Unit-1

- Types of controllers (depending on process)

Continuous type

Process is continuous in day &night.
Egg: Process industries

Batch type

Process is in Batches
Egg: Pharma industries

ON-OFF type

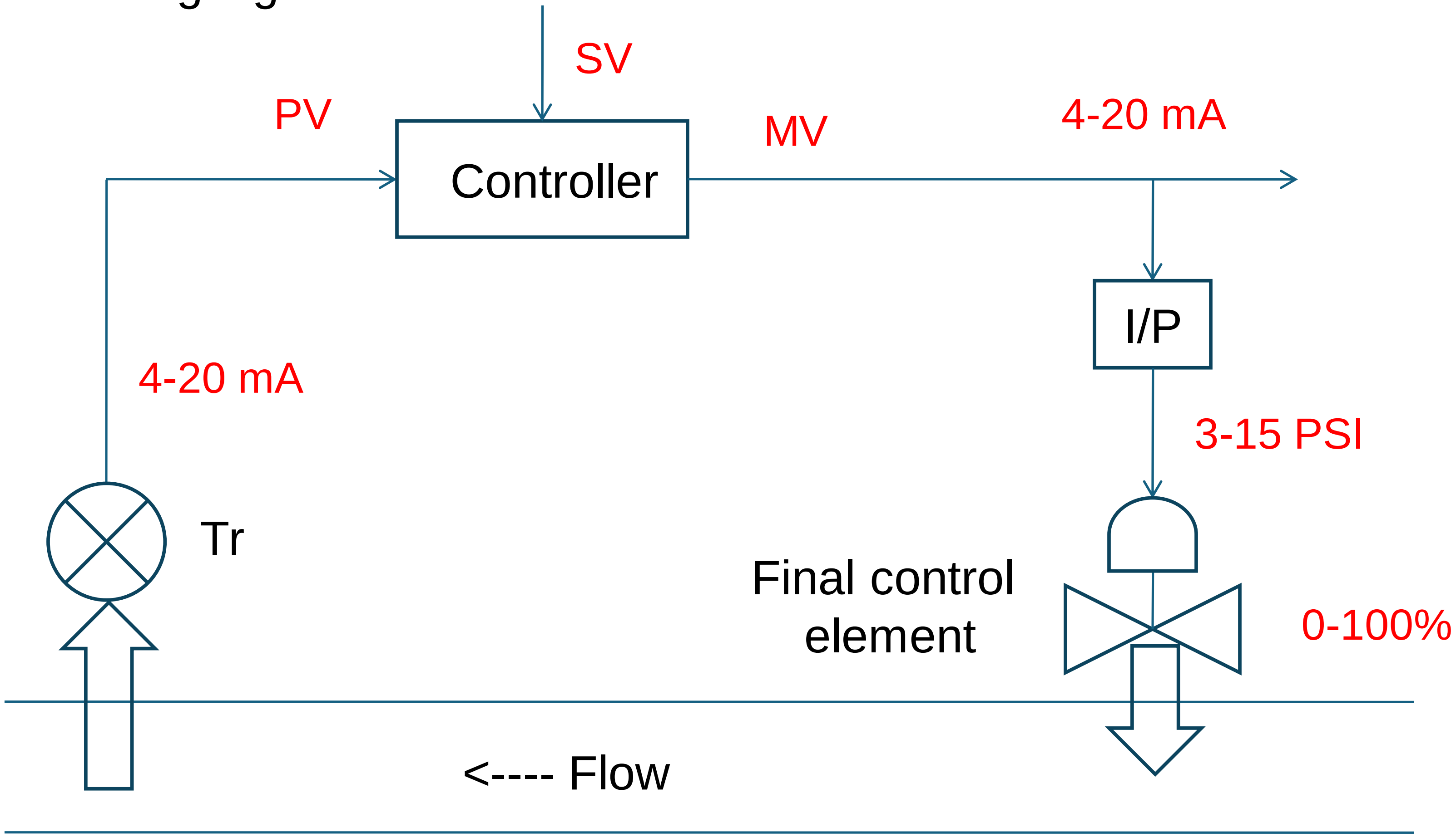
For process either ON/OFF
Egg: relay based contacts

SIMPLE PROCESS

PV = Process variable value (or) controlled variable.

SV = Set point value (or) desired value (or) reference value.

MV = Manipulated value (or) output value (or) controlling variable (or) actuating signal



- A Process control consists
  - Analog control system (Operational amplifier based)
  - Digital control system (Micro processer based)

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  - CCS (Centralized CS)
  - DCS (Distributed CS)

CONTROLLERS

- Controller is a device, which is used to control transient and steady state response as per the requirements.
- The best system demands smallest rise time, smallest settling time, smallest steady state error and smallest peak overshoot.
- Depending on the control actions provided the controllers can be classifieds as follows.

  1. Two position or on-off controllers
  2. proportional controllers
  3. integral controllers
  4. Derivative controllers

5. PI Controllers

6. PD Controllers

7. PID Controllers

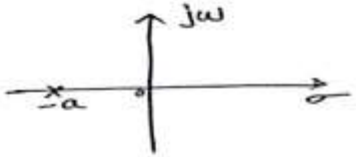
- The on-off control action may be provided by a relay. It is a device which has NO(Normally open) and NC(Normally closed) contacts, whose opening and closing are controlled by the relay coil. When the relay coil is excited, the relay operates and the contacts change their position (ie., NO to NC and NC to NO).

BIBO stability: A linear relaxed system is said have BIBO stability if every bounded (finite) input results in a bounded (finite) output.

Location of roots on the S-plane for stability.

Transfer function and location of roots	Sketch of time domain function.

① $M(s) = \frac{A}{s+a}$

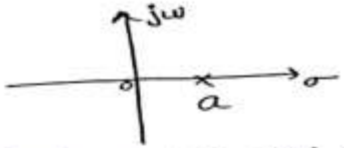


Root on -ve real axis

$m(t) = L^{-1}\left[\frac{A}{s+a}\right] = Ae^{-at}$

Exponentially decaying.

② $M(s) = \frac{A}{s-a}$

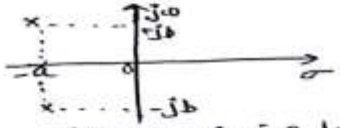


Root on +ve real axis

$m(t) = L^{-1}\left[\frac{A}{s-a}\right] = Ae^{at}$

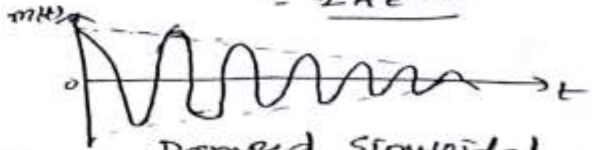
Exponentially Increasing.

③ $M(s) = \frac{A}{s+a+jb} + \frac{A}{s+a-jb}$



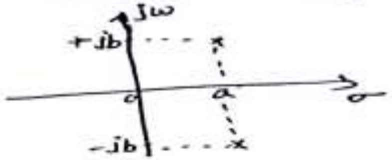
Complex Conjugate roots

$m(t) = Ae^{-(a+jb)t} + Ae^{-(a-jb)t}$
$= 2Ae^{-at}$



Damped Sinusoidal.

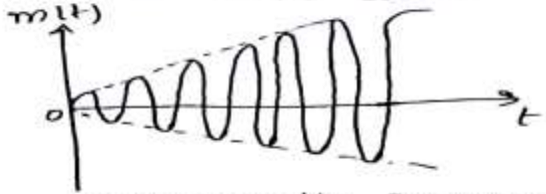
(4) $M(s) = \frac{A}{s-a+jb} + \frac{A}{s-a-jb}$



complex conjugate roots on R.H.S.P.

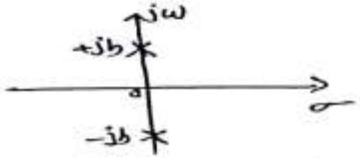
$m(t) = A e^{-(-a+jb)t} + A e^{-(-a-jb)t}$

$= 2A e^{at} \cos bt$



Exponentially increasing sinusoidal.

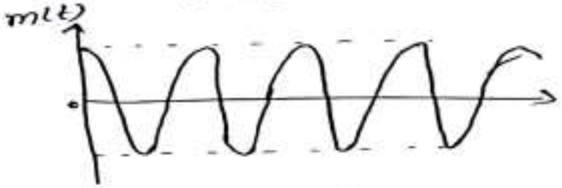
(5) $M(s) = \frac{A}{s+jb} + \frac{A}{s-jb}$



single pair of roots on imaginary axis.

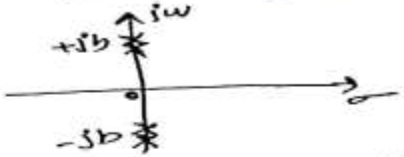
$m(t) = A e^{-jb} + A e^{+jb}$

$= 2A \cos bt$



oscillatory.

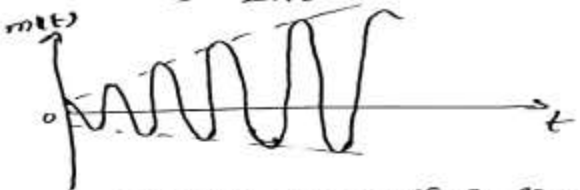
(6) $M(s) = \frac{A}{(s+jb)^2} + \frac{A}{(s-jb)^2}$



Double pair of roots on I. Axis.

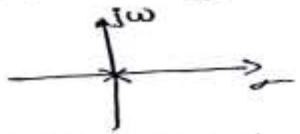
$m(t) = At e^{-jb} + At e^{+jb}$

$= 2At \cos bt$.



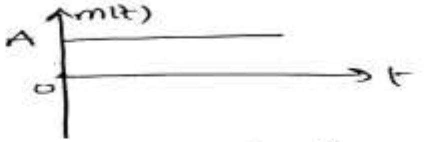
Linearly increasing sinusoidal.

(7) $M(s) = \frac{A}{s}$



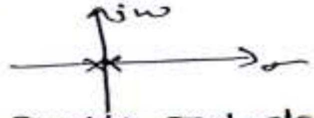
single root at origin

$m(t) = A$

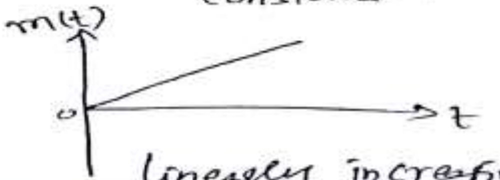


constant.

(8) $M(s) = \frac{A}{s^2}$

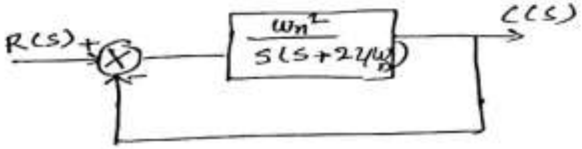


Double root at origin



Linearly increasing.

Standard form of closed loop transfer function of second order system.



$$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$$

ω_n = Undamped natural frequency rad/sec

ζ = Damping ratio.

Depending on 'ζ' the system can be classified as

<u>Case 1</u>: undamped system; <u>$\zeta = 0$</u>.

$CE = s^2+2\zeta\omega_n s+\omega_n^2 = 0$.

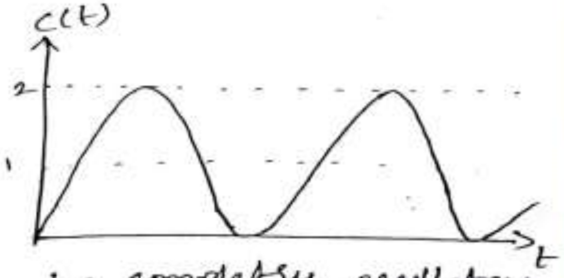
roots $\Rightarrow s_1, s_2 = \pm j\omega_n$

i.e roots are purely imaginary, system undamped.

→ Response of undamped 2nd order system for unit step input.

$$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2+\omega_n^2}$$

$$\boxed{c(t) = 1 - \cos\omega_n t}$$



i.e completely oscillatory.

Case 2: Critically damped system. ($\xi = 1$)

roots $\Rightarrow$ $s_1, s_2 = -\omega_n$.

i.e; roots are real and equal.

$$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{s^2 + 2\omega_n s + \omega_n^2} = \frac{\omega_n^2}{(s+\omega_n)^2}$$

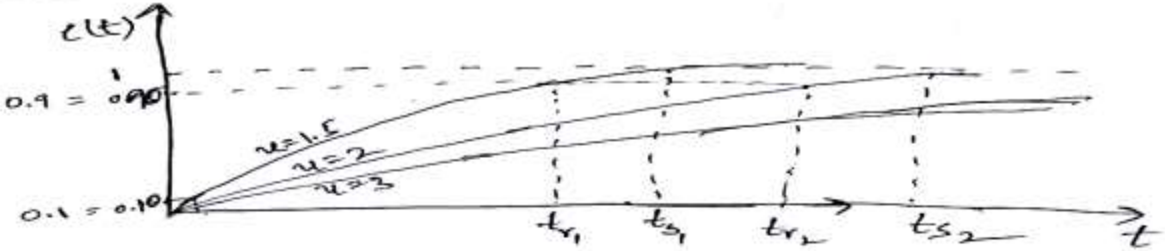
$$\Rightarrow \boxed{c(t) = 1 - e^{-\omega_n t}(1+\omega_n t)}$$

Case 3: Over damped system ($\xi > 1$)

roots $\Rightarrow$ $s_1, s_2 = -\xi\omega_n \pm \omega_n\sqrt{\xi^2 - 1}$

i.e; roots are real and unequal.

$$\boxed{c(t) = 1 - \frac{\omega_n}{2\sqrt{\xi^2-1}}\left(\frac{e^{-s_1 t}}{s_1} - \frac{e^{-s_2 t}}{s_2}\right)}$$



Case 4: under damped system. $0 < \zeta < 1$

roots $\Rightarrow s_1, s_2 = -\zeta\omega_n \pm j\omega_n\sqrt{1-\zeta^2}$

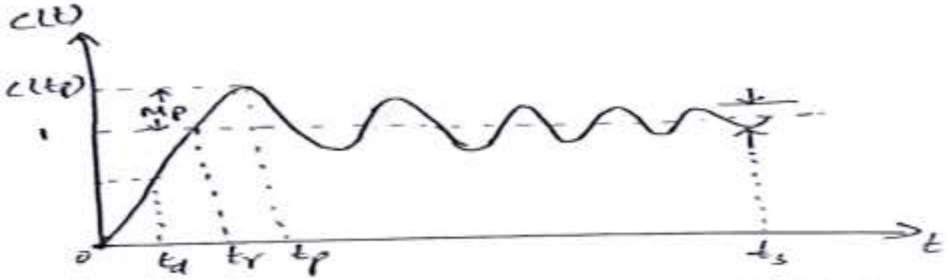
$= -\zeta\omega_n \pm j\omega_d$

i.e; roots are complex conjugate.

where, $\omega_d = \omega_n\sqrt{1-\zeta^2}$. ω_d is called damped frequency of oscillations.

→ Response for unit step input

$$\boxed{c(t) = 1 - \frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}} \sin(\omega_d t + \theta)}, \quad \theta = \tan^{-1}\frac{\sqrt{1-\zeta^2}}{\zeta}$$



Damped oscillatory response.

→ The transient response of a practical control system often exhibits damped oscillation before reaching steady state.