ElCoM
ELECTRICAL COMPUTER MECHATRONICS

تقدم لجنة ElCoM الاكاديمية

دفتر لمادة:

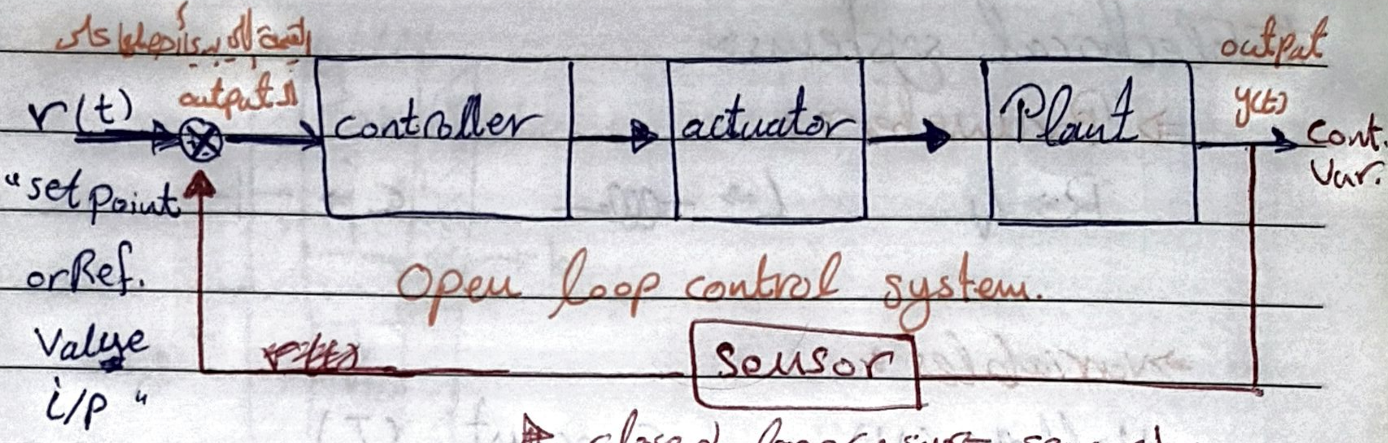
تحكم آلي

من شرح:

م. فدوى المومني

جزيل الشكر للطالبة:

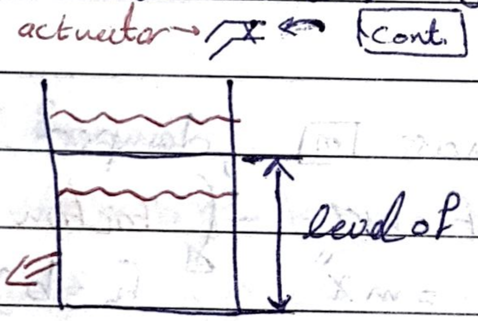
راية جهاد



closed loop con. sys. (sensor) مع
"Feedback control system"

$r(t) \rightarrow \otimes \rightarrow e(t)$ "error"
($+ r(t)$, $- y(t)$)

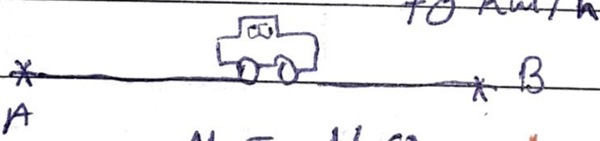
$$e(t) = r(t) - y(t)$$



$\Rightarrow$ sensor $\rightarrow$ closed loop
$\hookrightarrow$ without sensor $\rightarrow$ open loop

level of water $h(t) \Rightarrow y(t)$
$\hookrightarrow$ Cont. Var. and ref val.

SISO "single i/p single o/p" and act. val. $y(t)$



MIMO "multi i/p multi o/p"

20/09/2018

Electrical systems:

⇒ Parameters:

R ⇒ (resistor), L ⇒ (inductor), C ⇒ (capacitor)

⇒ variables:

Voltage (V), Current (I)

$V_R = IR$, $V_L = L\frac{di}{dt}$, $V_C = \frac{1}{C}\int i\,dt$

Mechanical systems:

⇒ Par:

spring $\overset{K}{}$, mass $\boxed{m}$, damper $^{b,\,c}$

$F_s = K\,x \rightarrow \Delta x$, $\Sigma F = ma = m x''$, friction $F_b = b\,\underbrace{v}_{\Delta x'} = b\,x'$

⇒ Var:

force (F) , Position, Velocity, acc.

x , x' , x''

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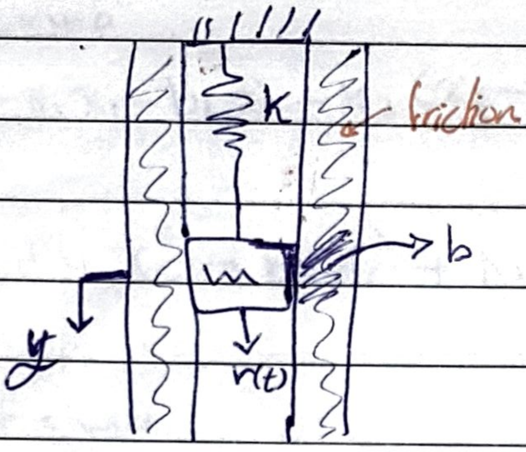
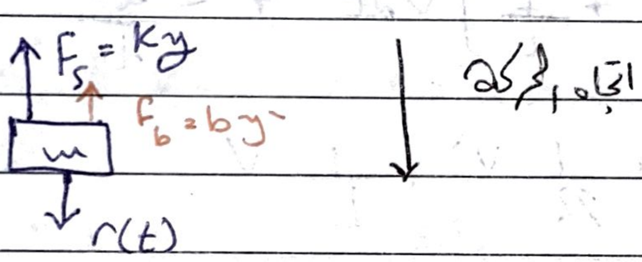
Ex:



1) freebody diagram:

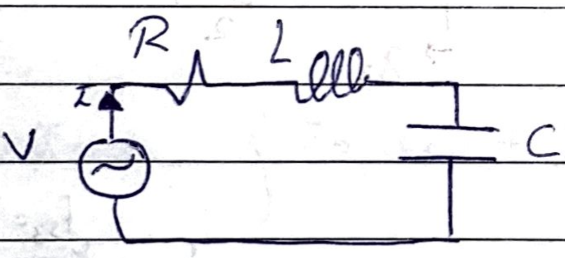


2) $\sum f = ma$

$$r(t) - by' - ky = m y''$$

$\hookrightarrow$ $my'' + by' + ky = r(t)$

Ex:



KCL: $I_R = I_L = I_c = I$

KVL: $V = V_R + V_L + V_c$

$$V = IR + L\frac{dI}{dt} + \frac{1}{C}\int I\,dt \Rightarrow \text{نشتقها}$$

«Integrodiff. equ.»

$$\Rightarrow LI'' + RI' + \frac{1}{C}I = V'$$

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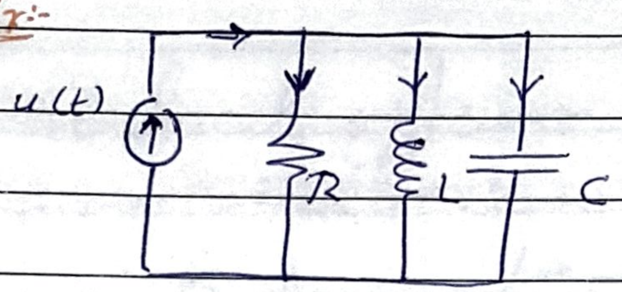
Ex:-



KCL $\Rightarrow$ $u(t) = I_R + I_L + I_C$

KVL $\Rightarrow$ $V_L = V_R \pm V_C = V$

$$\Rightarrow u(t) = \frac{V}{R} + \frac{1}{L}\int V\,dt + C\frac{dV}{dt}$$

نشتق

$$u' = CV'' + \frac{1}{R}V' + \frac{1}{L}V$$

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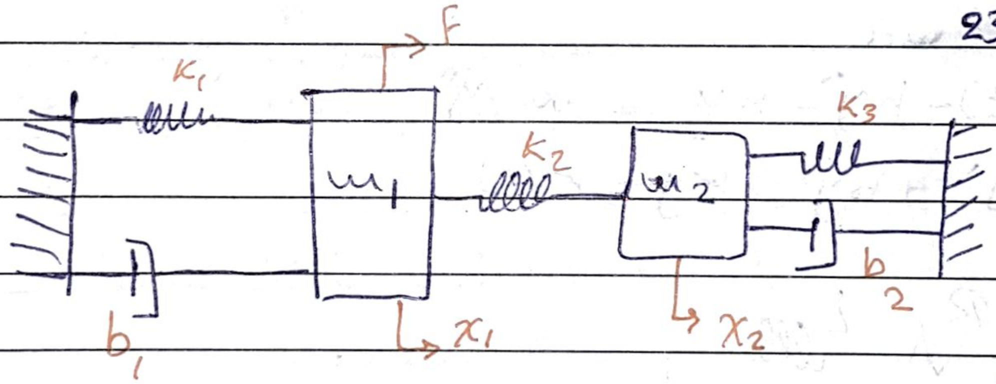
Ex:



$\Rightarrow F_{s_1} = k_1 x_1$ $\qquad$ $F_{s_3} = k_3 x_2$

$F_{b_1} = b_1 x_1'$ $\quad$ m_1 $\quad$ F $\quad$ $F_{s_2} = k_2(x_1 - x_2)$ $\qquad$ $F_{s_2} = k_2(x_1 - x_2)$ $\quad$ m_2 $\quad$ $F_{b_2} = b_2 x_2'$

عكس اتجاه الحركة

OR

$k_2(x_2 - x_1)$

23/09/2018.

$\Sigma F = ma$

$F - k_1 x_1 - b_1 \dot{x}_1 - k_2 (x_1 - x_2) = m_1 \ddot{x}_1$ # for m_1

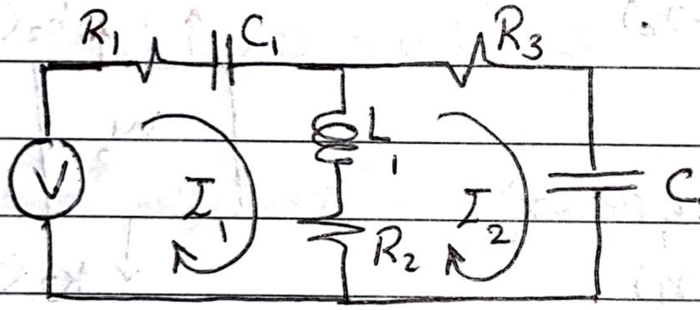
$\hookrightarrow \; m_1 \ddot{x}_1 + b_1 \dot{x}_1 + k_1 x_1 + k_2 (x_1 - x_2) = F$

$\Sigma F = ma$ # for m_2

$-k_2 (x_2 - x_1) - k_3 x_2 - b_2 \dot{x}_2 = m_2 \ddot{x}_2$

$\hookrightarrow \; m_2 \ddot{x}_2 + b_2 \dot{x}_2 + k_3 x_2 + k_2 (x_2 - x_1) = 0$

Ex:



mesh (1)

$$V = R_1 I_1 + \frac{1}{C_1} \int I_1 \, dt + L \frac{d(I_1 - I_2)}{dt} + R_2 (I_1 - I_2)$$

mesh (2)

$$R_3 I_2 + \frac{1}{C_2} \int I_2 \, dt + R_2 (I_2 - I_1) + L \frac{d(I_2 - I_1)}{dt} = 0$$

$\rightarrow$ نشتقهم

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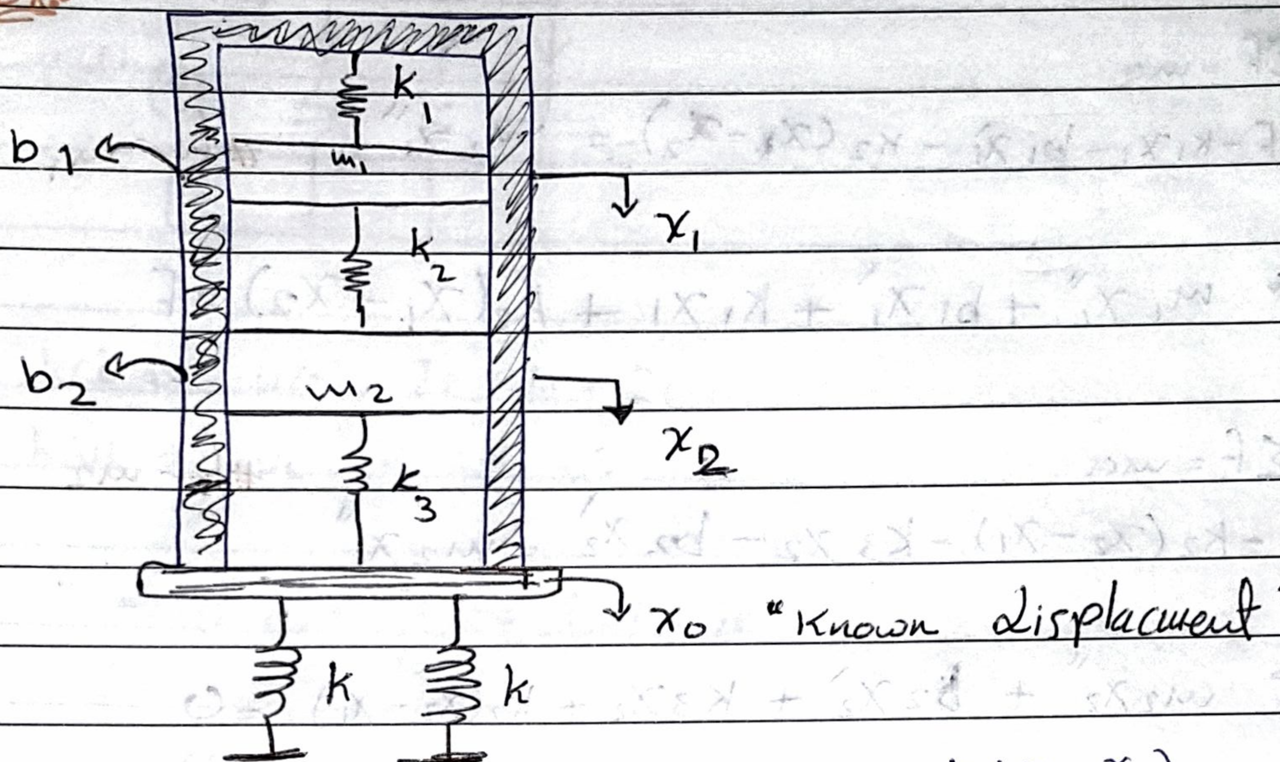
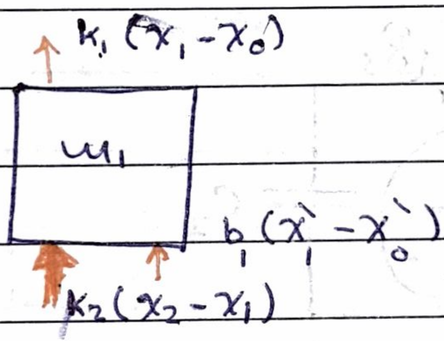
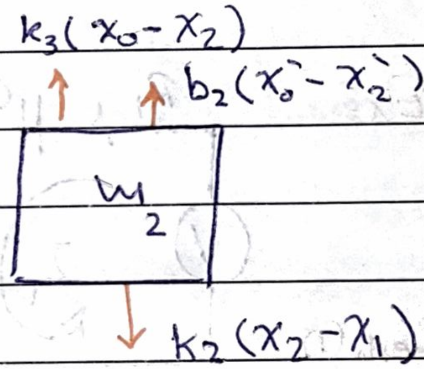
Ex:







$\Sigma F = ma$

$-b_1(\dot{x}_1-\dot{x}_0)-k_1(x_1-x_0)-k_2(x_2-x_1) = m_1 x_1''$ # m_1

$\hookrightarrow m_1 x_1'' + b_1(\dot{x}_1-\dot{x}_0) + k_1(x_1-x_0) + k_2(x_2-x_1) = 0$

$-k_2(x_2-x_1) + k_3(x_0-x_2) + b_2(\dot{x}_0-\dot{x}_2) + m_2 x_2'' = 0$

m_2

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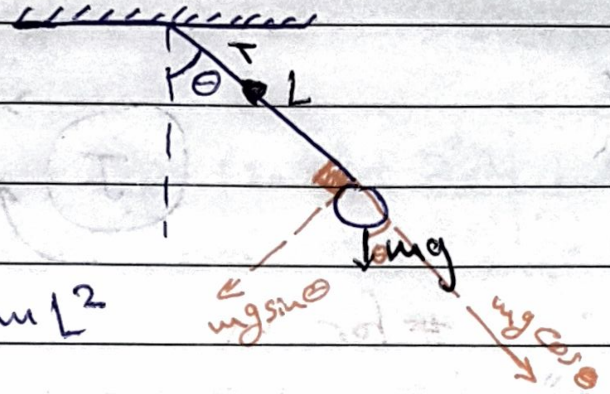
Ex:



$mg\cos\theta \Rightarrow T$ "بيلغوا بعض"

$J = mL^2$

$\Rightarrow \tau = mgL\sin\theta$

$\Sigma F = ma \Rightarrow \Sigma\tau = J\alpha$

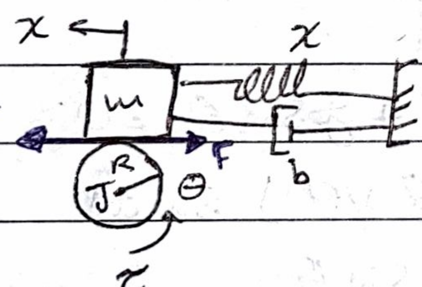
$-mgL\sin\theta = J\alpha = J\theta''$

$\hookrightarrow -\cancel{m}g\cancel{L}\sin\theta = \cancel{m}L^{\cancel{2}}\theta''$

$\hookrightarrow L\theta'' + g\sin\theta = 0$

25/09/2018

Ex:



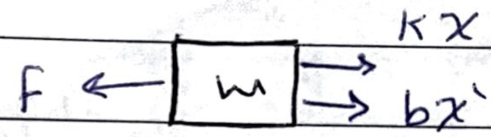
$\Sigma F = ma \Rightarrow \Sigma\tau = J\alpha$

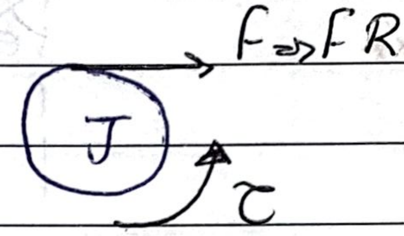
$\Rightarrow x = R\theta$

$\Rightarrow \tau = FR$

linear	circular
x	θ
v, x'	ω, θ'
a, x''	α, θ''
F	τ
m	J

25/04/2018





$\sum F = ma$ # for m

$F - bx' - kx = mx''$

$F = mx'' + bx' + kx$

$\sum \tau = J\alpha$ # for J

$\tau - F \cdot R = J\theta''$

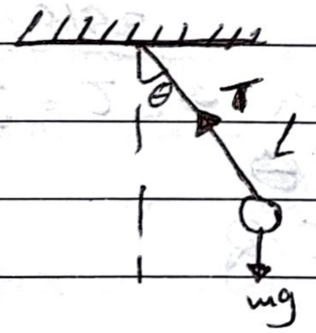
$\tau = J\theta'' + FR$

↳ $\tau = J\theta'' + [mx'' + bx' + kx]R$

where $x = R\theta \Rightarrow \theta = x/R$

$\tau = \frac{J}{R} x'' + R[mx'' + bx' + kx]$

Ex:



$L\theta'' + g\sin\theta = 0$

* If θ very small

$\theta \simeq \sin\theta$

↳ $L\theta'' + g\theta = 0$

25/04/2018

Taylor Series expansion :

$$y = g(x_0) + \frac{\partial g}{\partial x}\Big|_{x=x_0}(x-x_0) + \frac{\partial^2 g}{\partial x^2}\Big|_{x=x_0}\frac{1}{2!}(x-x_0)^2 + \dots + \frac{1}{n!}\frac{\partial^n g}{\partial x^n}\Big|_{x=x_0}(x_n-x_0)^n$$

$$\rightarrow \left[\sin\theta_0 + \cos\theta_0(\theta-\theta_0) - \frac{1}{2}\sin\theta_0(\theta-\theta_0)^2\right]\Big|_{\theta_0=\theta}$$

$$0 + \theta - 0 = \theta$$

$\rightarrow$ 3 terms accurate.

Laplace Transform :

$$F(s) = \mathcal{L}[f(t)] = \int_0^\infty e^{-st} f(t)\, dt \qquad t>0$$

$$f(t) = \mathcal{L}^{-1}[F(s)]$$

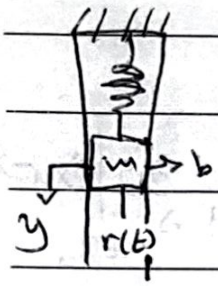
table 2-3

$f(t)$		$F(s)$
step fun $\Rightarrow f(t)=A$	$\rightarrow$	$\frac{A}{s}$
Ae^{-at}	$\rightarrow$	$\frac{A}{s+a}$
$\sin\omega t$	$\rightarrow$	$\frac{\omega}{s^2+\omega^2}$
$\cos\omega t$	$\rightarrow$	$\frac{s}{s^2+\omega^2}$
t^n	$\rightarrow$	$\frac{n!}{s^{n+1}}$
impulse fun. δ	$\rightarrow$	1

shift of e

$f(t)$		$F(s)$
$f^k(t) = \frac{\partial^k f}{\partial t^k}$	$\rightarrow$	$s^k F(s) - s^{k-1} f(0^-) - s^{k-2}\dot{f}(0)$
$\int_{-\infty}^{t} f(t)\,dt$		$\frac{F(s)}{s} + \dots$

27/04/2018



$$my'' + by' + ky = r(t)$$

$$\Rightarrow m\left[s^2Y(s) - sy(0) - y'(0)\right] + b\left[sY(s) - y(0)\right]$$

$$+ kY(s) = R(s)$$

⊛ if all initial conditions $= 0$, $y(0), y'(0) = 0$

$$ms^2Y(s) + bsY(s) + kY(s) = R(s)$$

$$\hookrightarrow Y(s)\left[ms^2 + bs + k\right] = R(s)$$

$$\Rightarrow Y(s) = \frac{1}{ms^2 + bs + k} \cdot R(s)$$

Ex: $Y(s) = \dfrac{s+3}{s^2+3s+2}$ ⇒ find $y(t)$

$$\left[= \frac{s+3}{(s+1)(s+2)} = \frac{A}{s+1} + \frac{B}{s+2} \right] * (s+1)(s+2)$$

$$s+3 = A(s+2) + B(s+1)$$

$\Rightarrow s = -1 \Rightarrow A = 2$

$\Rightarrow s = -2 \Rightarrow B = -1$

29/09/2018

$$Y(s) = \frac{2}{s+1} + \frac{-1}{s+2}$$

$$\Rightarrow y(t) = 2e^{-t} - e^{-2t}$$

Exs $Y(s) = \dfrac{2}{(s+1)(s+2)^2}$ find $y(t)$.

$$= \left.\frac{A}{s+1} + \frac{B}{(s+2)^2} + \frac{C}{s+2}\right] * (s+1)(s+2)^2$$

$$\Rightarrow 2 = A(s+2)^2 + B(s+1) + C(s+1)(s+2)$$

$s=-1 \Rightarrow A = 2$

$s=-2 \Rightarrow B = -2$

$s=0 \Rightarrow C = -2$

$$Y(s) = \frac{2}{s+1} + \frac{-2}{(s+2)^2} + \frac{-2}{s+2}$$

$$\Rightarrow y(t) = 2e^{-t} - 2te^{-2t} - 2e^{-2t}$$

27/09/2018

* complex

Ex 80 $Y(s) = \dfrac{3}{s(s^2+2s+5)}$

$s = 0, -1 \mp j2$

$= \left[\dfrac{A}{s} + \dfrac{Bs+C}{s^2+2s+5}\right] * s(s^2+2s+5)$

$\Rightarrow 3 = A(s^2+2s+5) + s(Bs+C)$

$\Rightarrow 3 = As^2 + 2As + 5A + Bs^2 + Cs$

$A+B=0$

$5A = 3 \Rightarrow * A = \dfrac{3}{5}$, $* B = -\dfrac{3}{5}$

$2A + C = 0 \Rightarrow 2\left(\dfrac{3}{5}\right) + C = 0 \Rightarrow * C = -\dfrac{6}{5}$

$\Rightarrow Y(s) = \dfrac{3}{5s} + \dfrac{\left(-\frac{3}{5}\right)s + \left(\frac{-6}{5}\right)}{s^2+2s+5}$

$\dfrac{-3}{5}\left(\dfrac{s+1+1}{(s+1)^2+4}\right)$

$\dfrac{s+1}{(s+1)^2+4} + \dfrac{1}{(s+1)^2+4} * 2/2$

$\dfrac{3}{5s} + \dfrac{-3}{5}\left[\dfrac{s+1}{(s+1)^2+4} + \dfrac{1}{2}\dfrac{2}{(s+1)^2+4}\right]$

$Y(t) = \dfrac{3}{5} - \dfrac{3}{5}e^{-t}\cos(2t) - \dfrac{3}{10}e^{-t}\sin(2t)$

30/09/2018

Transfer function: (linear systems)

The ratio of laplace tranform of the O/p variable to the laplace transform of the I/p variable with all initial conditions = 0 zero

$$G(s) = T(s) = \frac{Y(s)}{R(s)} = \frac{\text{output}}{\text{Input}}$$

$$m y'' + b y' + k y = r(t)$$

O/p ⇒ y   i/p ⇒ r

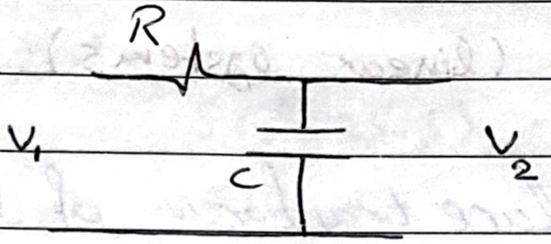
$$m s^2 Y(s) + b s Y(s) + k Y(s) = R(s)$$

$$Y(s)\left[m s^2 + b s + k\right] = R(s)$$

$$\frac{Y(s)}{R(s)} = \frac{1}{m s^2 + b s + k}$$

02/10/2018

Ex:



$T.F = \frac{O/P}{I/P}$

$\Rightarrow O/P = T.F * I/P$

$Y(S) = G(S) \cdot R(S)$

$\hookrightarrow y(t)$ #note

I/P V_1 , O/P I

Find:

$T.f = T(S)$, $\frac{I(s)}{V_1(S)}$

$\frac{V_2(S)}{V_1(S)} = ?!$ $\Rightarrow V_1 = V_R + V_C$

$V_1 = IR + \frac{1}{C}\int I \, dt$

$\Rightarrow V_2 = V_C = \frac{1}{C}\int I \, dt$

$V_1(S) = I(S) R + \frac{1}{CS} I(S)$

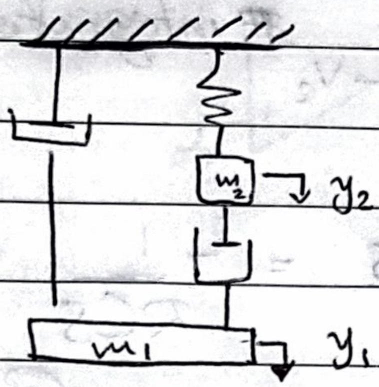
$V_1(S) = I(S)\left[R + \frac{1}{CS}\right]$

$\Rightarrow \frac{I(S)}{V_1(S)} = \frac{CS}{RCS + 1}$

02/10/2018

Ex من الكتاب

H.W



O/P $\Rightarrow y_1 , y_2$

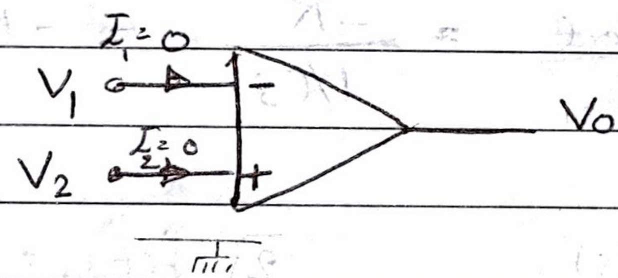
I/P $\Rightarrow r(t)$

$\frac{Y_2(s)}{R(s)}$, $\frac{Y_1(s)}{R(s)}$

OP-Amp transfer function :

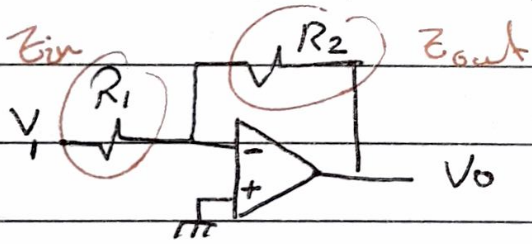
↳ operational amplifier

* controller



for Ideal op-amp : $I_1 = I_2 = 0$

Ex:



$$\frac{V_o(s)}{V_i(s)} = \frac{-Z_{out}}{Z_{in}} = \frac{-R_2}{R}$$

$Z_c = \frac{1}{Cs}$

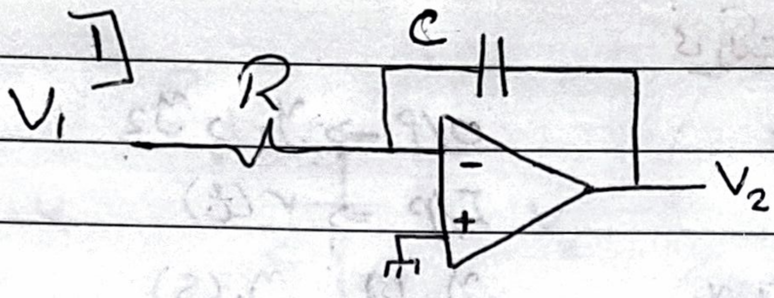
$Z_L = LS$

Propotional (P)

02/10/2018

Ex:

1]

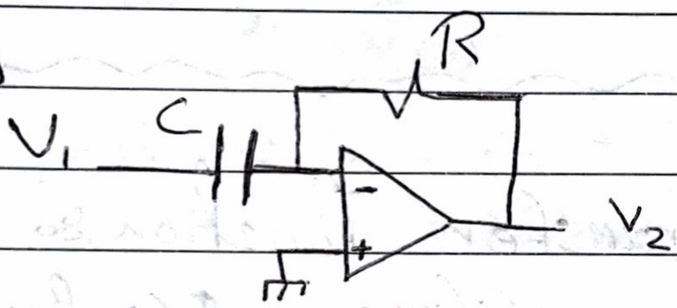


integrator

$$\frac{V_2(s)}{V_1(s)} = \frac{-Z_{out}}{Z_{in}} = -\frac{1/CS}{R} = -\frac{1}{RCS}$$

I

2]



D

$$\frac{V_2(s)}{V_1(s)} = \frac{-Z_{out}}{Z_{in}} = \frac{-R}{1/CS} = -RCS$$

1] $\int f(t) = \frac{f(s)}{s}$

2] $f(t) = S\,f(s)$
diff

PID

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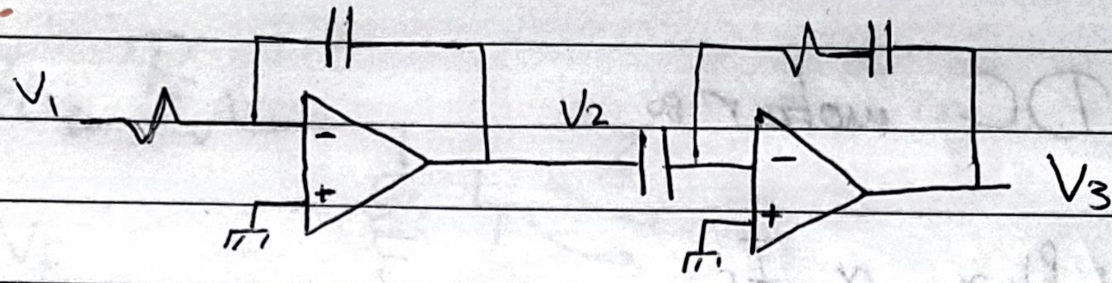
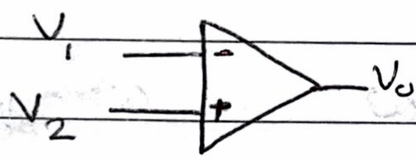
Ex:

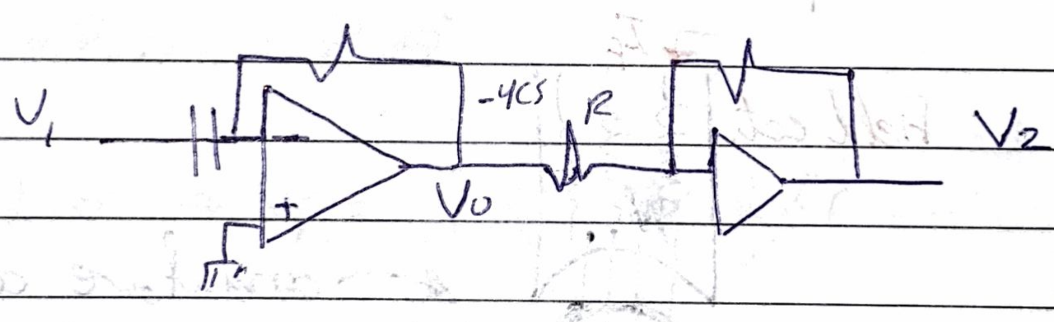


$$\frac{V_3}{V_1} = \frac{V_3}{V_2} * \frac{V_2}{V_1}$$



⇒ Summing Point.

Ex: $\frac{V_2}{V_1} = 4CS$



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DC motor:

* ϕ : flux $\propto I_f$

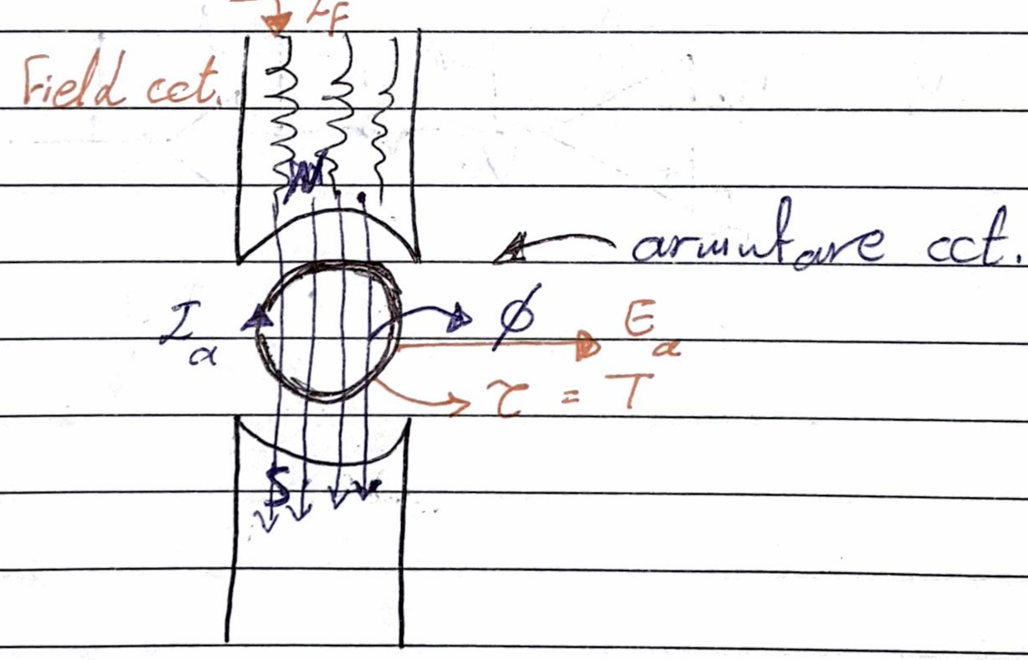
   $\Rightarrow \phi = K_f I_f$

* E = emf $\propto \phi\, \omega$

   $\Rightarrow E_a = K_b \phi\, \omega$ ω: angular speed

* $T \propto I_a \phi$

   $\Rightarrow T = K_1 \phi I_a$



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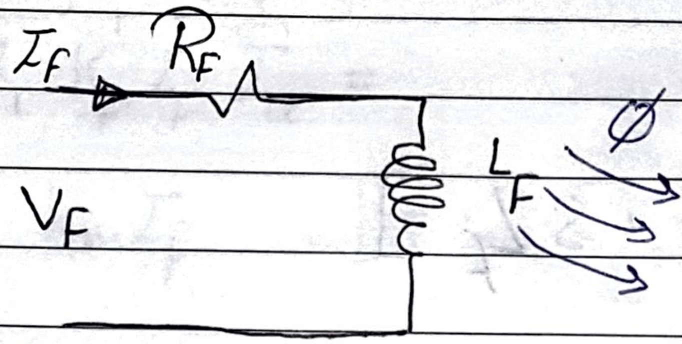
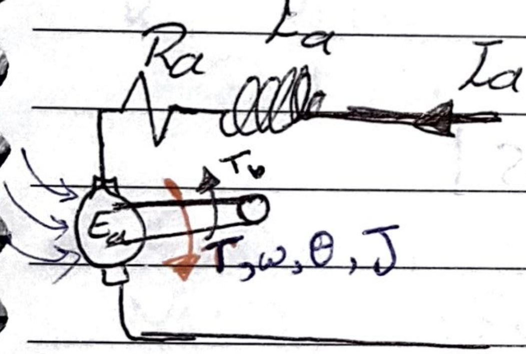


field cct. ⇒



R_f, R_a, L_f, L_a, J → constant

armature cct.

$$T_B = B\omega = B\dot{\theta}$$

filed cct ⇒ $V_f = I_f R_f + L_f \dfrac{dI_f}{dt}$ --- (1)

armature cct ⇒ $V_a = I_a R_a + L_a \dfrac{dI_a}{dt} + E_a$ -- (2)

$$\sum T = J\ddot{\theta}$$

↳ $T - T_b = J\ddot{\theta} \Rightarrow T - b\dot{\theta} = J\ddot{\theta}$

$$T = J\ddot{\theta} + b\dot{\theta} \quad \text{----} \ (3)$$

07/10/2018

To laplace :

1 $V_f(s) = I_f\left[R_f + S L_f\right]$

2 $V_a(s) = I_a\left[R_a + S L_a\right] + E_a(s)$

3 $T(s) = \theta(s)\left[J S^2 + b S\right]$

If the input is $V_f(s)$ and o/p is $\theta(s)$

V_f : field voltage , θ : Position

$\cancel{\frac{V_f(s)}{\theta(s)}}$ $\quad \frac{O/P}{I/P} = \frac{\theta(s)}{V_f(s)}$

$T(s) = K_1 \phi(s) I_a(s)$ T elec.

$= \theta(s)\left[J S^2 + b S\right]$ T mech.

07/10/2018

$$\underbrace{K_1 K_f}_{\text{constant } K_m} I_f \, I_a =$$

$$K_m I_f = [J S^2 + bs]\,\theta(s)$$

from eq. 1 ∴

$$K_m \frac{V_f(s)}{R_f + SL_f} = [JS^2 + bS]\,\theta(s)$$

$$\Rightarrow \frac{\theta(s)}{V_f(S)} = \frac{K_m}{(R_F + SL_f)(JS^2 + bS)}$$

09/10/2018

If the input V_a, output θ ∴
"armuture voltage controlled DC motors"

$$T_{elec} = T_{mech}$$

$$\underbrace{K_1 \phi}_{\text{cons.} = K_{m_1}} I_a(s) = \theta(s)\,[Js^2 + bs]$$

$$K_{m_1} I_a(s) = \theta\,[Js^2 + bs]$$

09/10/2018

* where $I_a = \dfrac{V_a - E_a}{R_a + S L_a}$

* $E_a = K_b \phi \omega \Rightarrow K_B \dot{\theta} \Rightarrow K_B S \theta(s)$

→ $K_m \left[\dfrac{V_a(S) - K_B S \theta(S)}{R_a + S L_a} \right] = \theta(s) \left[J S^2 + b S \right]$

$$\frac{\theta(S)}{V_a(S)} = \frac{K_m}{S[(R_a + L_a S)(JS + b) + K_b K_m]}$$

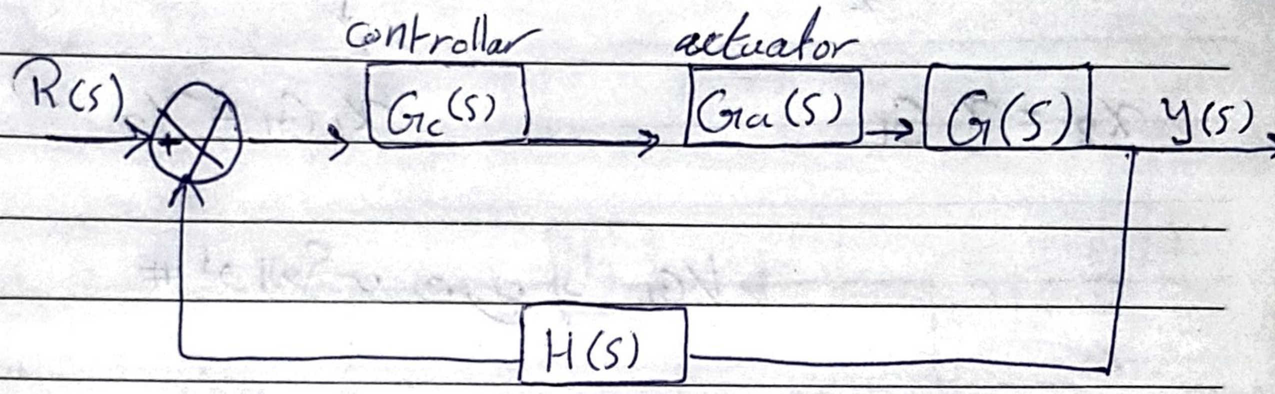
notes: 2 inputs ⇒ one output ⇒ 2 T.F ⇒ sum

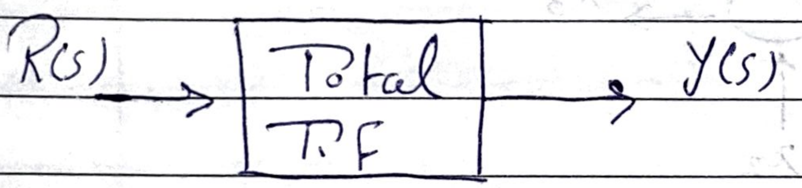
Ex: $V_a \xleftrightarrow{1} \theta \Rightarrow 1 + 2$

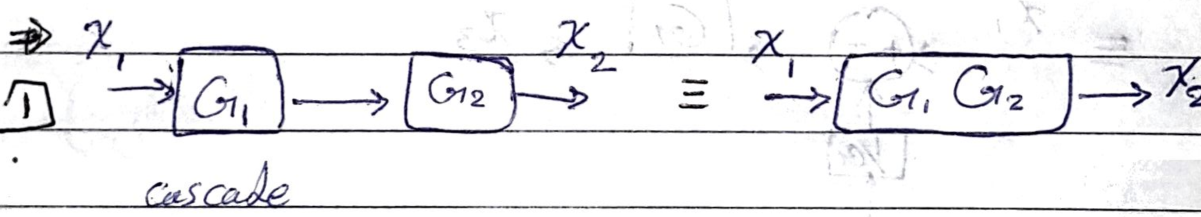
$V_f \xrightarrow{2} \theta$

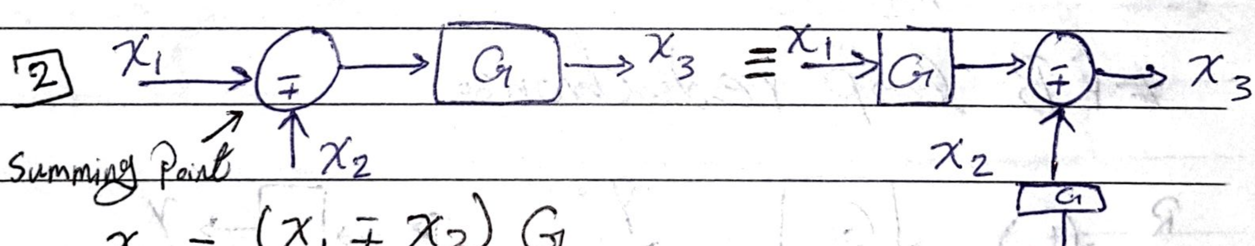
09/10/2018

Block Diagram :







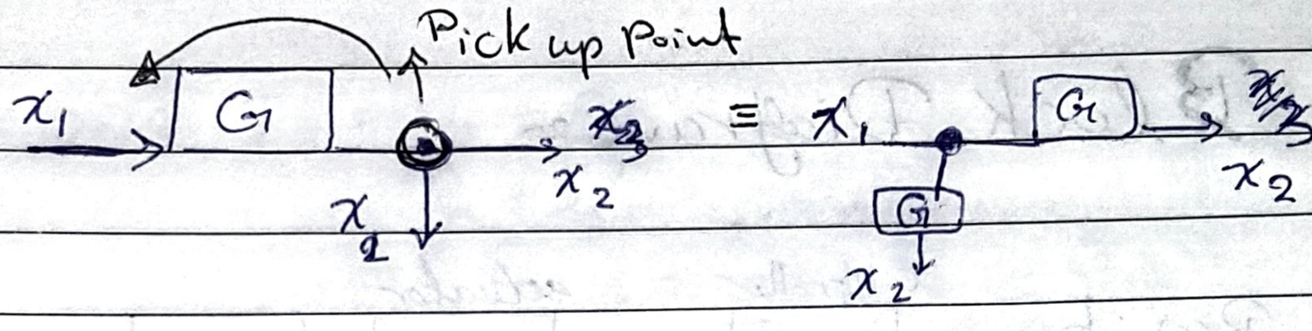


$x_3 = (x_1 \mp x_2) G$

$= x_1 G_1 \mp x_2 G_1$

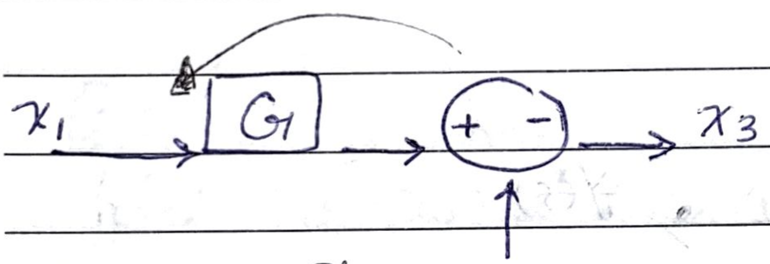
$x_1 G \mp x_2 G_1 = x_3$

09/10/2018

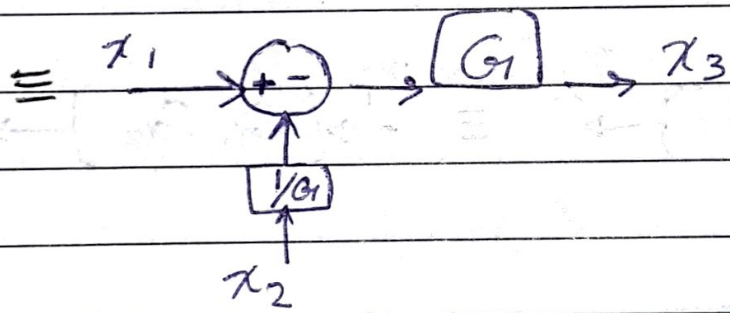


$x_2 = x_1 G_1$ $\qquad$ $x_1 G_1 = x_2$

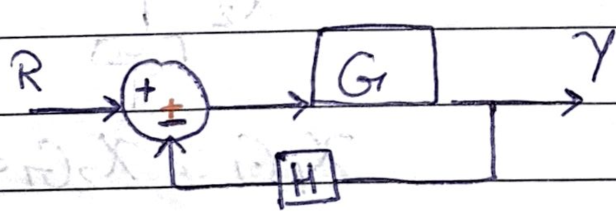
لو العكس بضرب بـ $1/G_1$

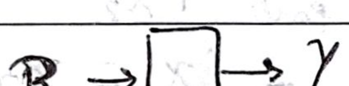


$x_1 G_1 \mp x_2 = x_3$



FB loop reduction

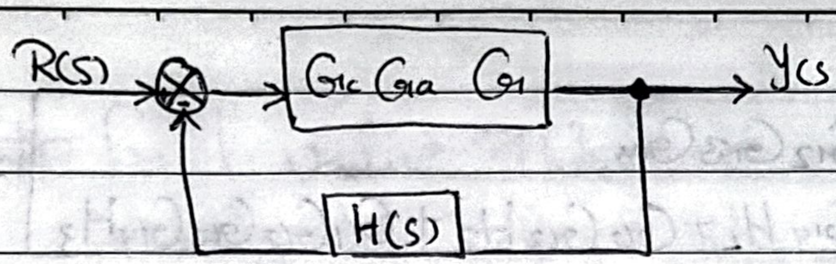




$$\frac{Y(s)}{R(s)} = \frac{G}{1 \mp GH}$$

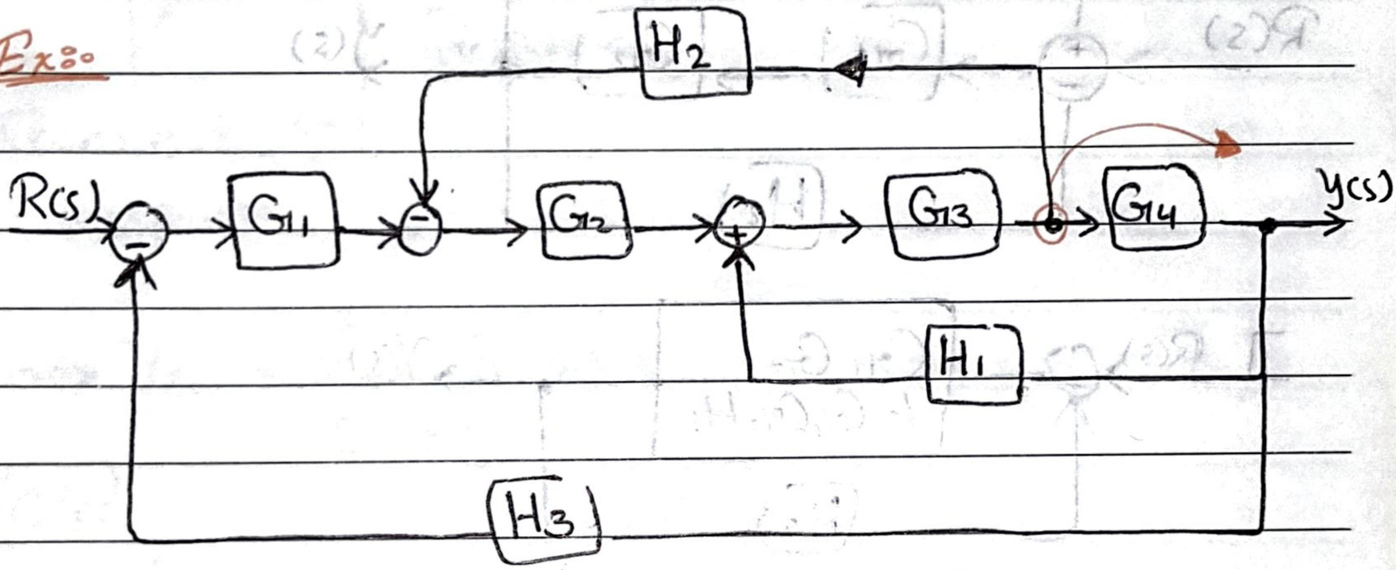
11/10/2018

Ex:

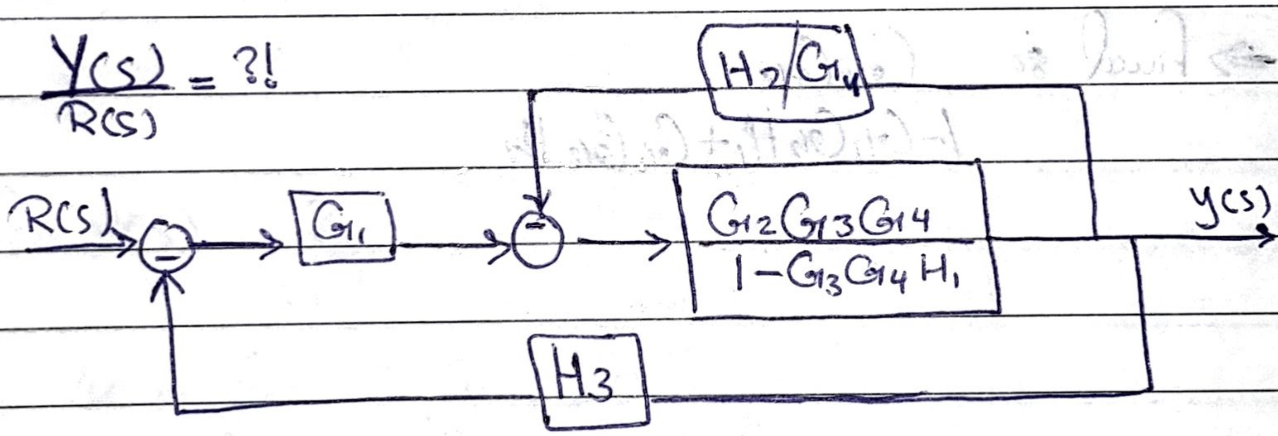


$$\frac{Y(s)}{R(s)} = \frac{G_c G_a G_1}{1 + G_c G_a G_1 H}$$

Ex:



$$\frac{Y(s)}{R(s)} = ?!$$

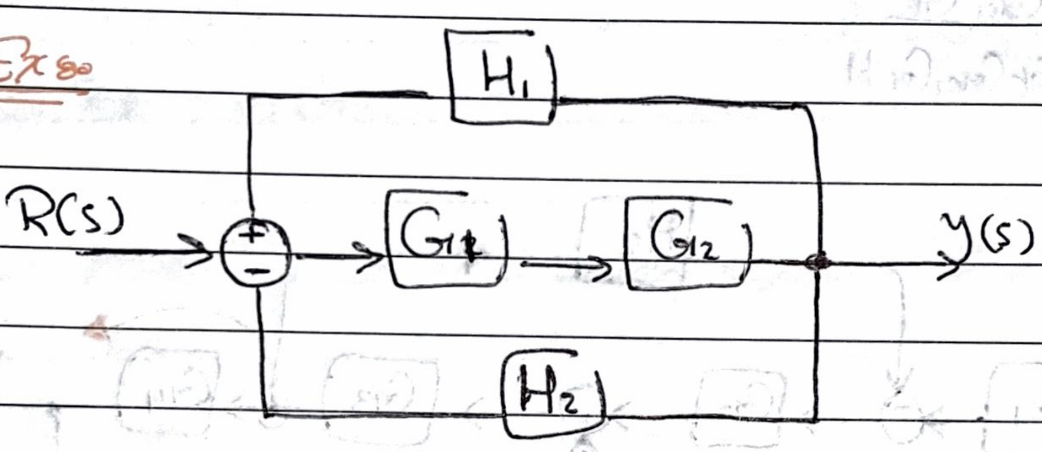


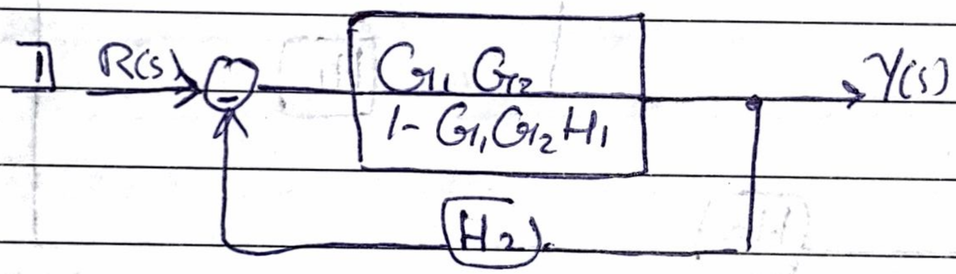
$$\frac{\dfrac{G_2 G_3 G_4}{1 - G_3 G_4 H_1}}{1 + \dfrac{G_2 G_3 \cancel{G_4}}{1 - G_3 G_4 H_1} \cdot \dfrac{H_2}{\cancel{G_4}}} = \frac{1 - G_3 G_4 H_1 + G_2 G_3 H_2}{1 - G_3 G_4 H_1}$$

11/10/2018

$\Rightarrow R(s) \rightarrow \boxed{\dfrac{G_1G_{12}G_3G_4}{1-G_3G_4H_1+G_{12}G_{13}H_2+G_1G_{12}G_3G_4H_3}} \rightarrow Y(s)$

Ex 80





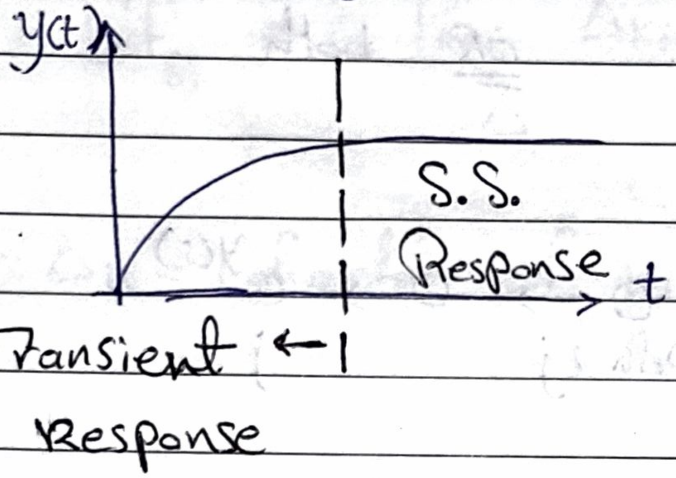
$\Rightarrow$ final 80 $\dfrac{G_1G_{12}}{1-G_1G_{12}H_1+G_1G_{12}H_2}$

11/10/2018

final value Theorm :

* study state value * عندما يستقر النظام

for any func. #
"sys."



→ $Y_{ss} = \lim_{S \to 0} S\, Y(S)$

OR

→ $Y_{ss} = \lim_{t \to \infty} y(t)$

Ex: $Y(S) = \dfrac{3}{S+4}$

$Y_{ss} = \lim_{S \to 0} S \dfrac{3}{S+4} = 0$

OR $y(t) = 3e^{-4t}$

$y_{ss} = \lim_{t \to \infty} y(t) = \lim_{t \to \infty} 3e^{-4t} = 0$

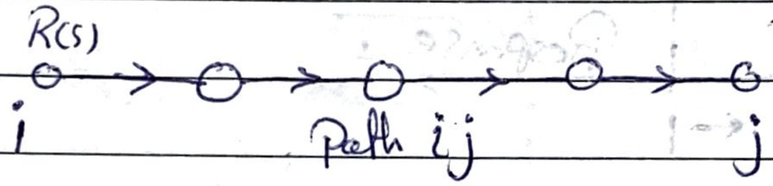
14/10/2018

Signal flow Graph:

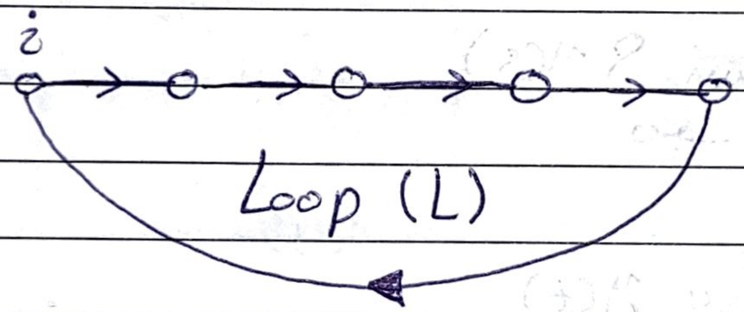
$\xrightarrow{G}$ branch

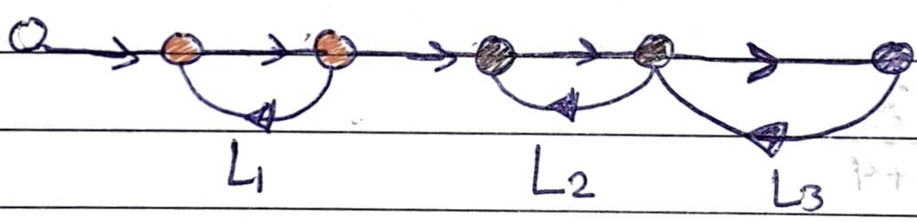
o node. ⇒ I/p OR O/p OR both

* Path (P)



* loop





non-touching loops: L_1 & L_2 , L_1 & L_3

2#

Touching loop: L_2 & L_3

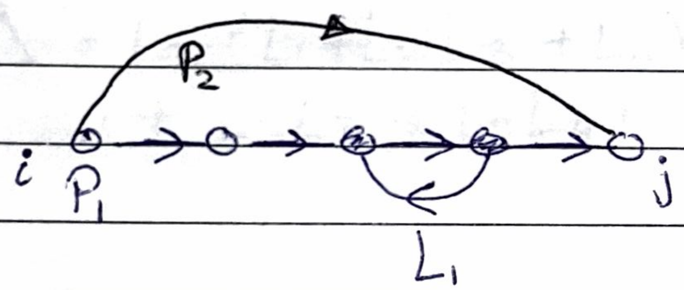
1#

14/10/2018

Mason's Rule :

$$T.F._{ij} = \frac{\sum P_{k i-j} \, \Delta_{k i-j}}{\Delta}$$

* Δ_K = Cofactor of Path (k)
  = 1 - Loops that don't touch Path k.



* $\Delta_1 = 1 - 0 = 1$ * $\Delta_2 = 1 - L_1$

* Δ : Determinant of the Graph

Δ = 1 - (Sum of all loops Gain)

+ [Sum of the product of all (2 n.t.L)]

- [Sum of the product of all (3 n.t.L.)]

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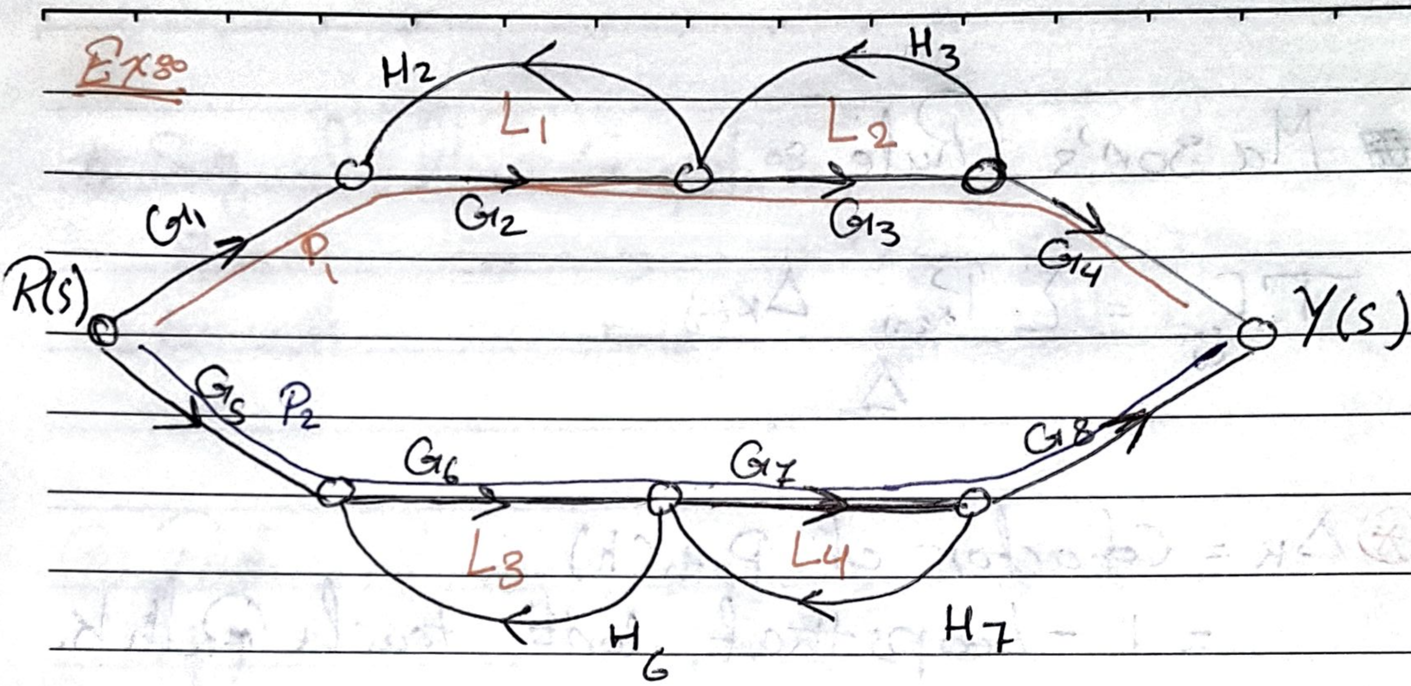
Ex:



Find T.F $\frac{Y(s)}{R(s)}$

$P_1 = G_1 G_2 G_3 G_{14}$

$P_2 = G_5 G_6 G_7 G_8$

$L_1 = G_2 H_2$

$L_2 = G_3 H_3$

$L_3 = G_6 H_6$

$L_4 = G_7 H_7$

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#2. N.T.Ls :

L_1, L_3 / L_1, L_4 / L_2, L_3 / L_2, L_4

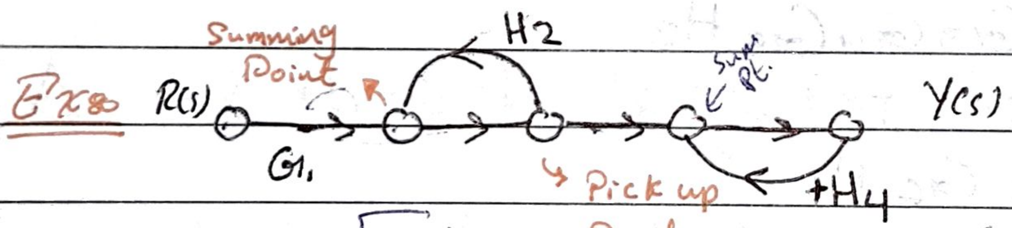
* $\Delta_1 = 1 - (L_3 + L_4) = 1 - L_3 - L_4$

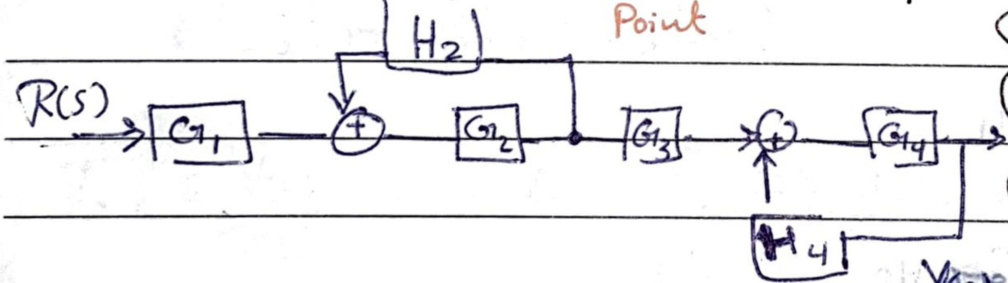
* $\Delta_2 = 1 - L_1 - L_2$

* $\Delta = 1 - (L_1 + L_2 + L_3 + L_4) + (L_1 L_3 + L_1 L_4 + L_2 L_3 + L_2 L_4)$

$\Rightarrow \dfrac{\sum P_K \Delta_K}{\Delta} = \dfrac{P_1 \Delta_1 + P_2 \Delta_2}{\Delta}$

Ex :





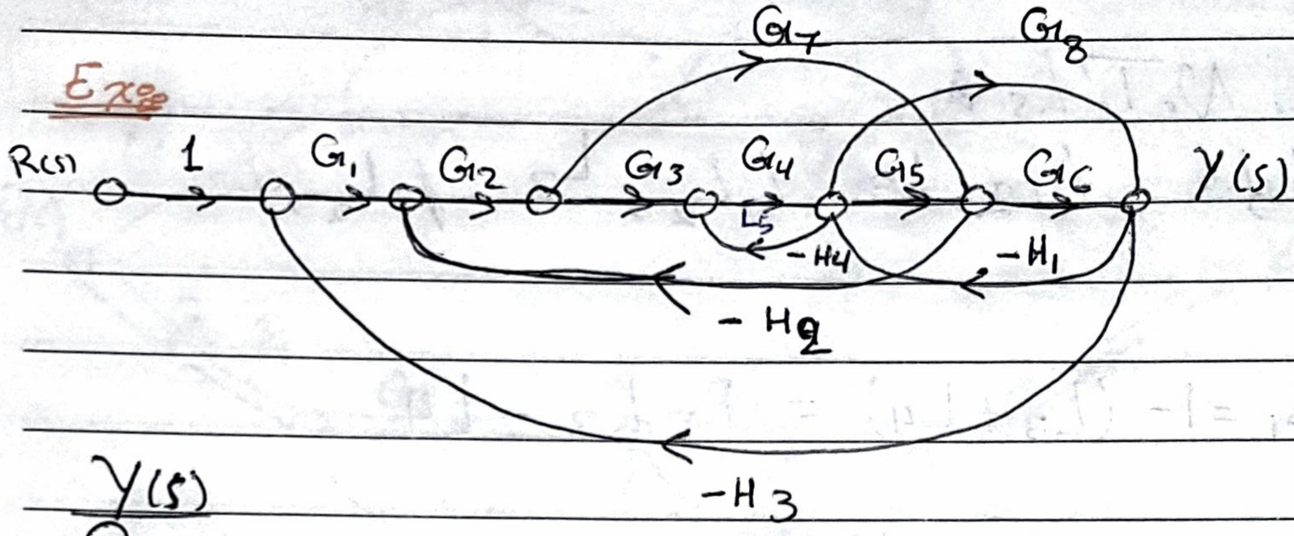
* كل node داخل عليها أكثر من br. ⟵ Sum. pt.

* كل node طالع منها أكثر من br. ⟵ Pick up. pt.

* إذا كانت −H4 ⟵ بالبلوك $\boxed{H_4}$ ⟵ بالـ Summing pt ⟵ $\ominus$

16/10/2018

Ex:



$$\frac{Y(s)}{R(s)}$$

$P_1 = 1 G_1 G_2 G_3 G_4 G_5 G_6$

$P_2 = 1 G_1 G_2 G_7 G_6$

$P_3 = 1 G_1 G_2 G_3 G_4 G_8$

$L_1 = -G_2 G_3 G_4 G_5 H_2$

$L_2 = -G_5 G_6 H_1$

$L_3 = -G_8 H_1$

$L_4 = -G_2 G_7 H_2$

$L_5 = -G_4 H_4$

16/10/2018

$L_6 = -G_1 G_2 G_3 G_4 G_5 G_6 H_3$

$L_7 = -G_1 G_2 G_7 G_6 H_3$ #ال Loop الي جاي

$L_8 = -G_1 G_2 G_3 G_4 G_8 H_3$

2 n.T.L.

$L_5 \; L_4$

$L_5 \; L_7$

$L_3 \; L_4$

$\Delta_1 = 1$

$\Delta_2 = 1 - L_5$

$\Delta_3 = 1$

$$\Delta = 1 - (L_1 + L_2 + L_3 + L_4 + L_5 + L_6 + L_7 + L_8)$$

$$+ (L_5 L_4 + L_5 L_7 + L_3 L_4)$$

$$T.f = \frac{Y(s)}{R(s)} = \frac{P_1 \Delta_1 + P_2 \Delta_2 + P_3 \Delta_3}{\Delta}$$

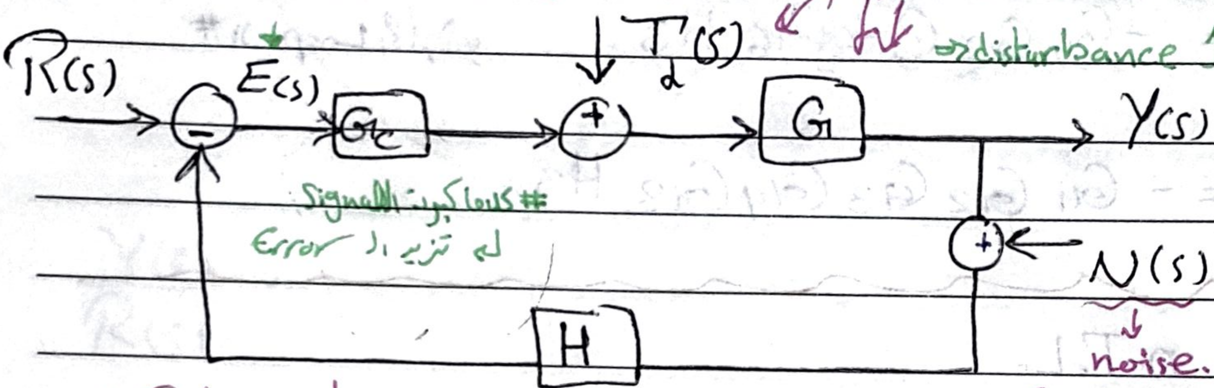
→ first Exam

23/10/2018

CH4: FB Sys. Charac.

Error signal → Summing Pt. تتكون بعد الـ

مؤثر خارجي يفضل التقليل منه

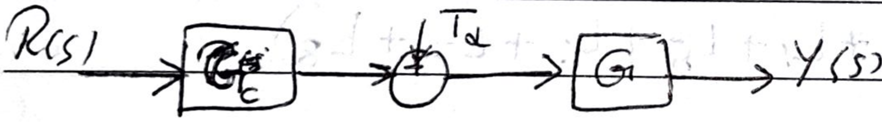


Closed sys.

مقارنة بين C.L و O.L من ناحية الـ accuracy ← إيجاد الـ Error

↳ steady state الـ في → E. of sys. ↓ ⇒ أحسن sys

Open sys. :



The disadvantages of C.L systems: [1] cost [2] complexity

23/10/2018

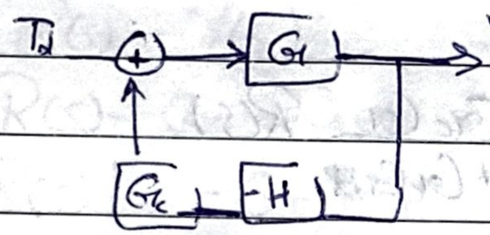
*for closed loop syst, so

$$\frac{Y(s)}{R(s)} = \frac{G_c G}{1 + G_c G H}$$

لانعتبر ال $N, T_d = 0$ ع شرح Sum PE.

$$\Rightarrow Y(s) = T.f * R(s)$$

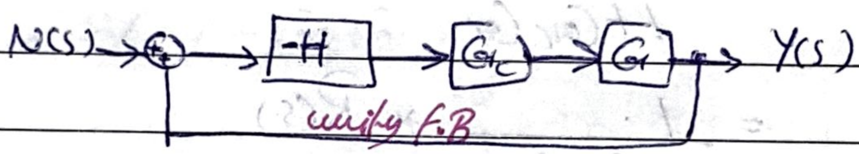
$$\frac{Y(s)}{T_d(s)} =$$



$$\Rightarrow \frac{G}{1 + G G_c H}$$

$$Y(s) = T.f * T_d$$

$$\frac{Y(s)}{N(s)} =$$



$$= \frac{-G_c G H}{1 + G_c G H} \Rightarrow Y(s) = T.f * N(s)$$

$$\text{Total } y = \sum Y(s)$$

for Open loop Sys. so

$$\frac{Y(s)}{R(s)} = G_c G \Rightarrow Y(s) = G_c G\, R(s)$$

$$\frac{Y(s)}{T_d(s)} = G \Rightarrow Y(s) = G\, T_d(s)$$

$$\text{Total } Y = G_c G\, R(s) + G\, T_d(s)$$

23/10/2018

$$E(s) = R(s) - Y(s)$$ # for Closed loop

Error due to $R(s)$ :: "if $H(s) = 1$

$N(s), T_d(s) = 0$

$$\hookrightarrow E(s) = R(s) - \frac{G_c G}{1 + G_c G} R(s)$$

$$= \frac{1 + G_c G - G_c G}{1 + G_c G} * R(s)$$

$$= \frac{1}{1 + G_c G} * R(s)$$

$$e_{ss} = \lim_{s \to 0} s \frac{1}{1 + G_c G} * R(s)$$

steady state error

$R(s) = \frac{1}{s}$

$\hookrightarrow$ unit step i/p

$$\hookrightarrow \lim_{s \to 0} \cancel{s} \frac{1}{1 + G_c G} * \frac{1}{\cancel{s}}$$

$$e_{ss\,C.L} = \frac{1}{1 + G_c(0) G(0)}$$

* عند التعويض بالـ s=0 وكانت قيمة الـ e_{ss} = -ve ← نهمل الإشارة عند المقارنة
بين الـ O.L والـ C.L

23/10/2018

Error for Open loop sys:

Error due to $R(s) = \frac{1}{s}$

$$E(s) = R(s) - Y(s)$$
$$= R(s) - G_c G_1 R(s)$$
$$= R(s)[1 - G_c G_1]$$

$$e_{ss} = \lim_{s \to 0} \cancel{s}(1 - G_c G_1)\frac{1}{\cancel{s}}$$

$$e_{ss\,O.L} = 1 - G_c(0) G_1(0)$$

so $e_{ss\,C.L} < e_{ss\,O.L}$

$acc_{C.L} > acc_{O.L}$

$E(s) = R(s) - Y(s)$ ⇒ due To $T_d(s)$, $N(s), R(s) = 0$, $H(s) = 1$

$$E(s) = 0 - \frac{G_1 T_d(s)}{1 + G_c G_1} = -\frac{G_1 T_d(s)}{1 + G_c G_1}$$ → unit step i/p

$$e_{ss\,C.L} = \frac{-G_1(0)}{1 + G_c(0) G_1(0)}$$

23/10/2018

\# for O.L.

Due to $T_d(s)$

$$E(s) = R(s) - Y(s)$$
$$= 0 - G_1 T_d(s) = -G_1 T_d(s)$$

$$e_{ss\,O.L} = \lim_{s \to 0} s(-G_1) \cdot \frac{1}{s} = -G_1(0)$$

so $e_{ss\,C.L} < e_{ss\,O.L}$ due to T_d

disturbance.
Rejection رفض التشويش > d.R. O.L
C.L أدد noise

25/10/2018

\# Noise Rejection : $H(s) = 1$

error due to $N(s)$ $T_d, R(s) = 0$

$$\frac{Y(s)}{N(s)} = \frac{-G_c G_1}{1 + G_c G_1}$$

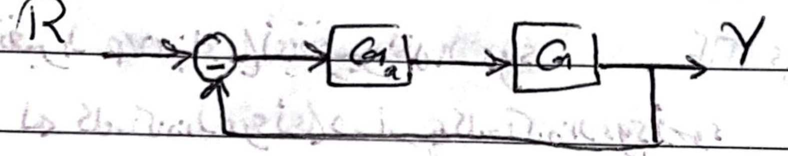
$$E(s) = R(s) - Y(s) \qquad N(s) = \frac{1}{s}$$

$$e_{ss} = \lim_{s \to 0} \left(0 - \frac{-G_c G_1}{1 + G_c G_1} \right) = \lim_{s \to 0} \cancel{s} \frac{G_c G_1}{1 + G_c G_1} \cdot \frac{1}{\cancel{s}} = \frac{G_c G_1}{1 + G_c(0) G_1(0)}$$

25/10/2018

Ex 8: $G(s) = \dfrac{10}{s(0.001s+1)}$, $G_a = K$

for unit step ~~function~~ input $\frac{1}{s}$, find e_{ss}



$\Rightarrow E(s) = R(s) - Y(s) = R(s)\left[1 - \dfrac{G_a G}{1+G_a G}\right] = R(s)\,\dfrac{1}{1+G_a G}$

توحيد مقامات

$\dfrac{Y(s)}{R(s)} = \dfrac{G_a G}{1+G_a G} \Rightarrow Y(s) = \dfrac{G_a G}{1+G_a G}\,R(s)$

$\Rightarrow e_{ss} = \lim_{s\to 0} \cancel{s} \cdot \dfrac{1}{1+\overset{K}{G_a}\overset{\infty}{G}} \cdot \dfrac{1}{\cancel{s}} = 0$ $\boxed{\text{no error - Perfect sys.}}$

⊛ If $r(t) = 10t = \frac{10}{s^2}$, $e_{ss} = 0.1\,mm$, find K?!

$\lim_{s\to 0} \cancel{s}\, \dfrac{1}{1+\underset{K}{G_a}\,\underset{\frac{10}{s(0.001s+1)}}{G}} \cdot \dfrac{10}{s^{\cancel{2}}} = 0.1 * 10^{-3}$

$\Rightarrow \lim_{\substack{s\to 0\\ s=0}} \dfrac{10}{s + K\,\dfrac{10}{s(0.001s+1)}} = 0.1 * 10^{-3} = \dfrac{1}{K}$

25/10/2018

Sensitivity:

→ The Ratio of the change in the sys. T.F. to the change of a process T.F for Small Change.

~~ratio~~ sys T.F

* تغير ال o/p بناءً على أي تغيير داخل ال sys

لو كلما كان ال sys ذو حساسية كلما كان ال sys أسوء

$$S_G^T = \frac{\Delta T}{\Delta G}$$

process T.F (plant)

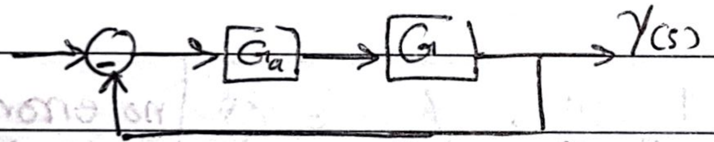
$$= \frac{\partial T / T}{\partial G / G} = \frac{\partial T}{\partial G} \cdot \frac{G}{T}$$

تغير في ال T.F

تغير في ال process

اشتقاق بالنسبة ل G

Ex:

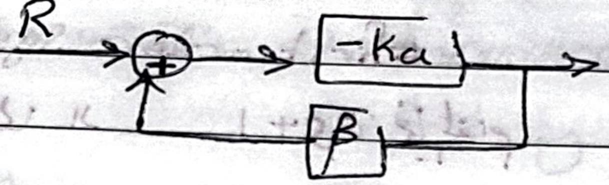


$$T = \frac{Y(s)}{R(s)} = \frac{G_a G}{1 + G_a G}$$

$$S_G^T = \frac{G_a}{(1+G_a G)^2} \cdot \frac{G}{\frac{G_a G}{1+G_a G}} = \frac{1}{1+G_a G}$$

25/10/2018

Ex:



$$\frac{-Ka}{1+Ka\,\beta} = T$$

$\underbrace{Ka\,\beta}$: open loop

$$S^{T}_{Ka} = \frac{\partial T}{\partial Ka} \cdot \frac{Ka}{T}$$

Closed loop

$$= \frac{-1}{(1+Ka\,\beta)^2} \cdot \frac{Ka}{\frac{-Ka}{1+Ka\,\beta}} = \frac{1}{1+Ka\,\beta}$$

Ex: $R \rightarrow \boxed{-Ka} \rightarrow Y$ open loop

$T = -Ka$

$$S^{T}_{Ka} = -1 \cdot \frac{Ka}{-Ka} = 1$$

$S_{O.L.\,sys.} = 1 \Rightarrow$ دايماً الـ O.L

$\hookrightarrow$ 1 "الـ sensitivity"

25/10/2018

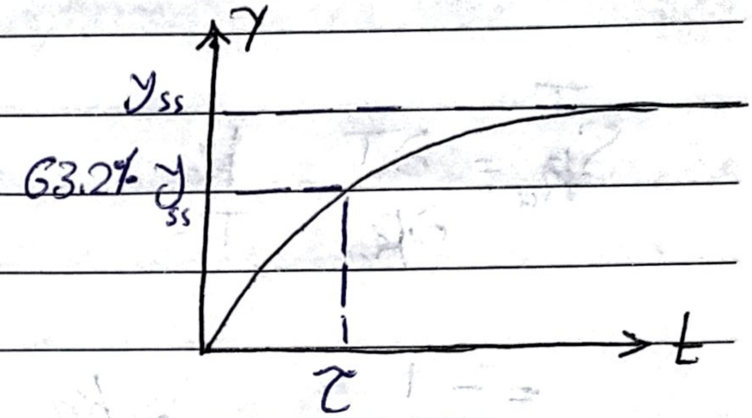
$$R(s) \rightarrow \boxed{\frac{1}{\tau s+1}} \rightarrow Y(s)$$

first order System

لما نلاقي الـ $\tau s+1$ في المقام

τ : Time constant

open loop



for closed loop :

$$\frac{\frac{1}{\tau s+1}}{\frac{\tau s+1}{\tau s+1}+\frac{1}{\tau s+1}} = \frac{1/2}{\frac{\tau}{2}s+\frac{2}{2}} =$$

⇒ Closed loop

⇒ So the advantages of CL: "through the role of signal error"

1] Decreased sensitivity of system to ① Ageing ② model uncertainty

③ variations in parameters of the process

④ environmental change sensor ⇒ "الحرارة، الرطوبة"

2] Improved rejection of disturbance — تخفيض الـ noise

3] " measurement → noise attenuation — St sys

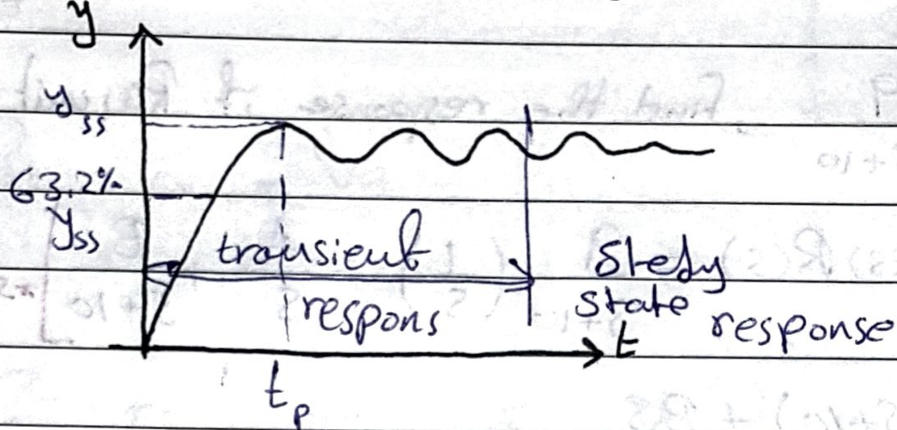
4] " reduction of steady state error — 1st order

5] " easy adjustment transient response

28/10/2018

تقسيم ال response الى قسمين

CH5: The performance of a feedback control systems:

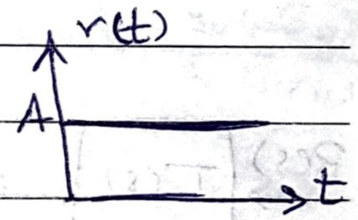


$\frac{Y(s)}{R(s)} * R(s) \Rightarrow$ laplace^{-1} ~~inverse~~ $\Rightarrow y(t)$

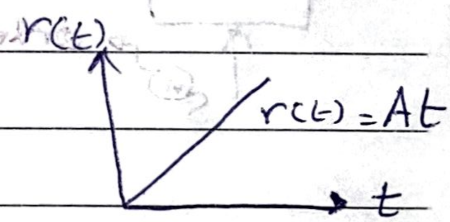
Test signals (Inputs), R(s)

① unit step input $\Rightarrow R(s) = \frac{1}{s}$

↳ $A = 1$



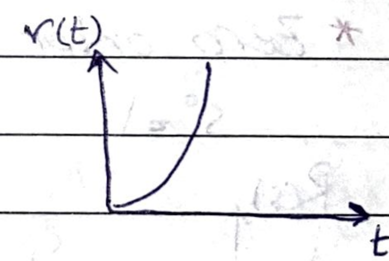
② Ramp input $\rightarrow R(s) = \frac{A}{s^2}$



③ parabolic Input

$r(t) = At^2$

$R(s) = \frac{2A}{s^3}$



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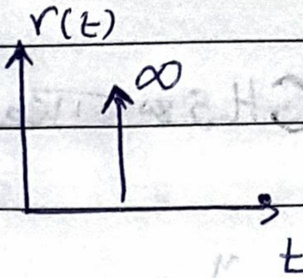
④ unit impulse input

$\delta(s) = 1$



Ex: $G(s) = \dfrac{9}{s+10}$, find the response if R(s) unit step

$$Y(s) = G(s)R(s) = \frac{9}{s+10}\left(\frac{1}{s}\right) = \frac{A}{s} + \frac{B}{s+10} \quad * s(s+10)$$

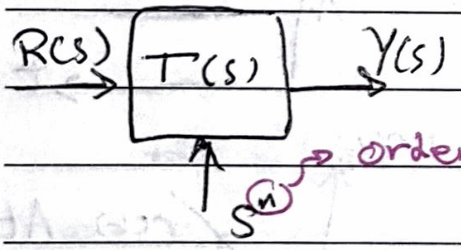
$$9 = A(s+10) + Bs$$

$\Rightarrow A = 0.9$, $B = -0.9$

when s=0 — when s=-10

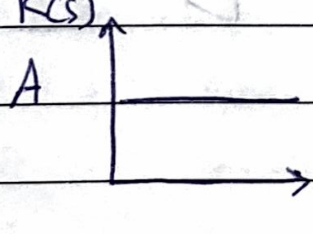
$$\Rightarrow y(t) = 0.9 - 0.9e^{-10t} = 0.9(1 - e^{-10t})$$

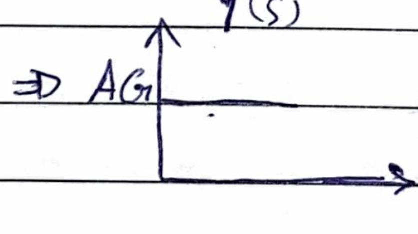
30/10/2018



* Zero order system :

$s^{0} = 1$, $T(s) = G$





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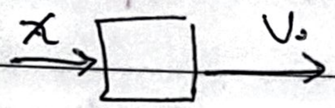
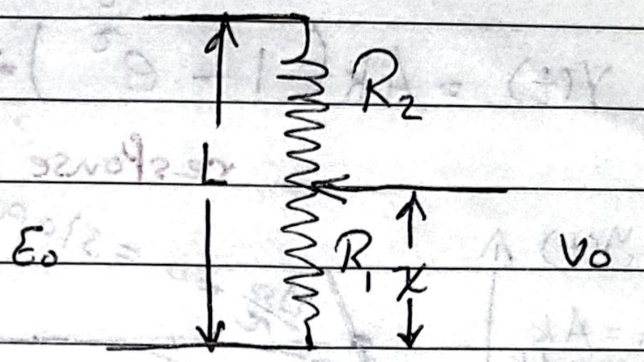
* Voltage Div. :-





$$\frac{R_1}{R_1+R_2} E_o = V_o$$

$$\frac{x}{L} E_o = V_o \Rightarrow \frac{V_o(S)}{x(S)} = \frac{E_o}{L}$$

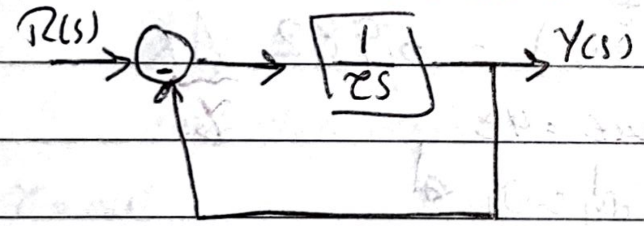
* First order System :-

$$\frac{Y(s)}{R(s)} = \frac{1/\tau s}{1+1/\tau s} = \frac{K}{\tau s+1}$$

K → Gain constant $= \frac{y_{ss}\ (o/p\ ss)}{R_{ss}\ (i/p\ ss)}$

τ → time constant.

General form of 1^{st} order system T.F



$y(t) = ?!$

⇒ Step input response :-

$$Y(s) = T(s)\,R(s) = \frac{K}{\tau s+1} \cdot \frac{A}{S} = \frac{B_1}{S} + \frac{B_2}{\tau s+1}$$

$B_1 = AK$, $B_2 = -AK$

$$Y(s) = AK\left(\frac{1}{S} - \frac{1}{\tau s+1}\right)$$

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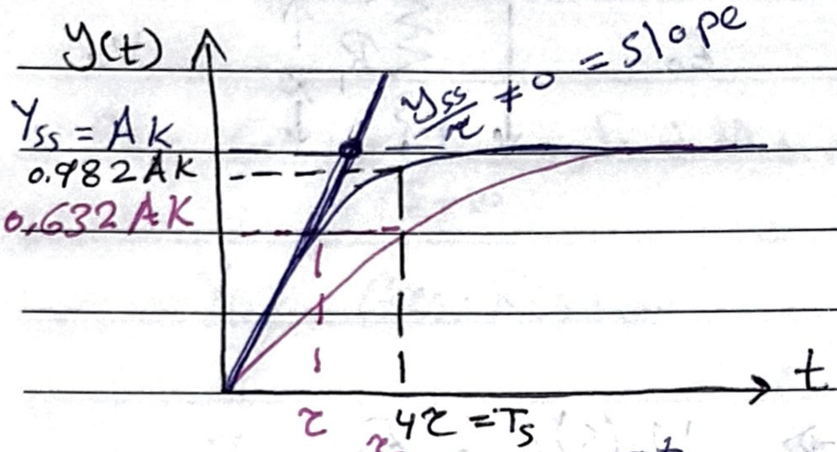
$$Y(t) = AK\left(1 - e^{\frac{-t}{\tau}}\right) \Rightarrow$$ General form step response for 1st order.



الـ sys 2nd أبطأ

$$Y_{ss} = \lim_{t \to \infty} AK\left(1 - e^{\frac{-t}{\tau}}\right) = AK$$

$$y(t)\Big|_{t=\tau} = AK\left(1 - e^{\frac{-\tau}{\tau}}\right) = 0.632 \underbrace{AK}_{Y_{ss}}$$

$$Y(t)\Big|_{t=4\tau} = AK\left(1 - e^{\frac{-4\tau}{\tau}}\right) = 0.982 \underbrace{AK}_{Y_{ss}}$$

\# settling time = 4τ

⇐ الزمن الي بيلزم ليوصل ل 98% من ال Y_{ss}

⇐ $98\% \, y_{ss} \pm 2\%$

$$y' = \frac{AK}{\tau} e^{-t/\tau}\Big|_0 \Rightarrow \frac{AK}{\tau} = \frac{y_{ss}}{\tau}$$

30/10/2018

from pre. Ex: $\frac{9}{S+10} \cdot \frac{1}{S}$

$y(t) = 0.9\,(1-e^{-10t})$

$e_{ss} \Rightarrow r(t) - y(t) = e(t)$

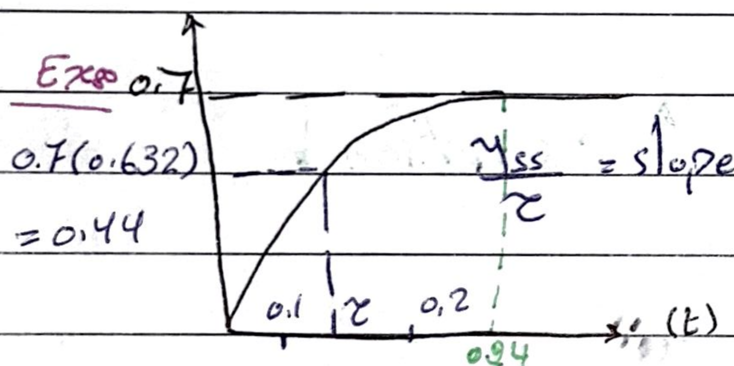
$E(s) = R(s) - Y(s)$

$\lim\limits_{t \to \infty} \left[1 - 0.9(1 - e^{-10t}) \right] = 1 - 0.9 = 0.1$

لما ال error ١٠٪

04/11/2018

Ex:



unit step response

$T(s) = ?!$

$R(s) = \frac{1}{s} \rightarrow A$

$\frac{K}{\tau S + 1}$

$\tau = 0.15$

$Y_{ss} = \overset{\rightarrow 1}{A} K = K = 0.7$

$\frac{0.7}{0.15 S + 1}$

$T_s = 4\tau$.

04/11/2018

Second order system :

ممكن يكون موجود او مش موجود

$$T(s) = \frac{K\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$$

زيتا

مهم

ξ : damping ratio $0, 1, 0<\xi<1, \xi>1$

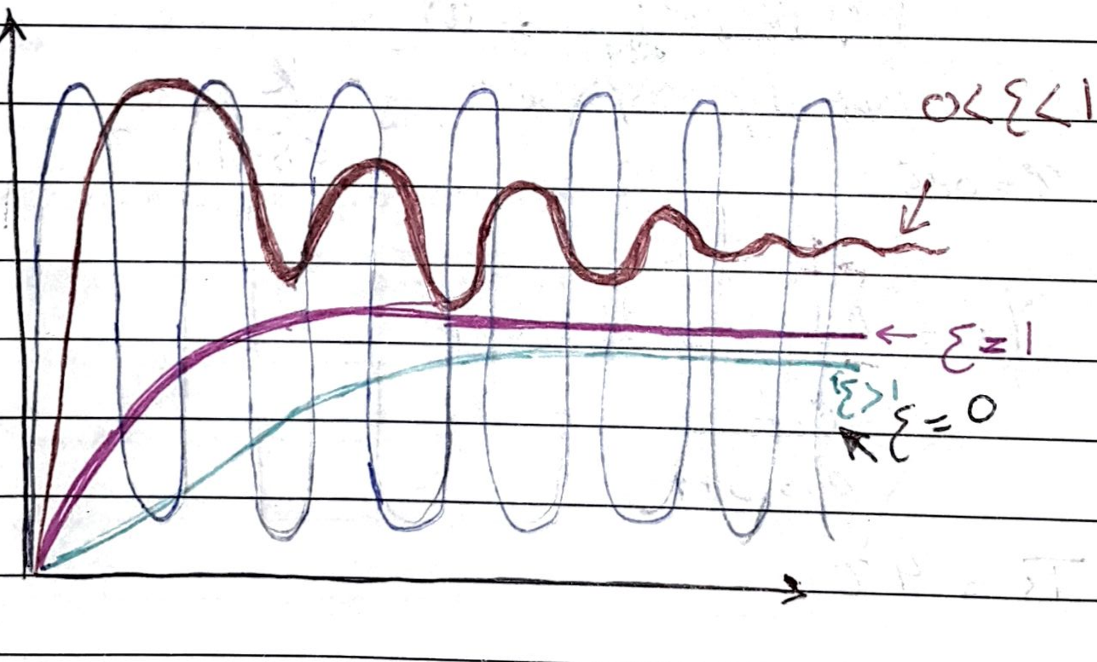
نسبة التخميد

ω_n : natural freq.

$Y(s) = T(s)\,R(s)$

Damper ↑ osalation ↓

الرد



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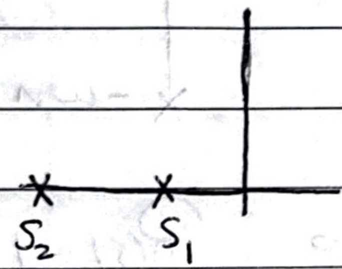
$\boxed{1}$ $\xi > 1$ over damped system $R(s) = \frac{1}{s}$

أصفار، قطام $S_{1,2} = -\xi \omega_n \pm \omega_n \sqrt{\xi^2 - 1}$ Real # [illegible] #



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

$\xi = 0.70$

$\boxed{2}$ $0 < \xi < 1$ under damped resp. $0 < \xi < 1$

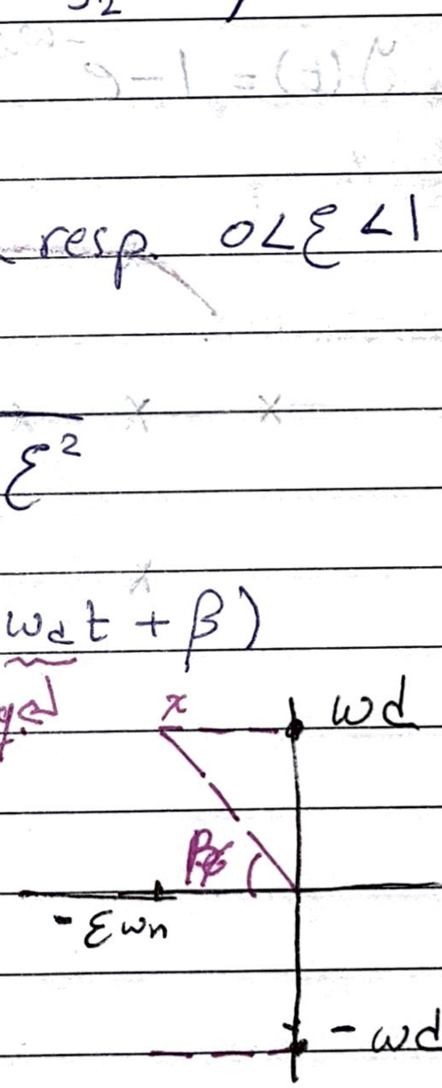
resp [illegible] # $R(s) = \frac{1}{s}$

$$S_{1,2} = -\xi \omega_n \pm j \omega_n \sqrt{1 - \xi^2}$$

$$y(t) = 1 - \frac{e^{-\xi \omega_n t}}{\sqrt{1 - \xi^2}} \sin(\omega_d t + \beta)$$

damped freq.

$$\beta = \tan^{-1} \frac{\omega_d}{\xi \omega_n}$$



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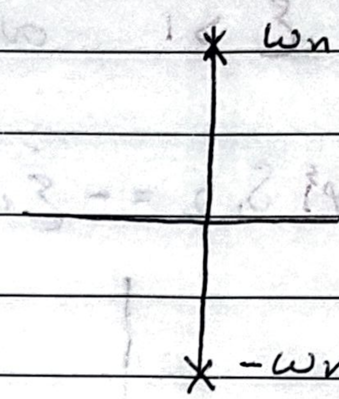
3) $\xi = 0$ undamped resp

$$S_{1,2} = \pm j\omega_n$$

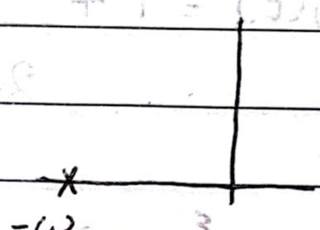


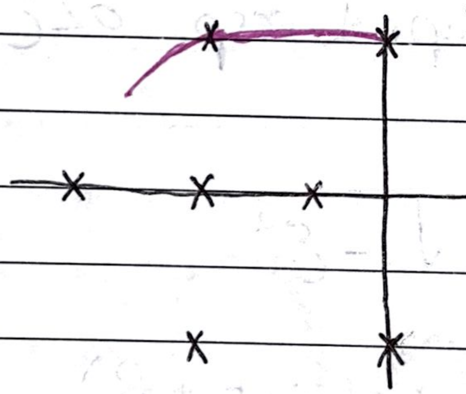
$$y(t) = 1 - \cos(\omega_n t)$$

4) $\xi = 1$ Critically damped resp $R(s) = \frac{1}{s}$

$$S_{1,2} = -\omega_n$$

$$y(t) = 1 - e^{-\omega_n t}(1 + \omega_n t)$$





$\xi = 0$

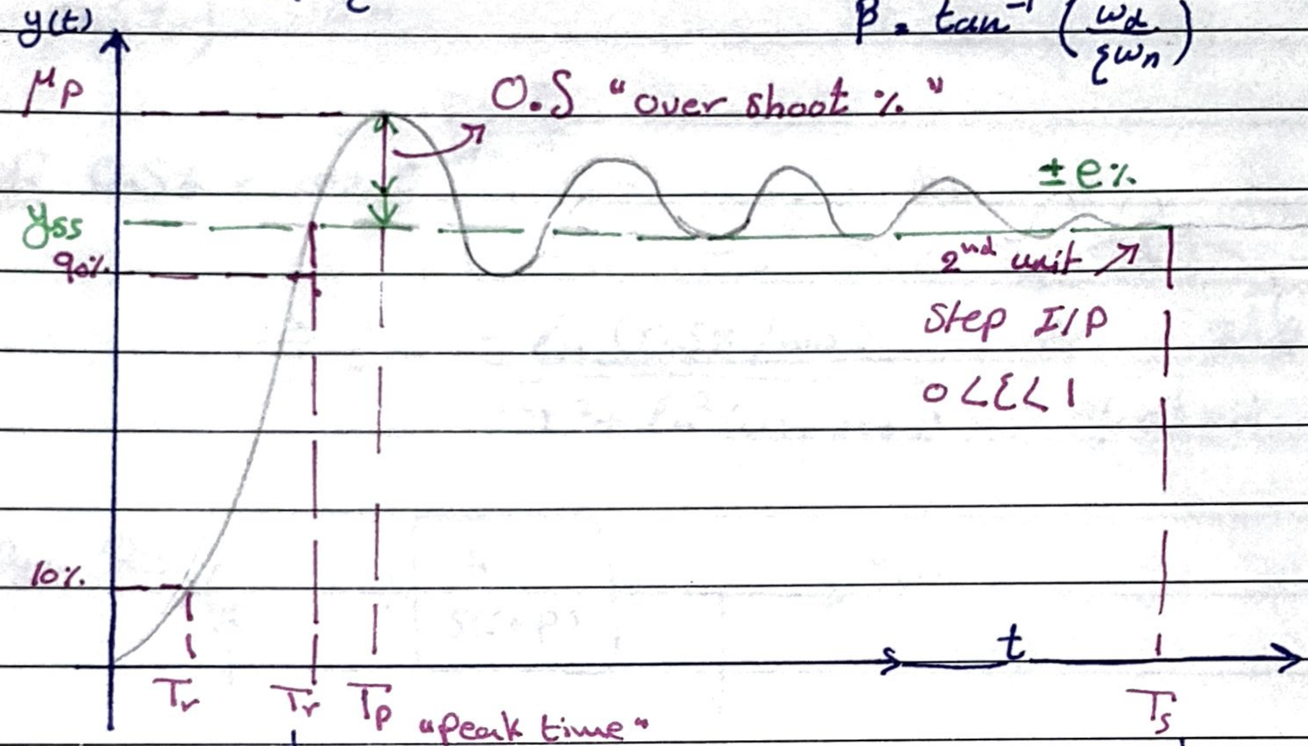
كل ما رايحة تصغر ع جهة اليسار

كل ما زاد stable ال sys.

04/11/2018

Ex: $y = 1 - \dfrac{e^{-\xi\omega_n t}}{\sqrt{1-\xi^2}} \sin(\omega_d t + \beta)$, $\omega_d = \omega_n\sqrt{1-\xi^2}$

$\beta = \tan^{-1}\left(\dfrac{\omega_d}{\xi\omega_n}\right)$



الزمن اللازم للوصول إلى y_{ss} الزمن الذي يستقر عنده السيستم

OR زمن الصعود هو للوصول إلى 90%

في الأب T_r = الزمن عند الانتقال من 10% ← 90% y_{ss}

06/11/2018

$*\ T_r$ = Rise time $= \dfrac{\pi - \beta}{\omega_d}$

$*\ T_p$ = Peak time $= \dfrac{\pi}{\omega_d} = \dfrac{\pi}{\omega_n\sqrt{1-\xi^2}}$

$*\ T_s$ = settling time $\rightarrow \dfrac{4}{\xi\omega_n}$ ± 2%

$\rightarrow \dfrac{3}{\xi\omega_n}$ ± 5%

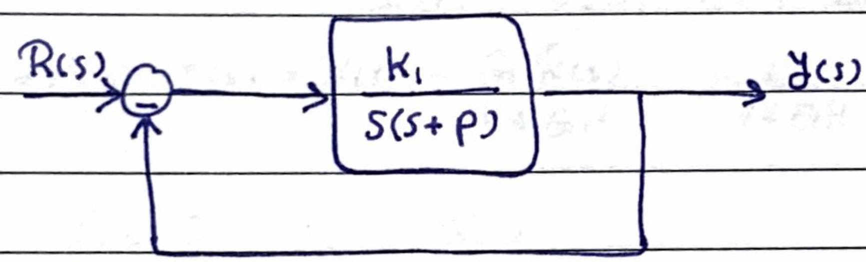
06/11/2018

* $Mp\% \text{ or } O.S\% = \frac{y_{max} - y_{ss}}{y_{ss}} * 100\% \quad \boxed{y_{ss} = y(\infty)}$ .... (1)

OR $O.S\% = 100\, e^{\frac{-\xi\pi}{\sqrt{1-\xi^2}}}$ .... (2)

$$\xi = \frac{-\ln(OS\%/100)}{\sqrt{\pi^2 + \ln^2(OS\%/100)}} \Rightarrow$$ لأنّه بتحلّه

Ex:-



select K, P $\quad T_s = 4\,sec$, $\xi = 0.707$

Sol:- $T(s) = \frac{K_1/(s+p)s}{\frac{s(s+p)}{s(s+p)} + \frac{K_1}{s(s+p)}} = \frac{K_1}{s(s+p)+K_1} = \frac{K_1}{s^2+ps+K_1}$

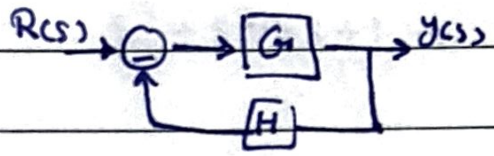
$$\frac{K\omega_n^2}{s^2 + \underbrace{2\xi\omega_n}_{P} s + \underbrace{\omega_n^2}_{K_1}} \Rightarrow \begin{aligned} P &= 2\xi\omega_n \\ K_1 &= \omega_n^2 \end{aligned}$$

$T_s = \frac{4}{\xi\omega_n} \Rightarrow \omega_n = \frac{4}{T_s\,\xi} = \frac{4}{4*0.707} = \frac{1}{0.707}$

settling time ±2%

$P = 2$, $K_1 = \left(\frac{1}{0.707}\right)^2$

Steady state error analysis :



$$T(s) = \frac{Y(s)}{R(s)} = \frac{G}{1+GH}$$

GH → loop Gain ⇐ B.w.P. في F.w.P. حاصل ضرب

$1+GH$ → Charac. equ. = 1 + loop Gain

$$* \; E(s) = R(s) - Y(s) = R(s) - \frac{G\,R(s)}{1+GH} = \frac{1}{1+GH} R(s)$$

$$e_{ss} = \lim_{s \to 0} S \cdot \frac{1}{1+GH} R(s)$$

$$GH = \frac{K(S+z_1)(S+z_2)(S+z_3) \cdots (S+z_n)}{S^N (S+P_1)(S+P_2)(S+P_3) \cdots (S+P_n)}$$

أصفار البسط ← z_n ← Zeros ، أصفار المقام ← P_n ← Poles

$$GH = \frac{K \prod_{i=1}^{m} (S+z_i)}{S^{N} \prod_{j=1}^{n} (S+P_j)}$$, system order > system type

Type of sys. ← N

* عدد ال S=0 ← كلى قيمة ال N ← sys type

08/11/2018

Ex: $S^3+S^2+S \Rightarrow S^{①}(S^2+S+1) \Rightarrow N=1$

$S^3+S^2+S+1 \Rightarrow N=0$

$$\frac{1}{1+GH} = \frac{1}{1+\frac{K\Pi(S+Z_i)}{S^N\Pi(S+P_j)}} = \frac{S^N\Pi(S+P_j)}{S^N\Pi(S+P_j)+K\Pi(S+Z_i)}$$

$$\lim S \cdot \frac{S^N\Pi(S+P_j)}{S^N\Pi(S+P_j)+K\Pi(S+Z_i)} \cdot R(S)$$

$\boxed{1}$ $R(S)=\frac{A}{S}$ "step" $\boxed{2}$ $R(S)=\frac{A}{S^2}$ "ramp" $\boxed{3}$ $R(S)=\frac{A}{S^3}$ "Acc"

Type Zero $\Rightarrow N=0$

$\boxed{1}$ $$\frac{\Pi P_j}{\Pi P_j+K\Pi Z_i} \cdot A = \frac{A}{1+K_p} \rightarrow \frac{K\Pi Z_i}{\Pi P_j}$$

قسمة كل معامل

ΠP_j

* K_p = Position error constant

	A/s	A/s^2	A/s^3	----	
0	$\frac{A}{1+K_p}$	∞	∞	---	∞
1	0	$\frac{A}{K_v}$	∞	---	∞
2	0	0	$\frac{A}{K_a}$		
	⋮	⋮			
	0	0			

08/11/2018

Type one : $N=1$ $\quad s^1$

for $R(s) = \frac{A}{s^2} \Rightarrow \frac{\Pi P_j}{K \Pi Z_i} \cdot A = \frac{A}{K_v}$

$K_v = \frac{K \Pi Z_i}{\Pi P_j}$ = velocity error const.

Type two :- $N=2$

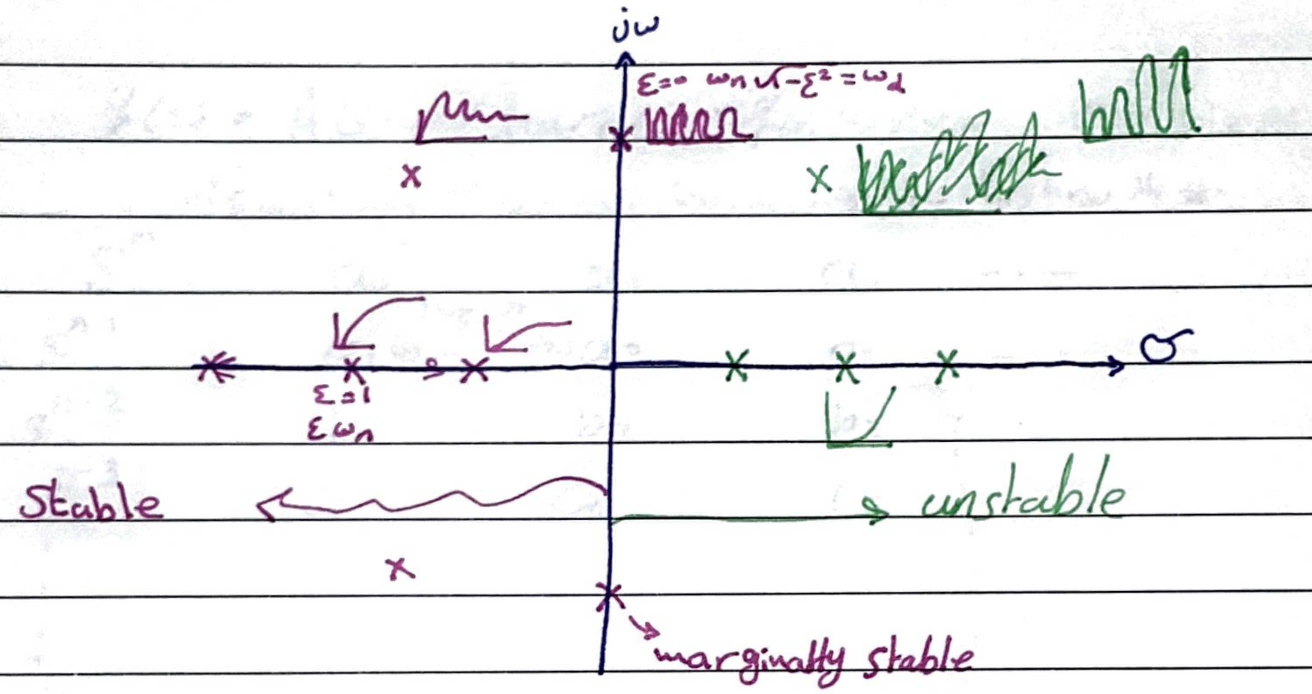
for $R(s) = \frac{A}{s^2} \Rightarrow \frac{\Pi P_j}{K \Pi Z_i} \cdot A = \frac{A}{K_a}$

K_a : acc error constant $= \frac{K \Pi Z_i}{\Pi P_j}$

* زيادة ال sys type ⇐ يقلل ال error

13/11/2018

CH 6 :



* إذا على الأقل واحد من ~~الأصفار~~ الأقطاب +ve ⇐ unstable

* إذا واحد على الأقل على الـ imagin ⇐ طبعاً بدون وجود +ve

لـ ⇐ marginally stable

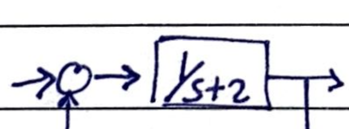
عدد أصفار البسط

$$T(s) = \frac{Y(s)}{R(s)} = \frac{b_0 S^{m} + b_1 S^{m-1} + b_2 S^{m-2} \cdots + b_m}{[a_0 S^n + a_1 S^{n-1} + a_2 S^{n-2} \cdots + a_n]}$$

Char. eq.

Ex:- loop Gain = GH ⇒ Char. eq = 1 + GH * مرّ سابقاً

⇒ if $1 + \frac{x}{y} = \frac{y + x}{y}$ ⇒ Char. eq = $y + x$

for ex ⇒ 

$$\frac{\frac{1}{s+2}}{\frac{s+2}{s+2} + \frac{1}{s+2}} = \frac{1}{\boxed{s+3}} \rightarrow \text{Char. eq.}$$

13/11/2018

Routh Herwitiz Criteria:

$q(s) = A(s) = $ Charac. equ. # كل معاملات s^n ... ـه موجودة

بال first row بلخد معامل ٥١ ومعامل ٨ وبال 2nd row اللي أخدته بالأول

s^n	a_0	a_2	a_4	---
s^{n-1}	a_1	a_3	a_5	---
s^{n-2}	b_1	b_2	b_3	
s^{n-3}	c_1	c_2	c_3	
$\vdots$				
s^0	a_n	0	0	---

← إذا كلهم نفس الإشارة ← stable

where: $b_1 = \dfrac{a_1 a_2 - a_0 a_3}{a_1}$ # تثبيت المسألة 1st column

$$b_2 = \frac{a_1 a_4 - a_0 a_5}{a_1}$$

$$c_1 = \frac{b_1 a_3 - a_1 b_2}{b_1}$$ — وهكذا

مجرد ما صار تغير بالإشارة بالـ 1st co. ← صار unstable

← كل تغير بالإشارة ← يعتبر عدد للأصفار على الـ right side

15/11/2018

Ex: $q(s) = s^3 + 2s^2 + 4s + 4$

Sol ⇒

s^3	1	4	} الحدود الفردية
s^2	2	4	} الحدود الزوجية
s^1	2	0	
s^0	4	0	

الحد المطلق

zero ما بتعمل +ve 1st co. كون كل قيم الـ left side لها 3 أصفار على الـ *

stable system

$b_1 = \frac{2(4) - 1(4)}{2} = 2$ $b_2 = \frac{2(0) - 1(0)}{2} = 0$

لو كان ⇒ $q(s) = s^3 + 2s^2 + 4s + K$ ⇒ for stable sys.

s^3	1	4
s^2	2	K
s^1	$\frac{8-K}{2}$	0
s^0	K	0

$b_1 = \frac{2(4) - 1(K)}{2} = \frac{8-K}{2}$

so ⇒ $\frac{8-K}{2} > 0$ } حتى تكون +ve ما تتغير الإشارة وتكون stable

$K > 0$ *بدون مساواة للـ 0 لأنه الـ zero ما اله polarity

$K < 8$, $0 < K < 8$

15/11/2018

Ex:- $q(s) = s^3 + 2s^2 + 4s + 8$

الحالة الثانية

s^3	1	4
s^2	2	8
s^1	$\cancel{0} \to 4$	0
s^0	8	0

⇒ معناها في 2poles على ال jw

لهيك marginally stable

لهيك لأنه ال row كله أصفار

كل row وصفر يعبر عن 2poles على ال jw

لأعرف إذا في أصفار على ال right ولا

1] بروح لل row الي قبل ال row الصفر

↳ $2s^2 + 8$ # بتروح وعامل وبروح للتاني — aux. eq.

$\pm j2$ لهيك يعني هون تركيب ال s

2] اشتقاق ال aux.eq بالنسبة ل s

↳ $\frac{d}{ds} = 4s + 0$

3] ↳ نقارن كونه كله +ve هون

ما في أصفار على ال right side

4] لو طلع في سالب بصير السيستم unstable

15/11/2018

Ex:- $q(s) = s^5 + 2s^4 + 2s^3 + 4s^2 + 11s + 10$

s^5	1	2	11
s^4	2	4	10
s^3	$\cancel{0} \to \epsilon$ (+ve)	6	0
s^2	$c_1 = \frac{-12}{\epsilon}$ (-ve) ①	10	0
s^1	$d_1 = 6$ (+ve) ②	0	0
s^0	10	0	0

$b_2 = \frac{2(11) - 1(10)}{2} = 6$

2 jω, 2 R, 3 L

كونه أول elem = 0

$\epsilon \to$ رقم صغير كتير يقترب من الـ zero ولا يساوي zero +ve

$c_1 = \frac{4\epsilon - 12}{\epsilon} = \frac{-12}{\epsilon}$

$c_2 = \frac{10\cancel{\epsilon} - 0}{\cancel{\epsilon}} = 10$, $d_1 = \frac{\frac{-12}{\cancel{\epsilon}} \times 6 - 10\cancel{\epsilon}}{\frac{-12}{\cancel{\epsilon}}} = 6$

2 zeros at right side
↳ unstable
↳ 3 zeros at left side
↳ no poles at jω

Ex:- $q(s) = s^4 + s^3 + s^2 + s + K$

s^4	1	1	K
s^3	1	1	0
s^2	$\cancel{0} \to \epsilon$	K	0
s^1	$\frac{\epsilon - K}{\epsilon} = \frac{-K}{\epsilon}$	0	0
s^0	K		

$\frac{-K}{\epsilon} > 0$

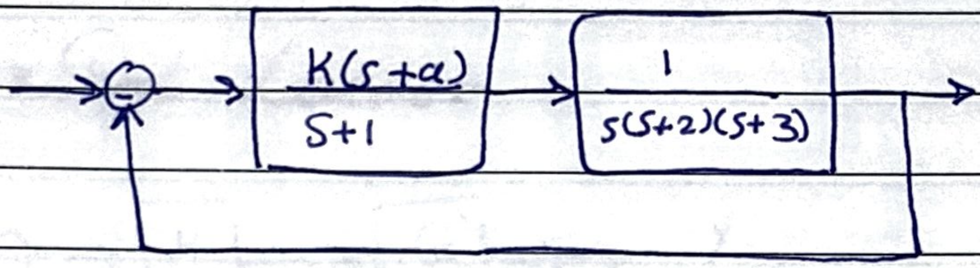
$K > 0$

لا مستحيل

there is no value of K that's make the sys. stable

15/11/2018

Ex:

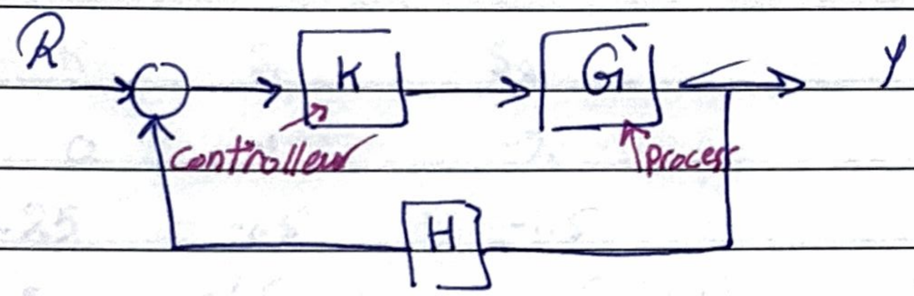


find the value of K, a ⇒ that's make the system stable.

H.W

25/11/2018

CH 7: Root locus:



$$\frac{Y(s)}{R(s)} = \frac{K G'}{1 + G'KH} \quad K G' \rightarrow G \quad = \frac{G}{1 + GH}$$

$GH \rightarrow$ loop Gain

$$GH = K\,\frac{a_0 s^n + a_1 s^{n-1} + \dots + a_n}{b_0 s^n + b_1 s^{n-1} + \dots + b_n}$$

$$\Delta(s) = 1 + GH = 1 + K\,\frac{a_0 s^n + a_1 s^{n-1} + \dots + a_n}{b_0 s^n + b_1 s^{n-1} + \dots + b_n}$$

↑ problem

Ex: loop gain $= \dfrac{K}{(S+1)(S+2)} = GH$

$$\Delta(s) \Rightarrow 1 + \frac{K}{(S+1)(S+2)} = \frac{(S+1)(S+2) + K}{(S+1)(S+2)}$$

$(S+1)(S+2) + K \rightarrow$ Charac. equ.

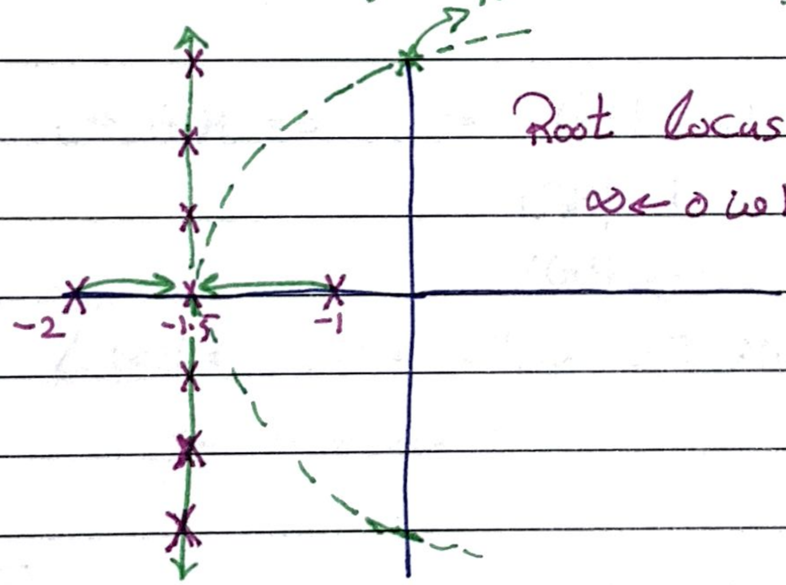
Charac equation $= S^2 + 3S + 2 + K = \Delta(s)$

25/11/2018

$\Delta(s) = s^2 + 3s + 2 + K$

K	S_1	S_2	
0	-1	-2	
0.25	-1.5	-1.5	
0.50	$-1.5+j0.5$	$-1.5-j0.5$	→ stable لسا ثابت
1	$-1.5+j0.866$	$-1.5-j0.866$	
2	$-1.5+j1.3229$	$-1.5-j1.3229$	
⋮			
	$-1.5+j$ قيمة	$-1.5-j$ نفس القيمة	

فرض # $K = x$ ⇒ unstable بصير x أكبر من



Root locus ⇒ الـ Path الي بيمشي فيه أصفار الـ system لما تتغير K من 0 ← ∞

معنى الأصفار واقعة على الـ root locus يعني هل قيمة الـ K تحقق معادلة الـ Δ(s)

↲ شرطين

magn. condition $|GH| = 1$

angle condition $\angle GH = -1$

27/11/2018

from Pre. Ex:-

$$1 + GH = 0$$

$$1 + \frac{K}{(S+1)(S+2)} = 0$$

$$\Delta(s) = S^2 + 3S + 2 + K$$

if $S = -1.5 \mp j1.3$ ⇒ نعوض لنوجد قيمة K التي تحقق المعادلة

↳ لو كان ~~الصفر~~ تحقق ال $\Delta(s)$

لازم يكون للصفر شرطين

1. mag condition.

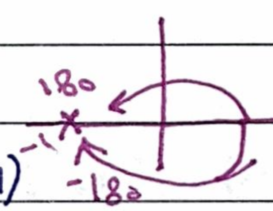
$$|GH| = 1$$

2. angle condition

$1 + GH = 0 \Rightarrow GH = -1$

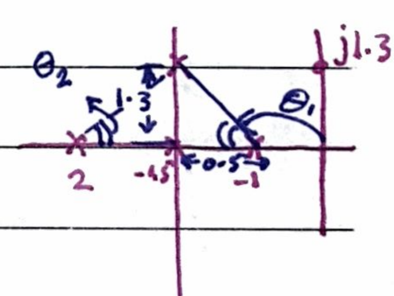
$$|GH| = 1$$

$$\angle GH = -1$$



$$\angle GH = \underbrace{\angle Zeros - \angle Poles}_{\text{for Loop Gain}} = \mp 180(2Z+1)$$

Sol $\frac{K}{(S+1)(S+2)}$, $S = -1.5 + j1.3$



1) angle condition: $\angle Zeros - \angle Poles$

$$\theta_1 = \tan^{-1}\frac{1.3}{0.5} = 70°$$

$$\Rightarrow 180 - 70 = 110$$

27/11/2018

$\theta_2 = \tan^{-1}\left(\frac{1.3}{0.5}\right) = 70^\circ$

$\angle zeros = 0 \Rightarrow \angle zeros - \angle poles$

$0 - 110 - 70 = -180$ ∴ تحقق الشرط

لـ $\mp 180(2Z+1)$

2] mag. condition :-

$|GH| = 1 \Rightarrow$ تعويض بقيمة الـ s

$$\left| \frac{K}{(-1.5+j1.3+1)(-1.5+j1.3+2)} \right| = 1$$

$\hookrightarrow$ « K = 2 »

A) * root locus منين بيبدأ وبينتهي

$$\frac{K(s+Z_1)(s+Z_2) \text{-----} (s+Z_m)}{(s+P_1)(s+P_2) \text{---} (s+P_n)} = 1$$

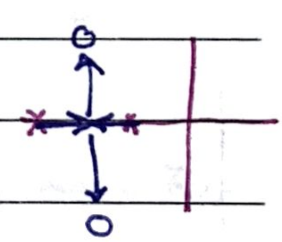
$\Rightarrow K(s+Z_1)(s+Z_2) \text{---} (s+Z_m) = (s+P_1)(s+P_2) \text{---} (s+P_n)$

0 تبدأ من — عدد الـ zeros — عدد الـ Poles

يتنهي عند الـ ∞

→ $K = 0 \Rightarrow$ ∴ sol. of this eq. ⇒ poles

1] R.L. starts at poles « X »



→ $K = \infty \Rightarrow$ ∴ sol. of the eq. ⇒ zeros

2] R.L ends at zeros « O »

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B) كم خط .R.L بدي ارسم

R.L. segment

عدد ال R.L. seg. = عدد ال Poles

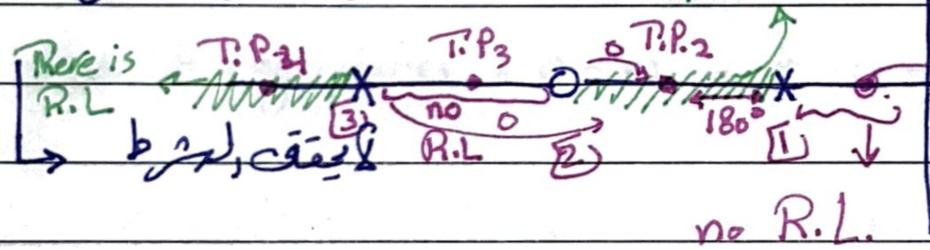
ليش مو نفسه # zeros ؟!

لـ لانه ممكن ما يكون في zeros

I # of RL segments = # of poles

T.P.① ∠zeros − ∠poles

$0 - 0 - 0 = 0$



→ Test point, بدي احط على check لك angel conditions

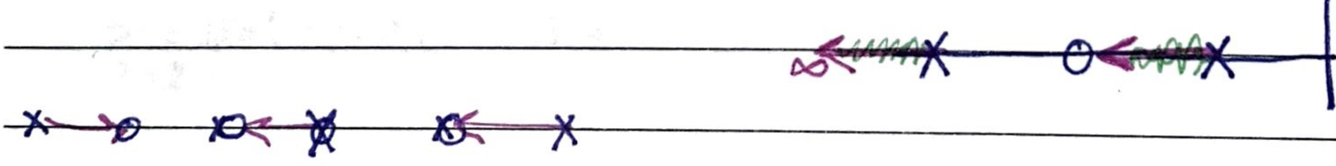
T.P.② ∠zeros − ∠poles $= 0 - 180 - 0 = -180$ تحقق الشرط

T.P.③ ∠zeros − ∠poles $= 180 - 180 - 0 = 0$ لا تحقق الشرط

T.P.④ ∠zeros − ∠poles $= 180 - 180 - 180 = -180$ تحقق الشرط

* ال R.L يقع على جهة اليسار من ال zero او ال pole الفردي

\# RL at <u>real axis</u> is on the left side of <u>ODD</u> Poles or Zeros



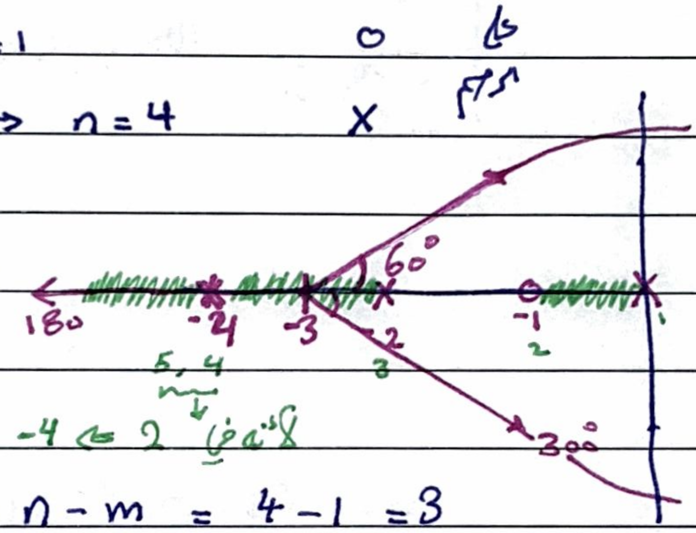
29/11/2018

Ex: $\Delta(s) = 1 + K\dfrac{(S+1)}{S(S+2)(S+4)^2} = 0$

Zeros $= -1 \rightarrow m = 1$

Poles $= 0, -2, -4, -4 \rightarrow n = 4$

R.L بتكون بعد بس odd# الـ



# of asymptotes $= n - m = 4 - 1 = 3$

$$\sigma = \frac{\Sigma \text{Poles} - \Sigma \text{Zeros}}{n-m} = \frac{0 + (-2) + (-4) + (-4) - (-1)}{4-1} = \frac{-9}{3}$$

$\sigma = -3 \rightarrow$ النقطة اللي رح يطلع منها الـ asym

$z = 0, 1, 2, \ldots, n-m-1 \Rightarrow 0, 1, 2$ (2) $\rightarrow 4-1-1$

$$\alpha = \pm \frac{180(2z+1)}{n-m} =$$

* الـ asym. line ≠ R.L. line ⇐ لكن تقاربها ، في حالات بيكونوا نفسهم

$$\alpha_{z=0} = \frac{180(2(0)+1)}{3} = 60^\circ$$

$$\alpha_{z=1} = \frac{180(2(1)+1)}{3} = 180^\circ$$

$$\alpha_{z=2} = \frac{180(2(2)+1)}{3} = 300^\circ$$

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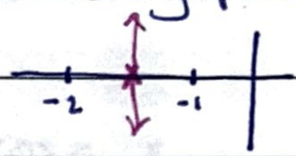
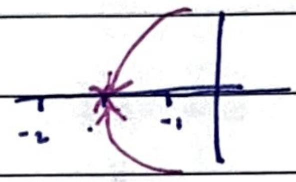
واقعة على ال real axis

Break away point → النقطة اللي تتفرع فيها عند ال real وتنصب خارج ال real axis



Break in اللي بيجتمعوا عندها الخطوط



$$\frac{dk}{ds} = 0$$

$$k = -\frac{s(s+2)(s+4)^2}{s+1}$$

$$\frac{dk}{ds} = \frac{-(s+4)(3s^3 + 12s^2 + 14s + 8)}{(s+1)^2} = 0$$

$s = -4, -2.599, -0.7 \mp j0.73$ → ليست Break away لأنها complex

* لازم تكون من ضمن ال RL

→ نأخذ ال -2.594 لأنها بداخل الفترة 3 حد وأقرب لل asym.

متى بيتقاطعوا مع ال jω axis ?

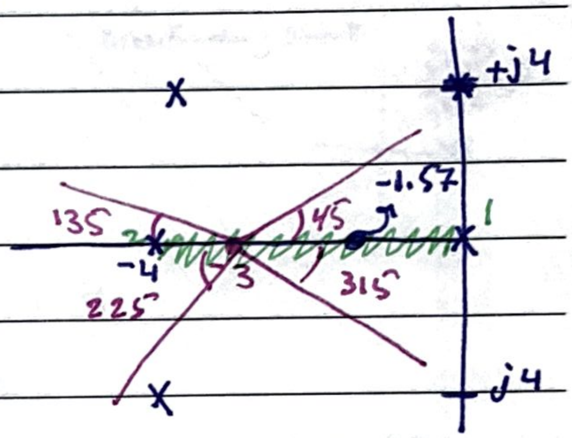
لما قيمة k اللي بتخلي في row كامل zero

لما By Routh Hurwitz

29/11/2018

Ex "book" $\Delta(s) = 1 + \dfrac{K}{s^4+12s^3+64s^2+128s} = 0$

* Zeros = X $m=0$
* Poles $= 0, -4, -4 \mp j4$ $n=4$



* # of asym $= n-m = 4$

$\sigma = \dfrac{0+(-4)+(-4)+j4+(-4)-j4-0}{4}$

* $\sigma = \dfrac{-12}{4} = -3$

$\alpha = \dfrac{\mp 180(2z+1)}{n-m}$ $z=0 \rightarrow n-m-1 = 4-0-1 = 3$

$z = 0, 1, 2, 3$

* $\alpha = 45°, 135°, 225°, 315$

* $K = -s^4 - 12s^3 - 64s^2 - 128s$

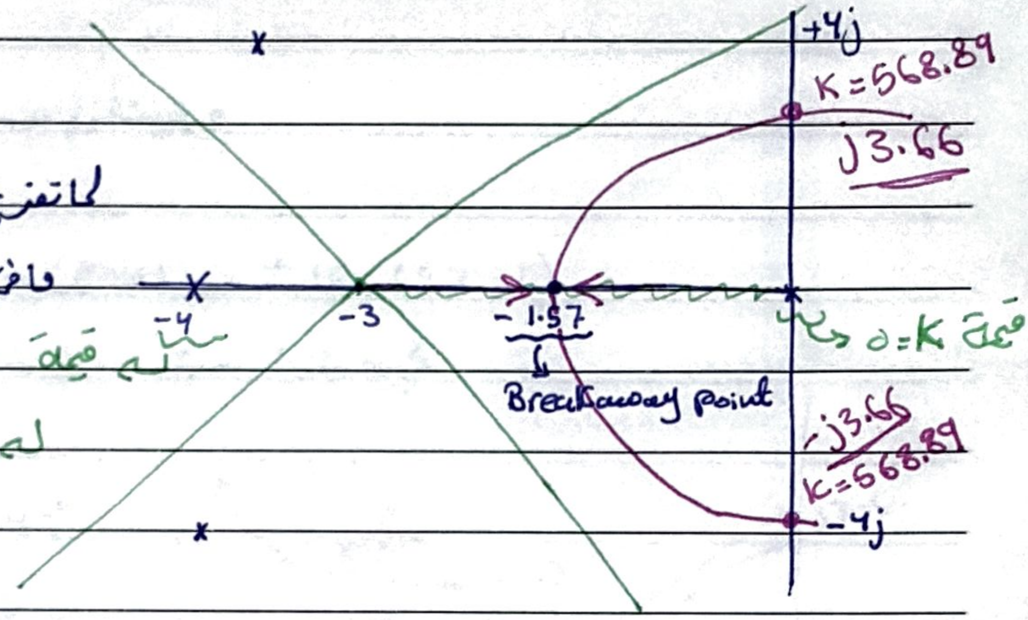
$\dfrac{dK}{ds} = -4s^3 - 36s^2 - 128s - 128 = 0$

complex not break away

$s = -1.57, -3.7 \pm j2.5$

$\therefore$ Break away point $= -1.57$.

Happy National Day 2/12/2018



لما تتفرع راح لا ∞ لأنه
ما في zeros يروح عليهم

قيمة K=0 لـ at poles = 0

$$\Delta s = s^4 + 12s^3 + 64s^2 + 128s + K$$

s^4	1	64	K
s^3	12	128	0
s^2	53.33	K	0
s^1	C_1	0	0
s^0	K		

$$C_1 = \frac{53.33(128) - 12(K)}{53.33}$$

لحتى يطلع أصفار عال رو

$$C_1 = 0 \Rightarrow 53.33(128) - 12K = 0$$

$\hookrightarrow K = 568.89$ → أي قيمة أكبر من K *

لأنه رح يصير unstable ← فرضنا K=600 هـ صفر بيصير على الـ R.S.

* لأطلع الـ رو ← بعوض مكان K بمعادلة الـ s^2 وبطلع الأصفار

$$\hookrightarrow 53.33s^2 + 568.89 = 0$$

$$s = \pm j3.66$$

"لازم يطلع pure img."

Happy National Day 2/12/2018

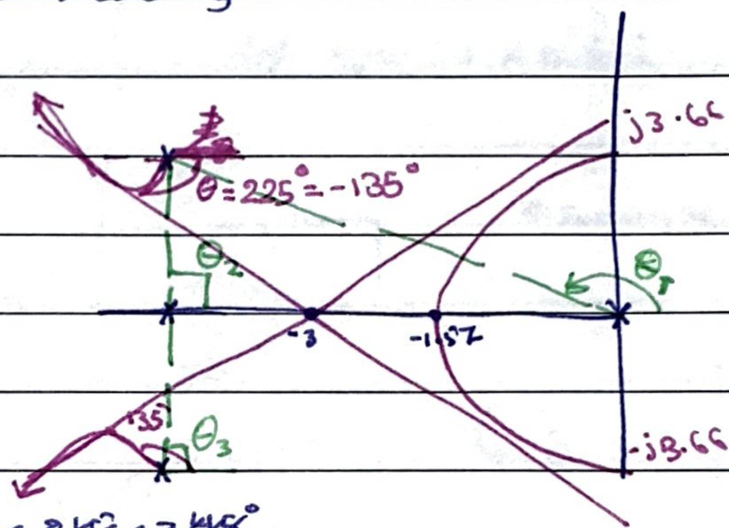
Angle condition:

$\angle Zeros - \angle Poles = \pm 180(2Z+1)$

$\angle Zeros = 0$ كونه ماعندنا Zeros

$\theta_1 \Rightarrow \tan^{-1}\left(\frac{4}{4}\right) = 45^\circ$

* $\theta_1 = 180 - 45 = 135^\circ$
* $\theta_2 = 90^\circ$
* $\theta_3 = 90^\circ$



$\Rightarrow \cancel{0 - 135 - 90 - 90 = -315 = 45^\circ}$

$0 - 135 - 90 - 90 - \theta = 180(2Z+1)$

$\theta = -135^\circ = 225$

$1 + \frac{K\,(Zeros)}{Poles}$ = Charac Equ. # سؤال مهم من الرابعة أوجد الـ

poles = 0, -4, -4 ∓ j4

$\rightarrow 1 + \frac{K}{S(S+4)(S+4\mp j4)}$

ex من الـ sys is marg., unstable

← قيمة K عند أي pole = 0

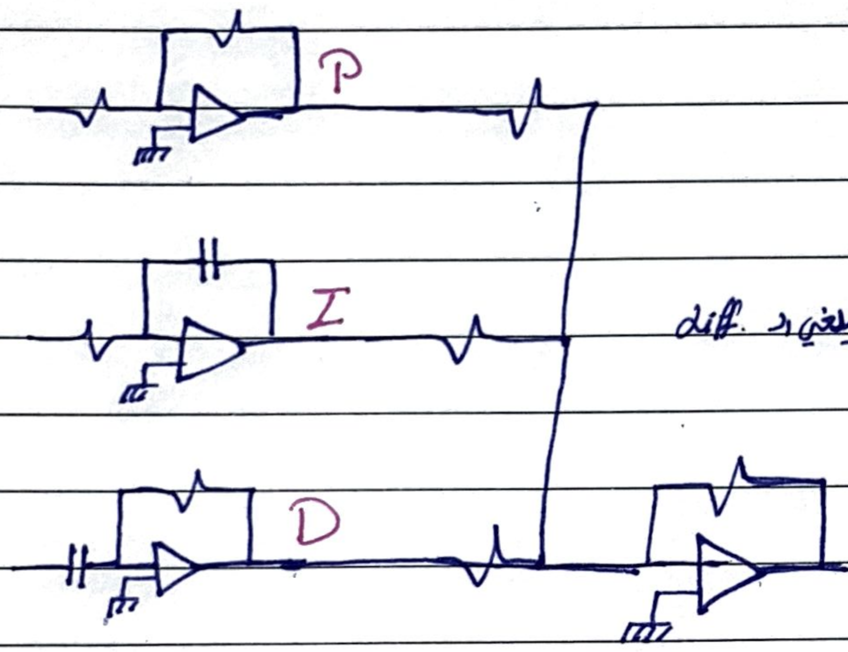
← قيمة K عند نقاط التقاطع مع jω

← عدد الأصفار على الـ R.S = 2 # مو شرط دايماً

← ممكن تكون بس الـ θ معنا و~~...~~ نوجد الـ θ للخطوط ☺

04/12/2018

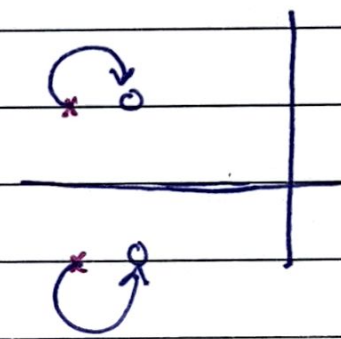
PID controller:



* ما في ID controller
لأنه الـ Int. بيلغي الـ diff.

#summing

2 Zeros



$$PID = K_P^{*S} + \frac{K_I}{S} + \frac{K_D S^{*S}}{S}$$

one pole

$$\Rightarrow \frac{K_D S^2 + K_P S + K_I}{S}$$

*ضرب بـ S ع توحيد مقام

* K_I : eliminate of s.s.e. $\Rightarrow e_{ss} = 0$ *زيادة الـ type ع تقليل الـ e_{ss}

* K_d : Dec. T_s

* K_p : Dec. e_{ss} ⇒ لازم يوصل الـ Zero ⇒ بس مارح تلغيه

*لو PI ع بضل stable

	T_r	O.S.	T_s	e_{ss}
K_p	dec.	dec.	s.c.	dec
K_I	dec.	dec.	inc.	eliminate
K_d	small change.	Inc. (disadv.)	dec. (adv.)	s.c.