedback system.

→ feedback network may consists transducer which converts the energy from one form to another form.

Transfer function :- It is a Mathematical equivalent model of the system.

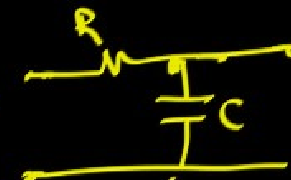
Ex :- RC network :- $\boxed{\theta} \Rightarrow$ check the system behavior (or) performance.



TF $\Rightarrow$ $$\frac{V_o(s)}{V_i(s)} = \frac{1/s1}{1+1/s1} = \underbrace{\left(\frac{1}{s+1}\right)}_{\boxed{MEM}}$$

To do the analysis (or) To check performances, we reqd (TF)

$$\Rightarrow \frac{V_o(s)}{V_i(s)} = \underbrace{\left(\frac{1}{s+1}\right)}_{\boxed{MEM}} \longleftrightarrow$$



$$\Rightarrow \frac{V_o(s)}{V_i(s)} = \underbrace{\left(\frac{1}{s+1}\right)}_{MEM}$$

Consider unit step

$r(t) = 1u(t) \rightarrow \boxed{R(s) = 1/s}$

↳ MEM of unit step i/p

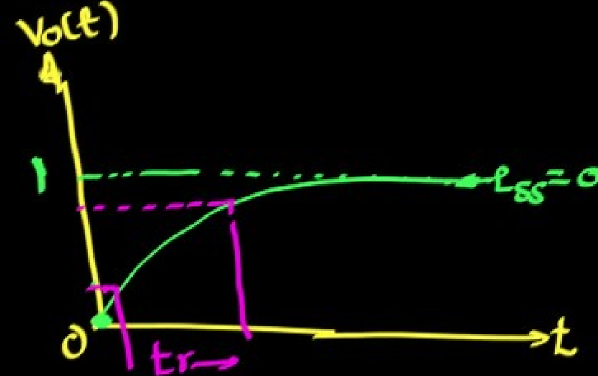
$$\Rightarrow V_o(s) = \left(\frac{1}{s+1}\right)\left(\frac{1}{s}\right) = \frac{1}{s\underbrace{(s+1)}_{s=-1}} = \frac{A}{s} + \frac{B}{s+1}$$

$$\Rightarrow V_o(s) = \frac{1}{s} - \frac{1}{s+1}$$

Apply ILT $\quad V_o(t) = (1 - 1e^{-t})u(t)$

$t = 0 \quad V_o \Rightarrow 0$

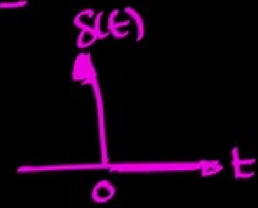
$t = \infty \quad V_o = 1$



$\Rightarrow$ TF [Mathematical equivalent model] is required to do the ideal analysis of the system (or) to check the behaviour (or) performance of the system.

Laplace transforms :-

Impulse :-

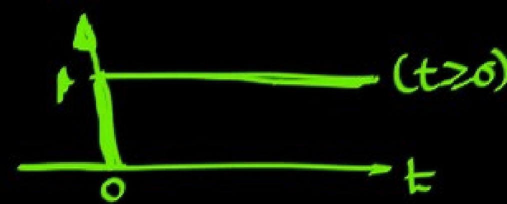


$r(t) = \delta(t)$

$R(s) = 1$

$L[\text{unit impulse}] \Rightarrow L[\delta(t)] = 1$

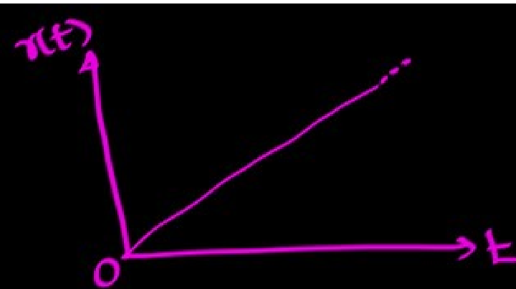
step signal :-



$r(t) = 1u(t)$

$L[\text{unit step}] = L[1u(t)] = 1/s$

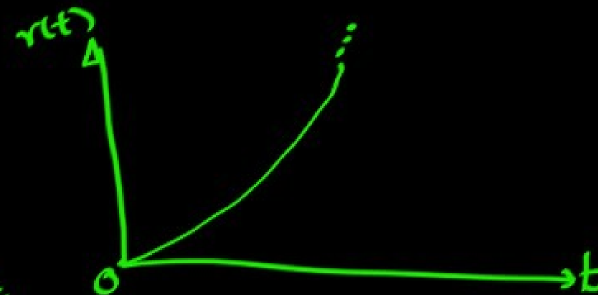
Unit Ramp signal:-



$$r(t) = t.u(t)$$

$$L[\text{Ramp}] = L[t\,u(t)] = 1/s^2$$

Unit Parabolic signal :-



$$r(t) = 1 \cdot t^2/2$$

$$L[\text{Unit Parabolic}] = L\left[1 \cdot t^2/2\right] = 1/s^3$$

$$f(t) \longleftrightarrow F(s)$$

$$L[t^n]u(t) \longleftrightarrow \frac{n!}{s^{n+1}}$$

$$L[e^{-at}]u(t) \longleftrightarrow \frac{1}{s+a}$$

$$L[t^n . e^{-at}]u(t) \longleftrightarrow \frac{n!}{(s+a)^{n+1}}$$

$$L[\sin bt]u(t) \longleftrightarrow \frac{b}{s^2+b^2}$$

$$L[\cos bt]u(t) \longleftrightarrow \frac{s}{s^2+b^2}$$

$$L[e^{-at} . \sin bt]u(t) \longleftrightarrow \frac{b}{(s+a)^2+b^2}$$

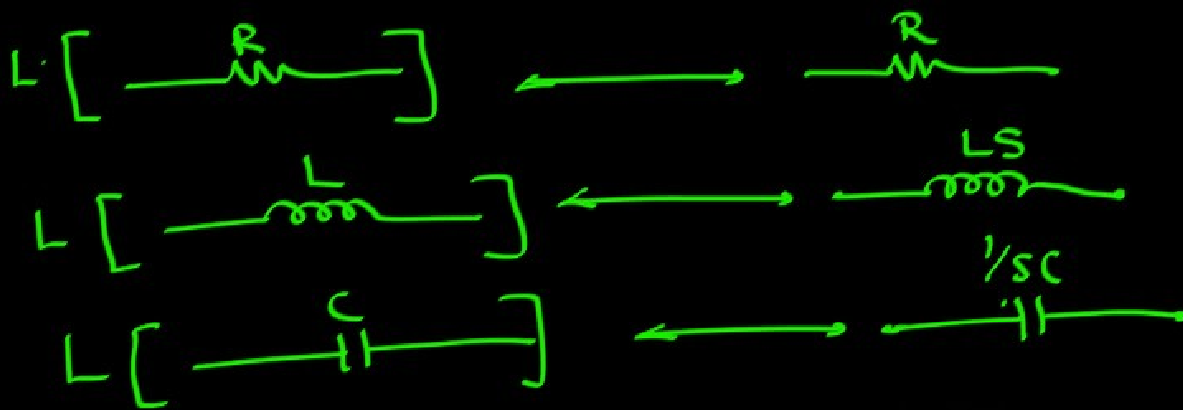
$$L[e^{-at} \cdot \cos bt] \longleftrightarrow \frac{(s+a)}{(s+a)^2+b^2}$$

$$L\left[\frac{dx}{dt}\right] \longleftrightarrow sX(s) - \cancel{x(0)} \xrightarrow{} 0$$

$\longrightarrow$ Initial condition are zero

$$\longrightarrow sX(s)$$

$$L\left[\int x\,dt\right] \longleftrightarrow \frac{X(s)}{s} \quad [IC = 0]$$



Defination of Transfer function :-

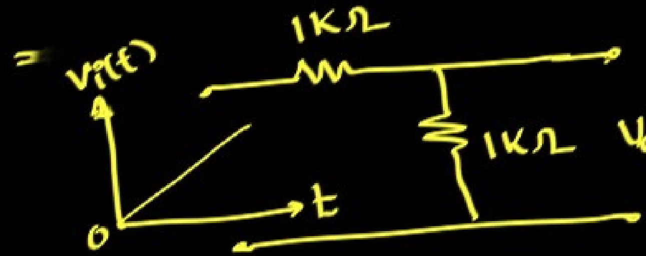
The transfer function of a Linear time invariant system is defined as ratio of Laplace transform of output to Laplace transform of input with all initial conditions are zero.

$$\Rightarrow \boxed{TF = \left.\frac{L[O/P]}{L[I/P]}\right|_{IC=0}}$$

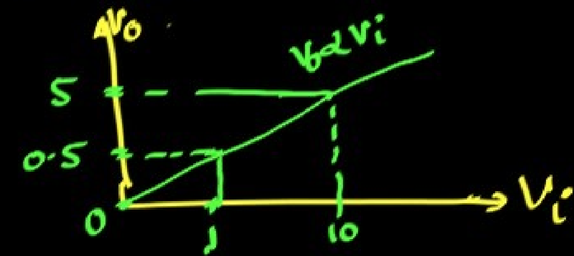
Linear Time Invariant Systems :→

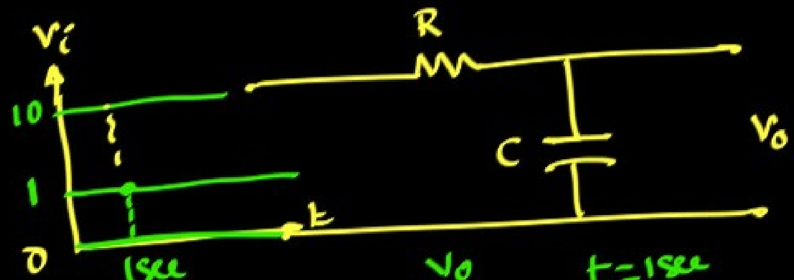
System is Linear ⇒ It will gives Linear Transfer characteristics.

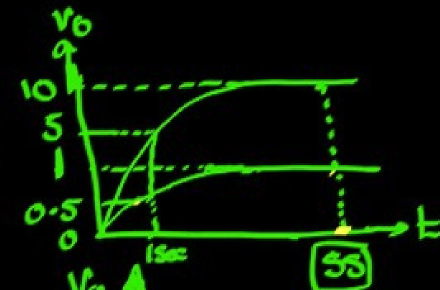
⇒ R, L, C components gives Linear T/F characteristics.
(V_o verses V_i)



$$V_0 = \frac{1K}{1K + 1K} V_i = 0.5 V_i$$







SS → steady state

t = const [tss]

⇒ R, L, C components gives Linear T/F Char

⇒ R, L, C component values are not changes with time.

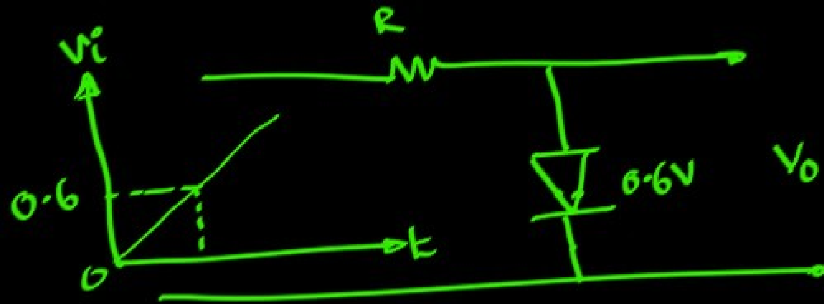
⇒ [Time Invariant]

⇒ LTI System is nothing but R, L, C Circuit.

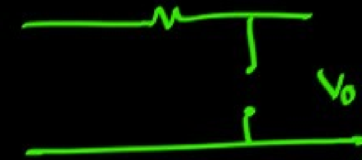
⇒ In the transfer function analysis, the Initial conditions are zero, to satisfy Linearity.

⇒ Initial conditions are zero means ⇒ No energy stored across the components & system is under the rest.

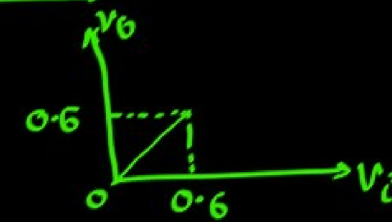
Ex :- Non-linear System



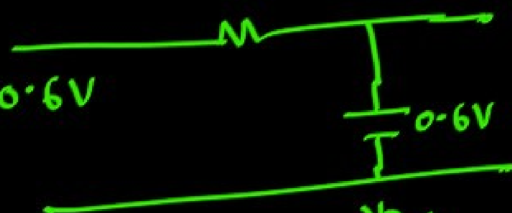
$\boxed{V_i < 0.6V}$



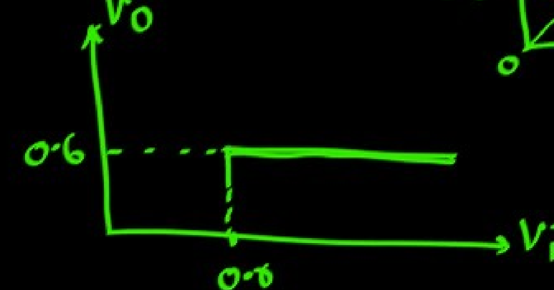
$V_o = V_i$

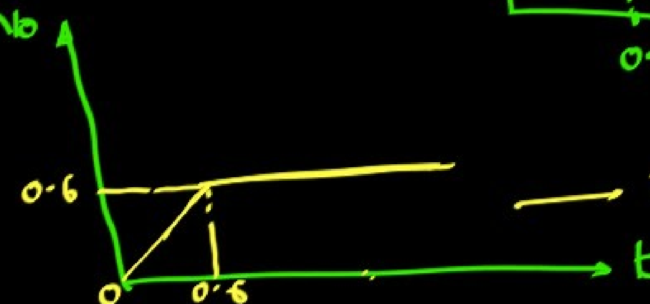


$V_i > 0.6V$



$V_o = 0.6V$





→ Non-linear characteristics

⇒ Any element which is having ON & OFF characteristics, then the element is called Non-linear element.