Control.

Jana Househ.

2parts in each page

part (1)	part (2)

Control

Laplace part (1):

$f(t) \rightarrow$ find Laplace : $\mathcal{L}\, f(t) = F(s)$

" " inverse : $\mathcal{L}^{-1} F(s) = f(t)$

*] 3 cases for partial fraction:

- unrepeted factor $\Rightarrow$ فش اشي بالمقام مكرر. $(S)(S+2)(S+3)$.
- repeted factor $\Rightarrow$ قوس اله قوة بالمقام. $(S+8)^2 / (S)^2$
- Complex $\Rightarrow$ عبارة تربيعية لا تحلل بالمقام (S^2+5S+3).

Ex: $\dfrac{\text{بسط}}{\underbrace{(S^2)}_{\text{repeted}}\underbrace{(S+2)(S+3)}_{\text{unrepeted}}\underbrace{(S^2+2S+5)}_{\text{complex}}}$

① unrepeted: $\dfrac{8(s+3)(s+8)}{(s)(s+2)(s+4)} = \dfrac{K_1}{s} + \dfrac{K_2}{s+2} + \dfrac{K_3}{s+4}$

$\mathcal{L}^{-1}(F(s)) \rightarrow f(t)$.

$\left.\dfrac{8(s+3)(s+8)}{(s+2)(s+4)}\right|_{s=0} = 24$, - - - - - $K_2 = -12$, $K_3 = -4$

$f(t) = 24 - 12e^{-2t} - 4e^{-4t}$

Laplace part (2): Repeted Roots.

Ex: $\dfrac{8(s+1)}{(s+2)^2} = \dfrac{K_1}{s+2} + \dfrac{K_2}{(s+2)^2}$, $\Rightarrow$ بنحل الحالة بستخدم توحيد المقامات

$8(s+1) = K(s+2) + K$
- $s=0 \Rightarrow 8 = 2K_1 + K_2$
- $s=-2 \Rightarrow -8 = K_2$

$\Rightarrow K_1 = 8$, $K_2 = -8$

ans: $8e^{-2t} - 8te^{-2t} = f(t)$.

② Complex:

منعمل إكمال مربع

Ex: $\dfrac{K_1 s + K_2}{s^2+2s+5} = \dfrac{K_1 s + K_2 + K_1 - K_1}{s^2+2s+1+4} = \dfrac{K_1(s+1) + (K_2 - K_1)}{(s+1)^2 + (2)^2}$

$\dfrac{K_1(s+1)}{(s+1)^2+2^2} + \dfrac{K_2-K_1}{(s+1)^2+2^2} = K_1 \cos 2t . e^{-t} + \left(\dfrac{K_2-K_1}{2}\right)\sin 2t . e^{-t}$

Laplace part (3):

Important case: find ($\mathcal{L}$) then ($\mathcal{L}^{-1}$) : $X(s) \rightarrow x(t)$

$\ddot{x} + 3\dot{x} + 2x = 5\sin(t)$. , Apply using Laplace to find $x(t)$.

$\mathcal{L}(\ddot{x} + 3\dot{x} + 2x) = \mathcal{L}(5\sin(t))$ → from table $= 5\left(\dfrac{1}{s^2+1}\right)$

$$\boxed{\begin{aligned}\ddot{x} &= s^2X(s) - s\,x(0) - \dot{x}(0)\\ \dot{x} &= s\,X(s) - x(0)\\ x &= X(s).\end{aligned}}$$
, $x(0) = 1$, $\dot{x}(0) = 0$

$\left(s^2X(s) - s\,\overset{s}{\cancel{x(0)}} - \overset{0}{\cancel{\dot{x}(0)}}\right) + 3\left(sX(s) - \overset{1}{\cancel{x(0)}}\right) + 2(X(s))$

$X(s)(s^2+3s+2) - s - 3 = \dfrac{5}{s^2+1}$.

$X(s) = \underbrace{\dfrac{5}{(s^2+1)(s^2+3s+2)}}_{\text{Part (A)}} + \underbrace{\dfrac{(s+3)}{(s^2+3s+2)}}_{\text{Part (B)}}$. → partial fraction then ($\mathcal{L}^{-1}$).

Part (A): $\dfrac{5}{(s^2+1)(s+2)(s+1)} = \dfrac{C_1 s + C_2}{s^2+1} + \dfrac{K_1}{(s+1)} + \dfrac{K_2}{(s+2)}$

$5 = (C_1 s + C_2)(s+2)(s+1) + K_1(s^2+1)(s+2) + K_2(s^2+1)(s+1)$.

① $s=-2$: $5 = K_2(5)(-1) \Rightarrow \boxed{K_2 = -1.}$

② $s=0$: $5 = C_2(2) + K_1(2) + \overset{-1}{\cancel{K_2}} \Rightarrow 3 = C_2 + K_1$.

③ $s=1$: $\overset{9}{\cancel{5}} = (C_1+C_2)(6) + K_1(6) + \overset{-4}{\cancel{(-1)(4)}} \Rightarrow 3 = 2(C_1+C_2) + 2K_1$

④ $s=-1$: $5 = K_1(2) \rightarrow \boxed{K_1 = 5/2}$

$\boxed{C_2 = 1/2} \Rightarrow \boxed{C_1 = -3/2}$.

Part (B) $= \dfrac{(s+3)}{(s^2+3s+2)} = \dfrac{K_1}{(s+1)} + \dfrac{K_2}{(s+2)}$.

$(s+3) = K_1(s+2) + K_2(s+1)$.

① $s=-2$: $1 = -K_2$ $\boxed{K_2 = -1}$

② $s=-1$: $2 = K_1$ $\boxed{K_1 = 2}$

the fainal answer:

$\boxed{\dfrac{\left(\frac{-3}{2}\right)s + \left(\frac{1}{2}\right)}{s^2+1}} + \dfrac{\overset{9/2}{\left(\frac{5}{2}\right)}}{(s+1)} + \dfrac{\overset{-2}{\cancel{-1}}}{(s+2)} + \cancel{\dfrac{2}{(s+1)}} + \cancel{\dfrac{-1}{(s+2)}}$

$\left(\dfrac{9}{2}\right)e^{-t} - (2)e^{-2t} + \mathcal{L}^{-1}\left[\dfrac{-\left(\frac{3}{2}\right)s}{s^2+1} + \dfrac{1/2}{s^2+1}\right]$

$= \left(\dfrac{9}{2}\right)e^{-t} - (2)e^{-2t} + \left(\dfrac{-3}{2}\right)\cos t + \left(\dfrac{1}{2}\right)\sin t. = x(t)$.

Laplace part (4):

① final value theorem (FVT), ② Initial value theorem (IVT).

$F(S) \to$ find FVT. / IVT.

$F(s) \cdot S \longrightarrow \lim$ $s \to 0$ (fainal) / $s \to \infty$ (initial).

Ex: $F(s) = \frac{s+3}{(s)(s+2)}$, find the (FVT) then (IVT).

$$\lim_{s\to 0} \left(\cancel{(s)} \cdot \frac{s+3}{\cancel{(s)}(s+2)} \right) = 3/2 \; , \; \lim_{s\to\infty} \left(\cancel{(s)} \cdot \frac{s+3}{\cancel{(s)}(s+2)} \right) = \frac{\infty}{\infty} = 1$$

The system start from (1) and goes to (3/2).

---

* $F(s) \to f(t)$: $\mathcal{L}^{-}$
  $f(t) \to F(s)$: $\mathcal{L}$

Matlab code : write the matlab code

Ex: $f(t) = te^{-4t} \Rightarrow (\mathcal{L})$:

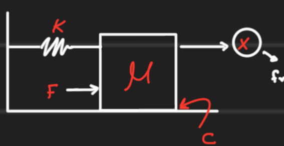
```
syms t s
Laplac(t*exp(-4*t)) = -4/(s+1)^2
```

→ case (1).

Ex: $F(s) = \frac{s(s+6)}{(s+3)(s^2+6s+18)} \Rightarrow \mathcal{L}^{-}$:

```
syms t s
ilaplace ......
```

Mchanical system :



- Mass M → always with one x
- Spring K
- Damper D, C. → can be fixed or free.

* عدد ال(x) الموجودين بالرسمة
= عدد المعادلات الي دح اكتبها.

دايما (F) بتأثر باتجاه عكس (M, K, C)

$M \longrightarrow M \cdot \ddot{x}$
$K \longrightarrow K \cdot x$
$C \longrightarrow C \cdot \dot{x}$

$$\boxed{\begin{aligned} \ddot{x} &= s^2 X(s) \\ \dot{x} &= s\,X(s) \\ x &= X(s) \end{aligned}}$$

*] Damper → fixed : effected by only one (x)
free : " " more than one (x).

fixed.

1] نحدد شو العناصر الي عندي
2] نحدد كل عنصر (free or fixed)

find the transfer function

$$= \frac{\text{output}}{\text{input}} = \frac{X(s)}{F(s)}.$$

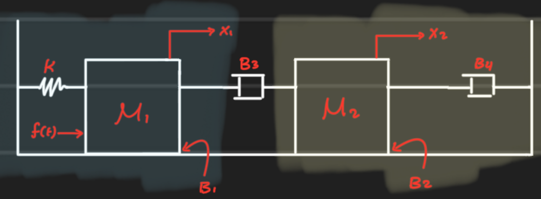
the solution : (one (x) means one equation)

$$F = M\ddot{x} + C\dot{x} + Kx \Rightarrow Ms^2X(s) + Cs\,X(s) + K\,X(s)$$

$$F(s) = X(s)\,(Ms^2 + Cs + K) \Rightarrow \frac{X(s)}{F(s)} = \frac{1}{Ms^2 + Cs + K}.$$

Anothe case :

will have two equations.



equation (1) for (x_1) : $F = M_1\ddot{x}_1 + K_1x_1 + B_1\dot{x}_1 + B_3(\dot{x}_1 - \dot{x}_2)$.

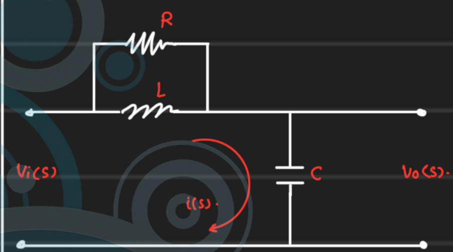
" (2) " (x_2) : $0 = M_2\ddot{x}_2 + B_3(\dot{x}_2 - \dot{x}_1) + B_4\dot{x}_2 + B_2\dot{x}_2$

$$F(S) = M_1 s^2 X_1(S) + K X(S) + B_1 s\, X_1(S) + B_3 s\,(X_1(S) - X(S)_2).$$

$$0 = M_2 s^2 X_2(S) + B_3 s\,(X_2(S) - X(S)) + B_4 s\, X_2(S) + B_2 s\, X_2(S).$$

Electrical system :

* find the transfer function: $\frac{\text{output}}{\text{input}}$



* impedance :
  $Z_R = R$
  $Z_C = \frac{1}{Cs}$
  $Z_L = L \cdot s$.

*] Zeq. in :

Series: $Z_{eq} = Z_R + Z_C + Z_L$

Parallel: $\frac{1}{Z_{eq}} = \frac{1}{Z_R} + \frac{1}{Z_C} + \frac{1}{Z_L}$.

in case of two element : $\left(Z_{eq} = \frac{Z_1 * Z_2}{Z_1 + Z_2} \right)$

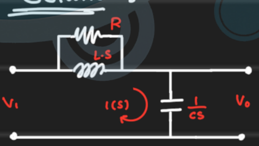
step (1) : find the impedance for each element.

step (2) : the relationship between (V_o & V_i) with the element.

step (3) : transfer equation.

* V_o = is the voltage of the element that parallel to it.
* V_i : is the voltage of all elements.

Solution :



V_o = Voltage of (C)

$V_o = I * \frac{1}{C \cdot S}$ ... ①

V_i = voltage for all element : $V_i = I * Z_{eq}$ --- ②

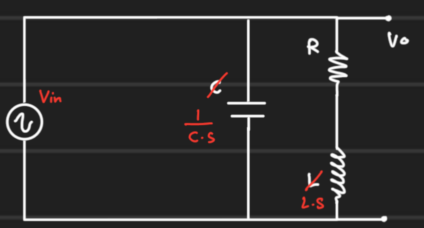
$$Z_{eq} = \frac{RLS}{R+LS} * \frac{CS}{CS} + \frac{1}{C \cdot S} * \frac{R+LS}{R+LS} = \frac{RLS^2C + (R+LS)}{LCS^2 + RCS}$$

$$T.F = \frac{V_o}{V_i} = \frac{\cancel{I} * \left(\frac{1}{C \cdot S}\right)}{\cancel{I}\left(\frac{RLS}{R+LS} + \frac{1}{C \cdot S}\right)} = \frac{1}{C \cdot S} * \frac{1}{\left(\frac{RLS}{R+LS} + \frac{1}{C \cdot S}\right)}$$

$$\frac{1}{\frac{RLCS^2}{R+LS} + 1} = T.F \; . \quad \neq$$

Example of Electrical systems:

* find the transfer function :



$V_o = I\, Z_{eq}$:

$Z_{PL} = (R+L\cdot s)$.

$$I Z_{eq} = \left(\frac{\frac{1}{C\cdot s} * (R+L\cdot s)}{\frac{1}{C\cdot s} + (R+L\cdot s)}\right) * I$$

$\& = V_{in}$.

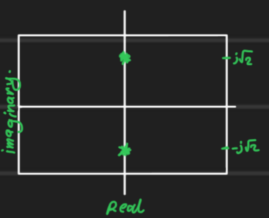
then the transfer function

$$\frac{V_o}{V_{in}} = \frac{I\cdot Z_{eq}}{I\cdot Z_{eq}} = 1 \ \#$$

because they have the same element.

Lec (6) m transfer functions.

Example (2) $\frac{X(S)}{F(S)} = \frac{0.001}{s^2+2}$.



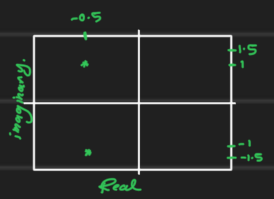
complex root, sys. without complex is slow

Sinosudal behavior.

$s^2 = 2 \rightarrow s = \sqrt{2}\, j$

we care about dominant الأقرب

Example (3). $\frac{X(S)}{F(S)} = \frac{0.001}{s^2+s+2}$.



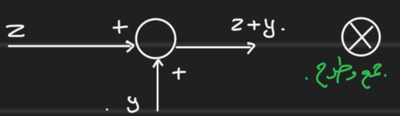
$(0.5) = \frac{1}{2}(s \text{ coefficient})$, $e^{-at} = e^{-0.5t}$

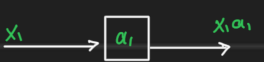
in the imaginary it's frequancy.

$\sin(1.4t)$ or $\cos(1.4t)$.

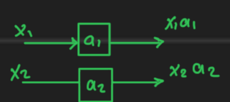
if I have a Real Root → will be in x-axis with no vaibralion.

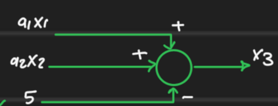
⊛ Block diagram :



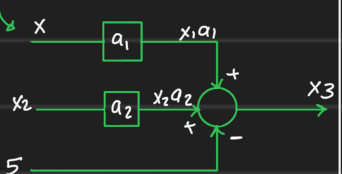


Example : $X_3 = a_1 X_1 + a_2 X_2 - 5$. ⇒





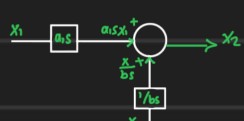
منلش بالجمع.

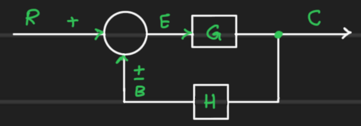


$$X_2 = a_1 \frac{dx_1}{dt} + \frac{1}{b}\int x_1\, dt$$

$\frac{dx_1}{dt} = sX$.

$\int x_1\, dt = \frac{x}{s}$





H: feedback tranfer function.

① $\frac{C}{R}$: closed-loop $= \left[\frac{G}{1 \pm GH}\right]$ فنقلب الاشارات

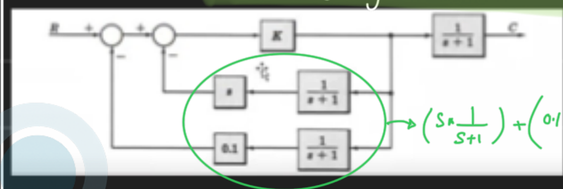
② $\frac{E}{R}$: error ratio $= \left\{\frac{1}{1 \pm GH}\right]$ بالمقام.

two block in series :

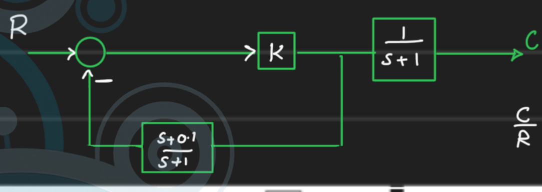
مربعين على التوالي ← ضربهم

″ على التوازي ← جمعهم وطرحهم.

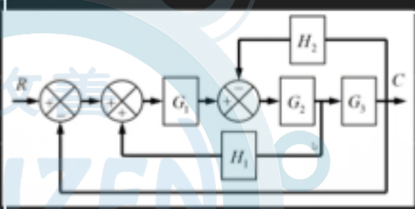
Lec (7) T. Block diagram reduction :

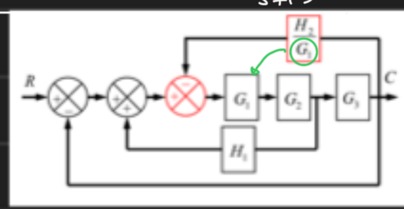


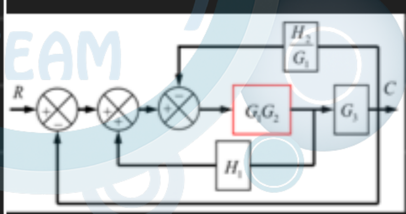
$$\left(s * \frac{1}{s+1}\right) + \left(0.1 * \frac{1}{s+1}\right) = \frac{s+0.1}{s+1}$$

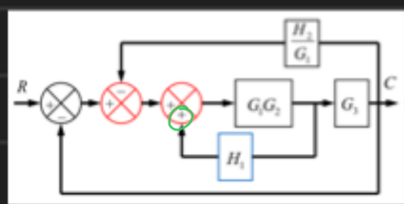


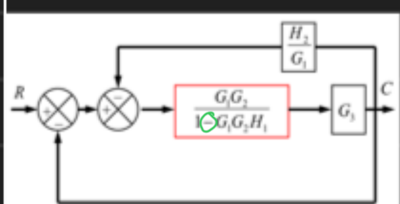
$$\frac{C}{R} = \frac{k}{1 + k\left(\frac{s+0.1}{s+1}\right)}$$

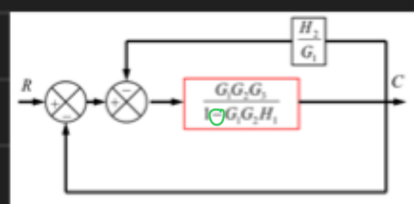


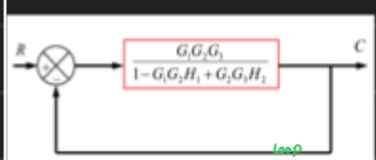


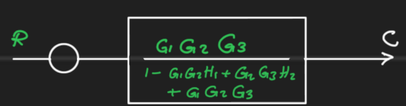




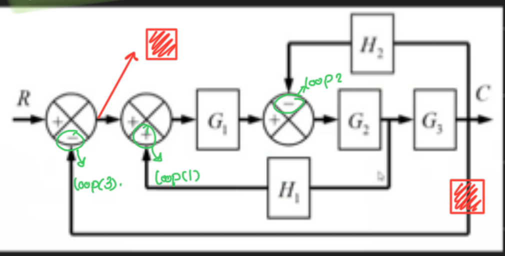








Lec(7)



Solving it using Masons Rule :

$$\frac{C}{R} = \frac{\sum P_i\,\Delta i}{\Delta} = \frac{G_1G_2G_3 * \Delta i}{1 - G_1G_2H_1 + G_2G_3H_2 + G_1G_2G_3}$$

P_i (path from R to C)
Δi

$\Delta = 1 -$ (loops مجموع.
+
مضروب 2 loop
(اذا ما في بينهم مشترك))

+0
لأنه كلهم بينهم G_2 مشترك

بالعادة منخط بالمكان الفاضي block عشان اشوف
شو مشترك بعدين بعوضه (1).

$\Delta i \leftarrow$ نفس Δ لكن لو في اشي مشترك مع البلك بحط صفر

$\Delta i = (1-0-0-0) = 1.$

instead of

Masons Role : to find the transfer function $= \frac{\text{output}}{\text{input}}$

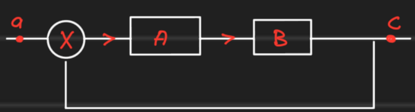
input → Tranfer . fun → output

$T.f = \frac{\sum P . \Delta k}{\Delta}$, P: path

in
out

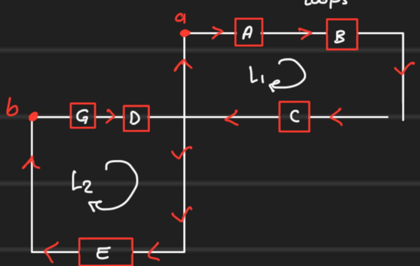
Loops
to the same point.

Δk : ($1 - (\sum$ loops (untouching to the choosen path).)

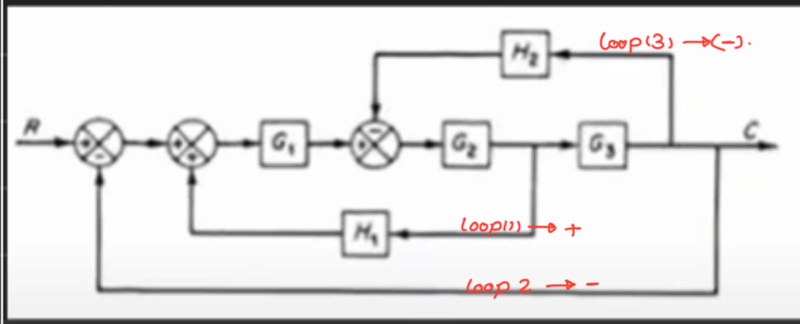


$P = A \cdot B$
$\Delta k = (1-0) = 1$.

$\Delta = 1 - (\sum \text{loops}) + 2\ \text{nontouching loops} - 3\ \text{nontouching loops}.$



$L_1 = A \cdot B \cdot C$
$L_2 = G \cdot D \cdot E$
nontoughing loops.



$P = G_1G_2G_3$

$\Delta k = (1-0-0-0)$

$\Delta = 1 - (G_1G_2H_1 - G_1G_2G_3 - G_2G_3H_2).$

* منحدد ال pathes
input ⟶ output.
* منحدد Δk
($1 - \sum$ loop nontouching).
* منحدد كل loops
مع الاشارة.
* منحدد Δ.

w.

Lec (8)

Steady State Response :

- any value over the target value is called overshot.

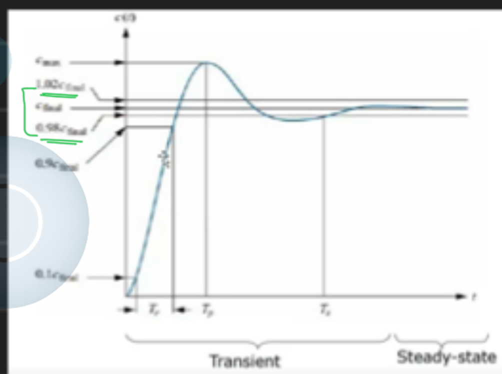
for Example [25-250] if I get 270 then it's overshot &

the time from (10% − 90%) : 250 − 25 = 225 (10% − 90%) : Rise time.

the time when it's stable with (2%) from 250 ⟶
then the sys. reach the stability. (settling)

if it reached 300
then the over shot
= (50/225) * 100

* from 98% to 102%
stability.



① First Order System using partial fraction.

*3 The fast response effect goes fast
so we will have the dominant root

we care about complex root. (best behavior).

First Order is about Real Roots.

$$\frac{C(s)}{R(s)} = \frac{1}{\tau s + 1} , \quad R(s) = \frac{1}{s} \ \text{(step response)}.$$

$$C(s) = \frac{1}{\tau s + 1} R(s) = \frac{1}{s(\tau s + 1)} = \frac{1}{s} - \frac{1}{s + \frac{1}{\tau}}$$

① First Order System

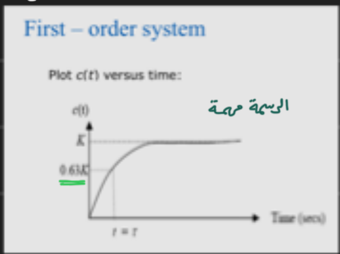
then with inverse laplace transform, $\boxed{c(t) = 1 - e^{-\frac{t}{\tau}}}$

if $t = \tau \Rightarrow$ step response $c(t) = (1 - 0.37) = 0.63$.

in case of having only one real root (we could have 9 roots & one of them real.).

Settling time when $t = 4\tau$.

$[\tau = RC] \to$ used here in time.



τ: could be used to measure the capacitor.

very slow sys.

Rise Time: (from step response to go from (10% to 90%)

$\boxed{T_r = 2.2\,\tau}$

Settling time: (2% from final value). $\boxed{T_s = 4\tau}$

x-axis. على ونبعد (0.63*final value) نوخذ من طريقه (τ) منحسب

Lec (9) Th.

② Second – Order System: way much better.

this system has a slight overshot.

We will two complex root:

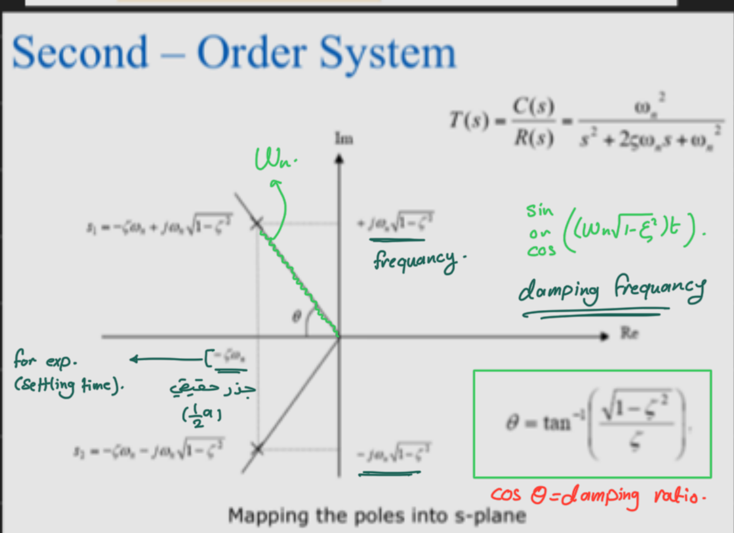
$$G(s) = \frac{b}{s^2 + as + b} \longrightarrow \frac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}, \quad \xi: \text{determain if it's complex.}$$

complex $\to (\frac{1}{2}a)^2 < b$.

$\omega_n = \sqrt{b}$, $2\xi\omega_n = a$, $\xi = \frac{a}{2\sqrt{b}}$

- $\xi = 1 \Rightarrow$ repeted
- $\xi > 1 \Rightarrow$ real.
- $\xi < 1 \Rightarrow$ complex

Poles;	$-\omega_n\zeta + \omega_n\sqrt{\zeta^2 - 1}$ $-\omega_n\zeta - \omega_n\sqrt{\zeta^2 - 1}$	Poles are complex if ζ< 1!



Mapping the poles into s-plane

damping ratio $\to$ at x-axis = 1, y-axis = zero ($\cos\theta$)

$\xi = \frac{a}{2\sqrt{b}}$

- $\xi = 1 \Rightarrow$ repeted Critically damped.
- $\xi > 1 \Rightarrow$ real $\longrightarrow$ Over damped, 2 real roots.
- $\xi < 1 \Rightarrow$ complex $\to$ $(0 < \xi < 1) \longrightarrow$ Underdamped. (wanted)

$\xi = 0 \to$ Undamped.

Given that the closed loop TF

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

to find rise time $\Rightarrow$ $T(0.9) - T(0.1)$.

" " settling time $\Rightarrow$ $-\xi\omega_n t = -4 \Rightarrow t = \frac{4}{\xi\omega_n}$

(A) For transient response, we have 4 specifications:

(a) Tr – rise time = $\frac{\pi - \theta}{\omega_n\sqrt{1-\zeta^2}}$ ($\theta \to \cos^{-1}(\xi)$. in Radian.)

(b) Tp – peak time = $\frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$

(c) %MP – percentage maximum overshoot = $e^{-\frac{\pi\zeta}{\sqrt{1-\zeta^2}}} \times 100\%$

(d) Ts – settling time (2% error) = $\frac{4}{\zeta\omega_n}$

لازم معامل $s^2 = 1$.

Example for Underdamped

$$G(s) = \frac{36}{s^2 + 4.2s + 36} : \omega_n = 6,\ \xi = 0.35$$

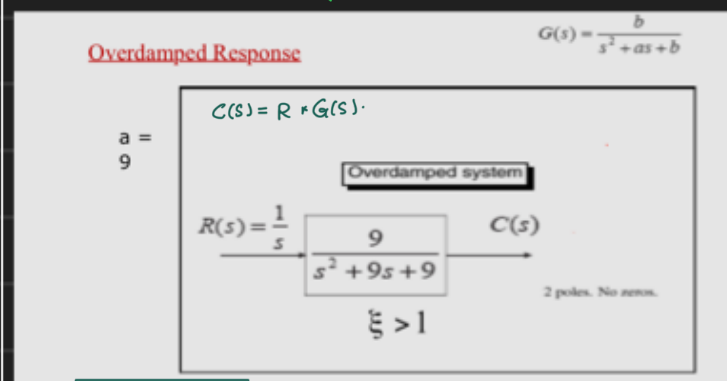
$2\xi\omega_n$: damping ratio = 4.2.

Example: Underdamped:

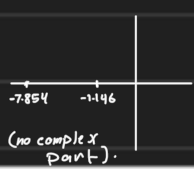
$$G(s) = \frac{100}{s^2 + 15s + 100}, \quad \omega_n = 10,\ \xi = 0.75$$

$$T_s = \frac{4}{0.75 * 10} = 0.5335, \quad OS\% = e^{-\frac{\pi * 0.75}{\sqrt{1 - 0.75^2}}} = 2.838\%$$

$$T_p = \frac{\pi}{10\sqrt{1 - 0.75^2}} = 0.475\,s$$

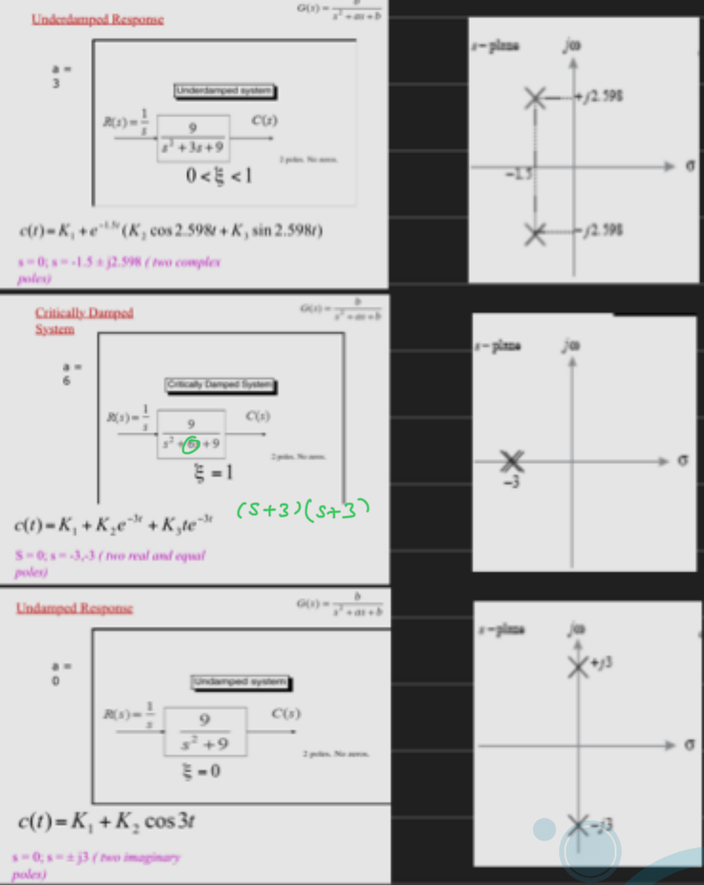


$$C(s) = \frac{9}{s(s^2 + 9s + 9)} = \frac{9}{s(s + 7.854)(s + 1.146)} = k_1 + k_2 e^{-7.854t} + k_3 e^{-1.146t}$$

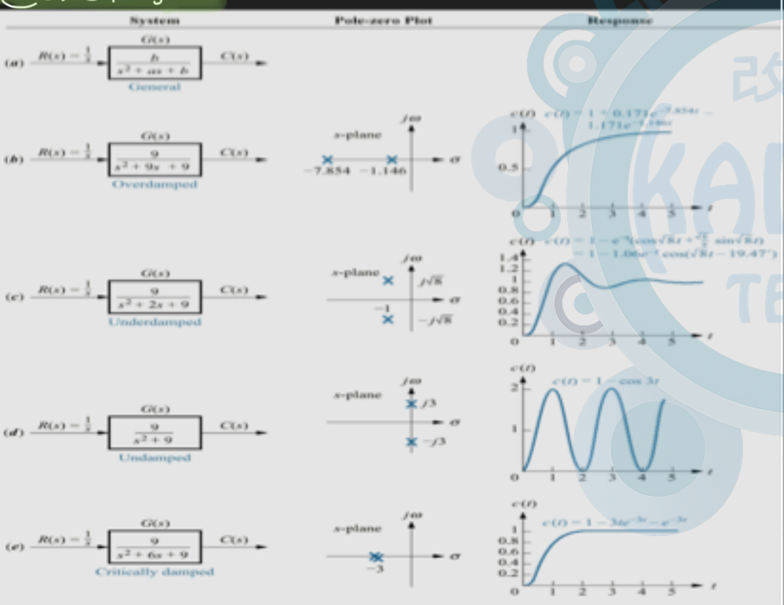


ξ: Damping ratio

makes sys. slower.



Conclusion



real part ⇒ Settling time

imagenary ⇒ frequancy.

⊕ First & Second order system:

First Order : $\frac{1}{\tau s+1}$, $\left[\tau = \frac{1}{a}\right]$.

$T_r = 2.2\tau$. , with zero MP % — first order equation

$T_s = 4\tau$.

Example $\frac{1}{3s+2}$, $\tau = 3 \Rightarrow a = \frac{1}{3} = 0.33$.

$T_r = 2.2 * 3 = 6.6$, $T_s = 4 * 3 = 12\,s$

Second Order

Example : $\frac{C}{R} = \frac{s+3}{s^2+s+4.25}$ $\omega_n = \sqrt{4.25} = 2.06$.

$2\xi\omega_n = 1 \Rightarrow \frac{1}{2 * 2.06} = 0.2427$

Second order equations:

$\cos\theta = \xi$, $T_s = \frac{4}{\xi\,\omega_n}$

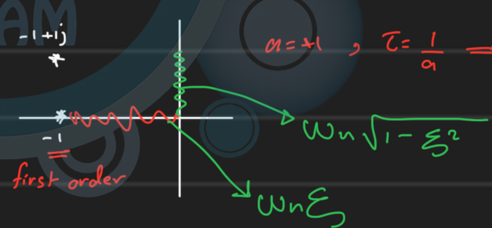
$\omega_n = \sqrt{\text{real}^2 + \text{imag}^2}$,

$T_r = \frac{\pi - \theta}{\omega_n\sqrt{1-\xi^2}}$, $T_p = \frac{\pi}{\omega_n\sqrt{1-\xi^2}}$

$MP = e^{\frac{-\pi\xi}{\sqrt{1-\xi^2}}} * 100$

$\theta = \tan^{-1}(y/x)$ in Radian $\boxed{\theta * \frac{\pi}{180}}$

in case first & Second Order in the same quastion.



$a = 1$, $\tau = \frac{1}{a} \Rightarrow T_r = 2.2\tau$.

$T_s = 4\tau$.

Lec (10) S

Steady State Error Analysis :

Design in General around Critical damped.

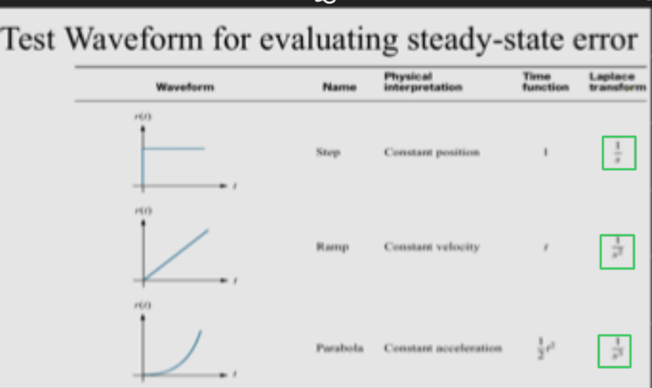
The fainal value is an Indicator for the accuracy.

accuracy ⟹ amount of error ⟹ diviation from fainal value.

المسألة متعلقة بجذر المقام الي قيمته صفر (اساس الحل) ⟵ اشتقاق $(*s)$

تكامل $(*\frac{1}{s})$

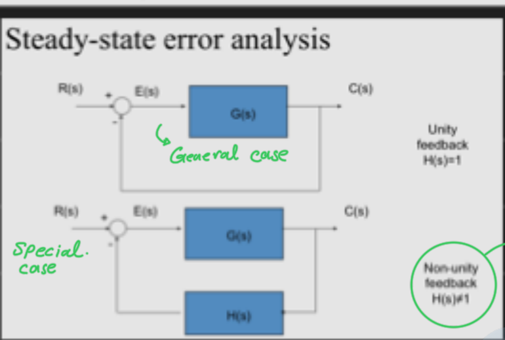
يعني التكامل $(*\frac{1}{s})$ مشان اوصل لـ (∞) ⟸ $(\frac{1}{\infty}=0)$



Test Waveform for evaluating steady-state error

Waveform	Name	Physical interpretation	Time function	Laplace transform
	Step	Constant position	1	$\frac{1}{s}$
	Ramp	Constant velocity	t	$\frac{1}{s^2}$
	Parabola	Constant acceleration	$\frac{1}{2}t^2$	$\frac{1}{s^3}$

types of input ⟸



case (2) if $R(s) = 250$

$H(s) = 2$ ⟹ then

$E(s) = 0$ when $C(s) = 125$

Complicated.

Unity feedback ⟶ $E(s) = R(s) - C(s)$: sys. error.

Non-Unity feed back ⟶ $E(s) = R(s) - H(s)\cdot C(s)$: Actuating error.

By Final Value Theorem:

steady-state error: $e_{ss} = \lim_{t\to\infty} e(t) = \lim_{s\to 0} sE(s)$ ⟵ from fainal value theorem.

$\frac{1}{s} = \frac{1}{\infty} = \text{zero}$

Unity feedback : $E(s) = R(s) - C(s)$, $\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)}$

$$G(s) = \frac{K\prod_{i=1}^{M}(s+z_i)}{s^N \prod_{j=1}^{Q}(s+p_j)}$$

type N ⟶ for ∞

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

high value for $G(s)$ to get small error. ⟶ or ∞

⟶ $G(s) = \frac{\text{constant}}{\text{zero}} = \infty$ ⟹ $E(s) = \frac{1}{\infty} = 0$ ⟹ most powerful control tool.

Case (1) ⟹ $R(s) = (1/s)$. $e_{ss} = \lim_{s\to 0} sE(s) = s * \frac{1/s}{1+G(s)} = \lim_{s\to 0} \frac{1}{1+G(s)}$

assuming $k_p = \lim_{s\to 0} G(s)$ ⟹ $\lim_{s\to 0} \frac{1}{1+G(s)} = \boxed{\frac{1}{1+k_p}}$ k_p: static position Error constant.

How to get (∞)

① if $N=0$ ⟹ $k_p = \text{constant}$ $e_{ss} = \frac{1}{1+k_p} = \text{finite} = \text{constant}$

② if $N \geq 1$ ⟹ $k_p = \text{infinite}$ $e_{ss} = \frac{1}{1+k_p} = \frac{1}{\infty} = 0$

as the type of sys. increase $(N\geq 1)$ the steady state error goes to zero.

Case (2) : $R(s) = (1/s^2)$

$e_{ss} = \lim_{s\to 0} s*\left(\frac{1/s^2}{1+G(s)}\right) = \lim_{s\to 0} \frac{1}{s + s\cdot G(s)}$, $K_v = \lim_{s\to 0} s\cdot G(s)$ static velocity error constant.

$e_{ss} = \frac{1}{\lim sG(s)} = \frac{1}{K_v}$, $\boxed{K_v = s\,\frac{\pi(s+z_i)}{\pi(s+p_j)}}$

① if $N=0$, $K_v=0$ ⟹ $e_{ss} = \frac{1}{0} = \infty$

② if $N=1$, $K_v = \text{finite}$ ⟹ $e_{ss} = \frac{1}{K_v} = \text{finite}$.

③ if $N \geq 2$, $K_v = \text{infinit}$ ⟹ $e_{ss} = \frac{1}{\infty} = 0$.

نكن الحالات المطلوب $K=\infty$ عشان نوصل بدنا e_{ss} للصفر.

Case (3) : $R(s) = (1/s^3)$

$e_{ss} = \lim_{s\to 0} s * \frac{1/s^3}{1+G(s)} = \lim_{s\to 0} \frac{1}{s^2 + s^2G(s)} = \frac{1}{\lim_{s\to 0} s^2G(s)} = \frac{1}{K_a}$.

K_a: static acceleration error constant $[K_a = \lim_{s\to 0} s^2G(s)]$

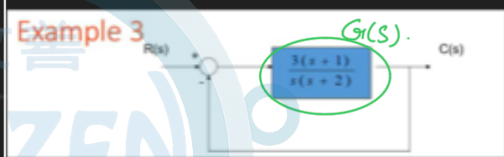
① $N=0$, $K_a=0$ ⟹ $e_{ss} = \frac{1}{0} = \infty$

② $N=1$, $K_a=0$ ⟹ $e_{ss} = \frac{1}{0} = \infty$

③ $N=2$, $K_a = \text{constant}$ ⟹ $e_{ss} = \frac{1}{\text{constant}} = \text{finite}$.

④ $N \geq 3$, $K_a = \text{infinit}$ ⟹ $e_{ss} = \frac{1}{\infty} = 0$

increasing sys. type (N) will accommodate more different inputs.



if $R(t) = (2+3t)u(t)$.

find steady-state error :

$R(t) = (2+3t)u(t)$ ⟹ $\underbrace{\frac{2}{s}}_{\text{case (1)}} + \underbrace{\frac{3}{s^2}}_{\text{case (2)}} = \left[\frac{2}{1+k_p} + \frac{3}{K_v}\right]$.

مثال يُجي بالامتحان

1 $k_p = \lim_{s\to 0} G(s) = \infty$, 2 $K_v = \lim_{s\to 0} sG(s) = 3/2$.

⟹ $e_{ss} = \frac{2}{1+\infty} + \frac{3}{3/2} = 2$ #

Steady state error :

Types of errors :

① Step unit $e_{ss} = \frac{1}{1+k_p}$, $k_p = \lim_{s\to 0} G(s)$

② ramp. $e_{ss} = \frac{1}{K_v}$ $K_v = \lim_{s\to 0} G(s)\cdot s$

③ purbolic $e_{ss} = \frac{1}{K_a}$ $K_a = \lim_{s\to 0} G(s)\cdot s^2$

Example : find the $e_{ss} = 3u(t) + 2t$

$3u(t)$ ⟶ step unit $= \frac{1*(3)}{1+k_p}$,

$2t$ ⟶ ramp $= \frac{1*(2)}{K_v}$,

Controler

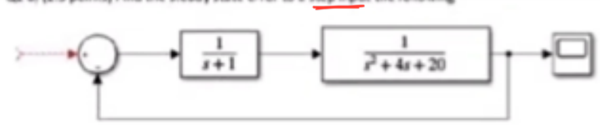
ramp : $K_v = \lim_{s\to 0} G(s)\cdot s * \frac{k}{s}$

step : $k_p = \lim_{s\to 0} G(s) * k$.

parabolic : $K_a = \lim_{s\to 0} G(s)\cdot s^2 * \frac{k}{s^2}$

Example :

Q2 a) (2.5 points) Find the steady state error to a step input the following



$e_{ss} = \frac{1}{1+k_p}$, $k_b = \lim_{s\to 0} G(s)$, $G(s) = \frac{1}{s+1} * \frac{1}{s^2+4s+20} = \frac{1}{(s+1)(s^2+4s+20)}$

$K_b = \lim_{s\to 0} G(s) = \frac{1}{1 * 20} = \frac{1}{20} \Rightarrow e_{ss} = \frac{1}{1+\frac{1}{20}} = \frac{20}{21}$ error of step unit #

or

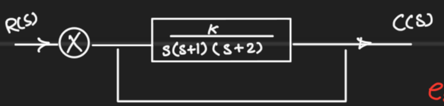
$\overbrace{\text{(design a controler)}}^{k}$ to achive $e_{ss} = 1$ when the input $(\frac{1}{s^2})$ ramp

$e_{ss} = \frac{1}{k_v}$, $k_v = \lim_{s\to 0} G(s)\cdot s$, $G(s) = \frac{1}{(s+1)(s^2+4s+20)}$

$k_v = \lim_{s\to 0} G(s)\cdot s \; \frac{k}{s}$ ← ramp $= [k_v = \frac{k}{20}] \Rightarrow e_{ss} = \frac{1}{\frac{k}{20}} = 1$, $k = 20$

s ← منقسم عليها ثم ان يح بالجواب

Example : Find e_{ss} for $R(s) = 3u(t) + 5t$



$e_{ss} = \frac{3}{1+k_p} + \frac{5}{k_v}$

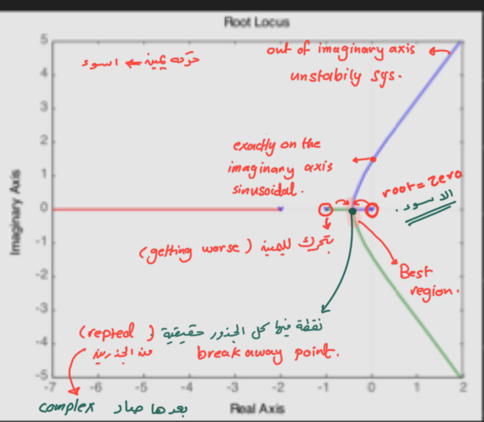
$k_p = \lim_{s\to 0} G(s) = \frac{k}{0} = (\infty)$, $k_v = \lim_{s\to 0} G(s)\cdot s = (\frac{k}{2})$.

$e_{ss} = \frac{3}{1+\infty} + \frac{5}{\frac{k}{2}} = 0 + \frac{10}{k}$, $e_{ss} = \frac{10}{k}$ #

28/7

Lec (11)^M Root Locus

about the dominant
أي واحد سالبة
used to Expresses performance :



In the best region the damping ratio ≈ 1 or 0.9

$G(s)\cdot H(s) = -1$ ... ①

$-1 \Rightarrow 180$ مضاعفات الزاوية

180 ± 360 , $180 \pm (2)(360)$ ...

For example : Point $(-2, +3j)$ $\angle G(s)H(s) = \pm 180(2k+1)$ ... ②

you will not achive the performance $\Rightarrow e^{-2t}$, $-2t = -4 \Rightarrow t = 2$.

الخطوط والنقاط المرسومة هي فقط النقاط الي بقدر احققها

assuming $G(s) = \frac{k}{s(s+1)(s+2)} = G(s)H(s)$ because $H(s) = 1$.

any complex value can be presented by the magnitude exp θ.

بالزوايا بوصل لصيغة انه زوايا البسط ناقص زوايا المقام.

$\angle G(s)H(s) = \angle k - \angle s - \angle (s+1) - \angle (s+2)$.

لو عوضت بنقطة وطلع معي (+ve) تكون قيمتها = صفر

$\angle G(s)H(s) = \angle k - \angle s - \angle (s+1) - \angle (s+2)$.

let's take point (-3) : $\angle G(s)H(s) = 0 - \angle -3 - \angle -2 - \angle -1 = -180 - 180 - 180$

$-180 - 360° \Rightarrow$. 180 من مضاعفات

point $(-1.5) \Rightarrow \angle G(s)H(s) = 0 - 180 - 180 + 0 = -360$ → ليست من مضاعفات 180 not part of Root Locus.

Part (2)

the magnitude of $G(s)H(s) = -1 \Rightarrow |G(s)H(s)| = 1 \Rightarrow K = \frac{1}{|G(s)H(s)|}$

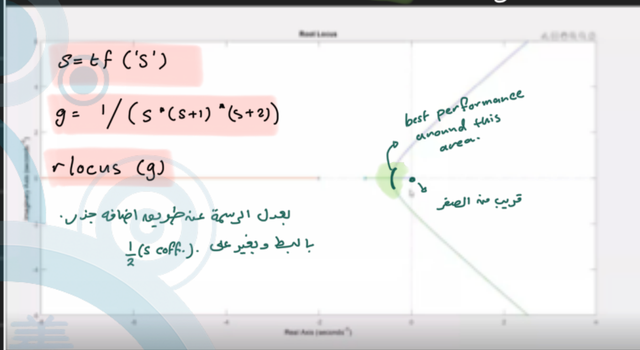
if $(s = -0.25)$: $G(s) = \frac{k}{s(s+1)(s+2)} = \frac{k}{|(-0.25)(0.75)(1.75)|} = 1 = \frac{k}{|-0.328|} = 1$

$K = 0.328$.

we can know the performance from rised time.

29.

Lec (12) Root Locus (2) using Matlab.



the type of questions is to determine the value of (K) such that - - - -

① if it's damping ratio $\Rightarrow \xi = \cos\theta \Rightarrow \theta = \cos^{-1}(\xi)$

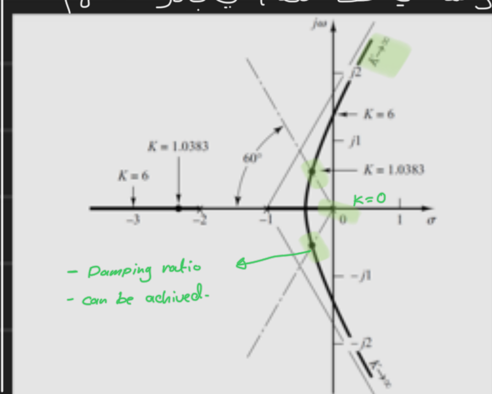
ونرسم قيمة الزاوية ضمن رسمة (root.loc)

② Persent of Overshot $\Rightarrow \xi = \frac{-\ln(\frac{\%MP}{100})}{\sqrt{\pi^2 + \ln^2(\frac{MP\%}{100})}}$.

all points with the same (θ) have the same damping ratio & persent of overshot.

البعد عن المركز فقط يأثر على (frequancy).

تقاطع خطوط (θ) مع الرسمة هي فقط النقاط الي بقدر احققها



two roots :

① $S_1 = -0.3337 + j\,0.5780$

② $S_2 = -0.3337 - j\,0.5780$

29

Lec (12) Root Locus (2)

① $S_1 = -0.3337 + j\,0.5780$

② $S_2 = -0.3337 - j\,0.5780$

] then we use it to find the value of (K). #

$$K = |S(S+1)(S+2)|_{S=-0.3337+j0.5780} = |-1.03829 - 1.28\times10^{-3} j|$$

$K = 1.0383$

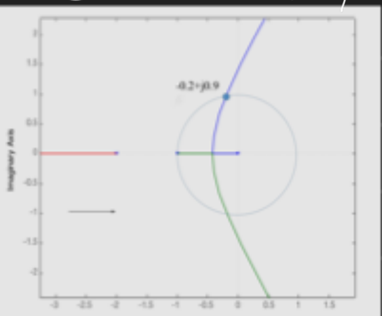
the type of questions is to determine the value of (K) such that - - - - .

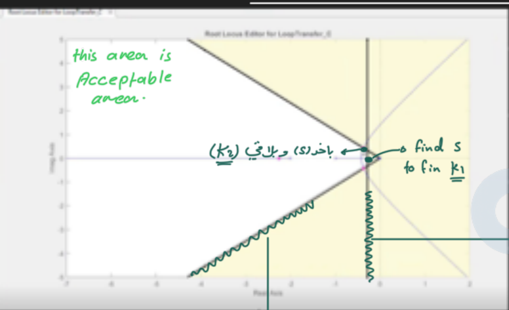
③ Natural frequancy :

البعد من المركز

النقاط الي على نفس الدائرة عندهم

نفس البعد





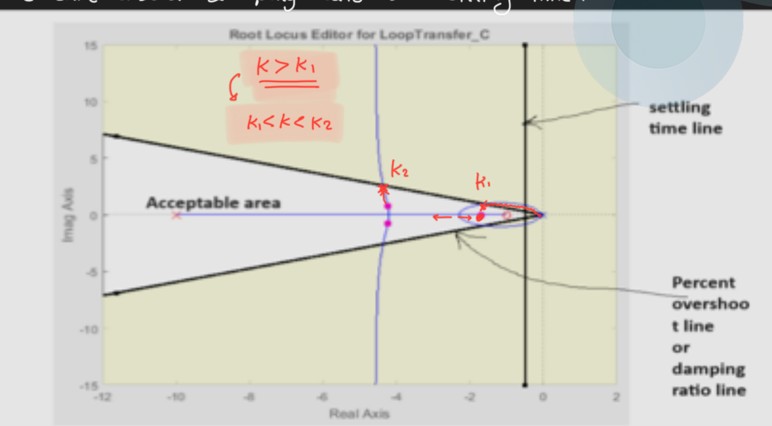
settling time

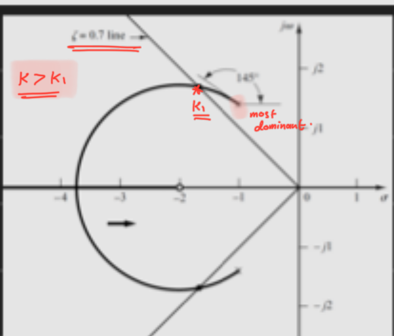
damping ratio

30

Lec (13). Root Locus (3).

we care about damping ratio or settling time.





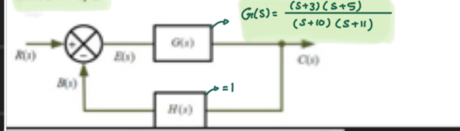
ان اذا طلبت منا acceptable area

وبعدين نحط $K < K_1$

31

Lec (14) Root Locus (4)

Q5) For the following system design a controller K to achieve a damping ratio of > 0.95 and settling time < 4/5



in Matlab :

tan (a cos (0.95)) $= 0.3287$

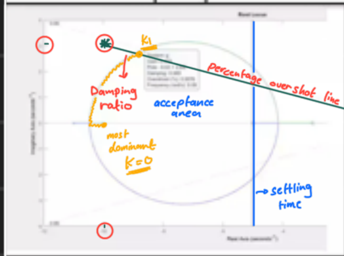
Theta = a cos (0.95) * (180 / pi) $= 18.1949$

اذا مستبين على (x) بمقدار (10) رح

امشي على (y) مقدار ←

$10 * 0.3287 = 3.287$

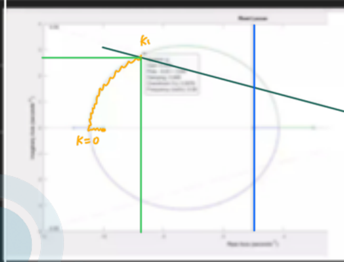
settling time : $\frac{4}{5} = -4 \Rightarrow T_s = -5$



(0,0)

the solution $0 < K < K_1$

$S_1 = -8.8 + j\,2.75$ in matlab



S = -8.8 + 2.7 i

g = (s+3)*(s+5) / ((s+10)*(s+11))

k_1 = abs (1/g) = 0.3451

final answer $0 < K < 0.3451$

Root locus : find K → damping ratio, settling time.

① if settling time < 3 $\Rightarrow -3t = -4 \Rightarrow (t = 4/3)$ - - - - ①

② Damping ratio or % MP $\Rightarrow \zeta = \dfrac{\ln\left(\frac{MP\%}{100}\right)}{\sqrt{\pi^2 + \ln^2\left(\frac{MP\%}{100}\right)}}$] we care about (ζ).

ζ given.

$\zeta = \cos\theta \Rightarrow \theta = \cos^{-1}(0.7)$. - - - ②

then $\tan(\theta) = \dots$

$\tan(\cos^{-1}(\zeta)) = \underline{c} \Rightarrow$ - - - ③

منحدد قيمة ل (x) ومنضربها ب (c)

عشان نحدد قيمة (y)

منشوف تقاطع الرسمة مع الخطين الي عنا .

find the (S)'s value for k_1 & k_2 - - - ④

$\zeta > x \Rightarrow$ always in the acceptance region.

$T_s < x \Rightarrow$ " " " " " ⑤

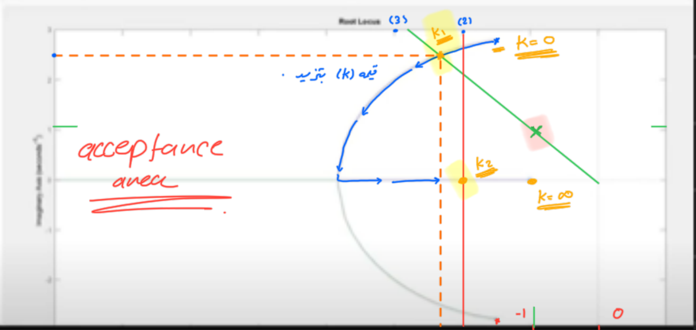
منروح مع اتجاه بأي اتجاه قيمتها بتكبر كل ما نمشي القيمة بتزيد

$$K = \frac{1}{|G(s)H(s)|}$$ - - - ⑥

Root locus :

For the following system determine K that achieves a damping ratio of > 0.7 and settling time < 3 s

GH(s)= (s+1)/ (s^2 +3s +10)



$\xi > 0.7 \Rightarrow \theta = \cos^{-1}(0.7) = 45.57 \rightarrow$ Scale $= \tan(\theta) = 1.02$

if $x = 1 \Rightarrow y = 1.02$

settling time $< 2 \Rightarrow \dfrac{4}{\omega \xi} = 2 \Rightarrow \omega \xi = 2$ ®

$$\left.\begin{array}{l} S_1 = -2.3 + j\,2.45 \\ S_2 = -2 \end{array}\right] \Rightarrow K = \frac{1}{|GH(s)|} = \left|\frac{s^2+3s+10}{(s+1)}\right|$$

$K_1 = 1.652$, $K_2 = 8 \Rightarrow K_1 < K < K_2$

$1.652 < K < K_2$.

11/8

Matlab

Control system Toolbox :

Transfer function assuming zero initial condition

Example : $y'' + 6y' + 5y = 4u' + 3u$.   ① Transfer function.

$s^2 Y(s) + 6s\,Y(s) + 5Y(s) = 4s\,U(s) + 3U(s) \Rightarrow \frac{Y(s)}{U(s)} = \frac{4s+3}{s^2+6s+5}$.

```
>> num = [4 3];
>> den = [1 6 5];          G=tf([4 3],[1 6 5])
>> G = tf(num,den)
```

② Zero-pole-gain (ZPK)

$\frac{Y(s)}{U(s)} = \frac{4s+3}{s^2+6s+5} = \frac{4(s+0.75)}{(s+1)(s+5)}$, `G=ZPK([-0.75],[-1,-5],4)`

* Normal : `S=tf('s')`

```
G=(4*s+3)/((s^2)+6*s+5)
```

③ State-Space Model (SS)

$\frac{Y}{R} = \frac{4s+3}{s^2+6s+5}$, $\frac{X}{R} = \left(\frac{1}{s^2+6s+5}\right)$, $\frac{Y}{X} = (4s+3)$.

$R = x'' + 6x' + 5x$, $Y = 4x' + 3x$

$$\begin{bmatrix} x_1' \\ x_2' \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -5 & -6 \end{bmatrix} * \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} R$$

$$Y = \begin{bmatrix} 3 & 4 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + [0] R.$$

```
G=ss([0 1;-5 -6],[0;1],[3,4],0)
```

Symbolic :

⇒ Solve the diff. equ. $\frac{dy}{dx} = e^{\frac{-1}{x}} \frac{1}{x^2}$:

```
syms y(x)
eqn= diff(y) == exp(-1/x)/x^2
cond= [y(0) == 1];
sol(x)= dsolve(eqn, cond)
```

⇒ system of differential equ.

$\frac{dy}{dt} = z$, $\frac{dz}{dt} = y$.

```
syms y(t) z(t)
eqns = [diff(y,t) == z          diff(z,t) == -y]
sol = dsolve(eqn)
sol.z
sol.y
```

$(1+t^2)\ddot{w} + 2t\dot{w} + 3w = 2$ 2 order

$t_0 = 0$, $t_f = 5$, $w(t_0) = 0$, $\dot{w}(t_0) = 1$

```
function dx= diff(t,x)
 [m,n]=size(x)
 dx= zeros(m,n)
 dx(1)= x(2)
 dx(2)= (2-2*t*x(2)-3*x(1))/(1+t^2)
tspan = [0 5]
x0= [0;1]
[t,x]= ode23(@diff, tspan, x0)
plot(t,x(:,1))
plot(t,x(:,1),t,x(:,2))
```

write MATLAB code using ODE45 to solve the following differential equations

$\ddot{x} + x = \log(t)$, $\dot{x}(0) = 0$, $x(0) = 0$

Plot(y) and plot(x) on same figure for a time interval 0 to 20 seconds.

ODE45 : Numerical answer :

convention ⇒ there is a second order

x_1 , x_2 $\qquad$ $\ddot{x} + x = \log(t)$

$\dot{x}_1 = x_2$ — ① $\qquad$ $\dot{x}_2 + x_1 = \log(t)$

$\ddot{x} = \dot{x}_2$ $\qquad$ $\dot{x}_2 = \log(t) - x_1$ --- ②

```
function dx= sos(t,x)
[m,n]= size x ;
dx = zeros (m,n) ;
dx(1) = x(2) ;
dx(2) = log10(t) - x(1) ;
```

```
tspan = [0 ,20]
x0 =[0;0];
[t x]= ode45 (at sos, tspan, x0)
plot (t,x)
plot (t, x(:,1))
```

Normal first order equation :

$\dot{x} + a x = b \Rightarrow \dot{x} + 2x = b$ $\qquad$ $\dot{x} = b - ax$

```
function dx= sos(t,x)
a=2 ;
b=4 ;
dx= b-a*x
```

```
tspan = [0 20];
x0 = [0]
[t x]= ode45 (at sos, tspan, x0)
plot (t,x)
```

Changing parameters :

$\dot{x} + a x = b$ $\qquad$ $\dot{x} = b - ax$

```
function dx= sos(t,x,param)
a= param(1)
b= param(2)
dx= b-a*x
```

```
tspan = [0 20];
x0 = [0];
param[ , ];
[t x]= ode45 (at sos, tspan, x0,[], param)
plot (t,x)
```

Symbolic :

write MATLAB symbolic code to solve the following differential equations

$\ddot{x}y + y = \log(t)$, $\ddot{y}x + \dot{y} = t$, $\dot{x}(0) = 0$, $\dot{y}(0) = 0$, $x(0) = 0$, $y(0) = 0$

x(t) , y(t)

```
syms x(t) y(t)
eqn = [diff(x,t,2)*y + y == log10(t)
      , diff(y,t,2)*x + diff(y,t) == t ];
dx = diff (x,t);
dy = diff (y,t);
cond = [dx(0)==0, dy(0)==0 , x(0)==0, y(0)==0];
sol = dsolve (eqn, cond)
```

في حال لغى المعادلة الثانية

```
syms x(t) y(t)
eqn = [diff(x,t,2)*y + y == log10(t)
      , ~~diff(y,t,2)*x + diff(y,t) == t~~ ];
dx = diff (x,t);
dy = diff (y,t);
cond = [dx(0)==0, dy(0)==0 , x(0)==0, y(0)==0];
sol = dsolve (eqn, cond)
```

بس منلغي هاي .

lec (4/8)

Routh hurwtz :

عشان الق الجذور الموجبة لل polynomials. ← حتى لو في رموز.

steps:

1. Block-diagram reduction : $\left[\dfrac{N(s)}{a_4 s^4 + a_3 s^3 + a_2 s^2 + a_1 s_1 + a_0}\right]$

$a_4 s^4 + a_3 s^3 + a_2 s^2 + a_1 s_1 + a_0 = 0$

parameter = (highest power + 1)

s^4	a_4	a_2	a_0
s^3	a_3	a_1	0
s^2	—	—	—
s	—	—	—
s^0	—	—	—

Example : $\dfrac{1000}{s^3 + 10s^2 + 31s + 1030}$

s^3	1	31	0
s^2	10	1030	0
s	—	—	—
0	—	—	—

$\Rightarrow \dfrac{\text{row}(2)}{10}$

s^3	1	31	0
s^2	1	103	0
s^1	—	—	—
s^0	—	—	—

$\dfrac{(1*31)-(1*103)}{1} =$ $\qquad \dfrac{(1*0)-(1*0)}{1}$

s^3	1	31
s^2	1	103
s^1	$\dfrac{31\times1-1\times103}{1}=-72$	$\dfrac{0\times1-1\times0}{1}=0$
s^0	$\dfrac{-72\times103-1\times0}{-72}=103$	$\dfrac{-72\times0-1\times0}{-72}=0$

عدد الجذور الموجبة
يساوي عدد تغيرات الاشارة
في العامود الاول.

Special Cases :

Zero in the first column ... (1)

Entire row is zero ... (2).

Example : the characteristic equation $[s^4 + 6s^3 + 11s^2 + 6s + k = 0]$

s^4	1	11	k	0
s^3	6	6	0	0
s^2	10 (1)	k		
s^1	$\dfrac{60-6k}{10}$ (2)			
s^0	k			

(1): $(6\times11)-(1\times6) = 60/6 = 10$

(2): $\dfrac{(10\times6)-(6\cdot k)}{10} = \dfrac{60-6k}{10}$

for stability : $\dfrac{60-6k}{10} > 0$

$k > 0$

$0 < k < 10$

row 3

$10s^2 + 10 = \text{zero}$

$s^2 = -1j$

Example : Construct a Routh table & find the # of Roots with positive real parts : $[2s^3 + 4s^2 + 4s + 12 = 0]$

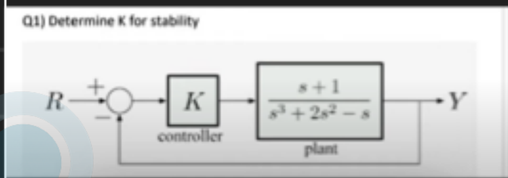
s^3	2	4	0
s^2	4	12	0
s^1	−2	0	
s^0	12		

2 changes of sign in the first column

so 2 real Roots positive.

* Stability :

determin (k) for stability :



feed back : $\dfrac{G(s)}{1 \pm G(s)\cdot H(s)}$

$$\frac{\left(\frac{k(s+1)}{s^3+2s-s}\right)}{1+\left(\frac{k(s+1)}{s^3+2s-s}\right)} \Rightarrow \frac{k(s+1)}{(s^3+2s^2-s)+k(s+1)} = \frac{k(s+1)}{s^3+2s^2-s+ks+k}$$

$s^3 + 2s^2 - s + ks + k = 0 \Rightarrow s^3 + 2s + (k-1)s + k = 0$

تنسيق القسمة

s^3	1	(k−1)	0
s^2	2	k	0
s^1	$\dfrac{k-2}{2}$ (1)	0 (2)	
s^0	k (3)		

(1): $2(k-1)-k = 2k-2-k = \dfrac{k-2}{2}$

* دايماً الضرب مع اول عامود

in stability the answer should be positive.

$\dfrac{k-2}{2} \geq 0 \Rightarrow k > 2$

$k \geq 0$

$\left.\begin{array}{l} k \geq 2 \\ k \geq 0. \end{array}\right]$

PID $\Longrightarrow$ [proportional Integral Derivative].

بالبداية / بالنهاية

$$C_{pid} = (K_p\, e(t)) + \left(K_i \int e(t)\, dt\right) + \left(K_d \frac{de(t)}{dt}\right).$$

amount of the electrical power

ما بيشتغل ال (٣) مكونات سوا بنفس الوقت.

K_p : to get less rise time

$K_d \frac{d}{dt}$: less overshot

$K_i \int$: more accurcy.

The Characteristics of P, I, and D controllers

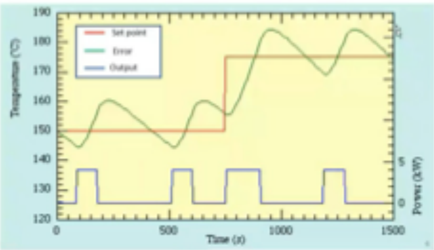
CL RESPONSE	RISE TIME	OVERSHOOT	SETTLING TIME	S-S ERROR
Kp ↑	Decrease	Increase	Small Change	Decrease
Ki	Decrease	Increase	Increase	Eliminate
Kd	Small Change	Decrease	Decrease	Small Change

PID part (3) :

1

On-Off Control

- This is the simplest form of control.

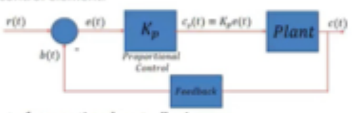


when the temp. decrease $\Rightarrow$ will switch to full power.

not accurate.

Proportional Control (P)

- In *proportional mode*, there is a continuous linear relation between value of the controlled variable and position of the final control element.



- Output of proportional controller is

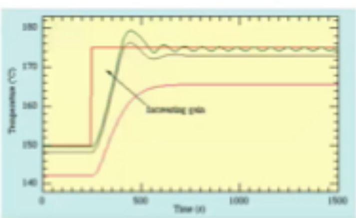
$$c_p(t) = K_p e(t) = \text{power}$$

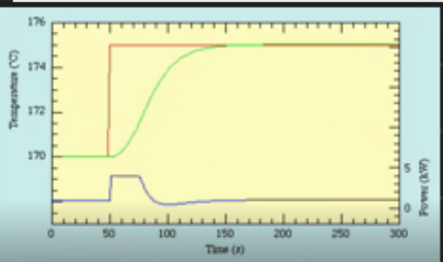
- The transfer function can be written as

$$\frac{C_p(s)}{E(s)} = K_p$$

Proportional Controllers (P)

- As the gain is increased the system responds faster to changes in set-point but becomes progressively underdamped and eventually unstable.





PID :

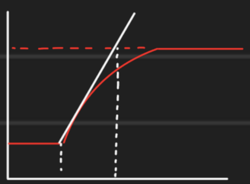
type (1)

Type of Controller	K_p	T_i	T_d
P	$0.5K_{cr}$	∞	0
PI	$0.45K_{cr}$	$\frac{1}{1.2}P_{cr}$	0
PID	$0.6K_{cr}$	$0.5P_{cr}$	$0.125P_{cr}$

K_{cr} ? given

P_{cr} ?

type (2)



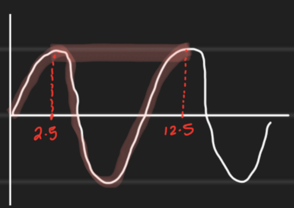
	K_p	T_r	T_d
P	$\frac{\nu_o}{K_o\tau_o}$		
PI	$\frac{0.9\nu_o}{K_o\tau_o}$	$3\tau_o$	
PID	$\frac{1.2\nu_o}{K_o\tau_o}$	$2\tau_o$	$0.5\tau_o$

V_o ?

K_o ?

T_o ?

Example : find the PID : ($K_{cr} = 3.5$).



$\Rightarrow P_{cr} = 12.5 - 2.5 = 10$

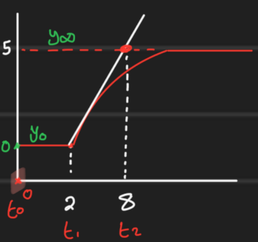
ونستعمل القيم من الجدول .

PID = $0.6K_{cr} = 0.6 * 3.5 = 2.1$

$0.5P_{cr} = 0.5 * 10 = 5$

$0.125P_{cr} = 0.125 * 10 = 1.25$.

Example : find the final PID ? $u_\infty = 1.25$, $u_o = 0.25$



① $V_o = t_2 - t_1 = 6$

② $T_o = t_1 - t_o = 2$

③ $K_o = \frac{y_\infty - y_o}{u_\infty - u_o} = \frac{5}{1} = 5$

(,) given

ونعوضها على الجدول .

PID : $\frac{1.2 V_o}{k_o T_o} = \frac{1.2 * 6}{5 * 2}$

$2T_o = 4$

$0.5 T_o = 1$

Arduino :

on , off
input , out put

Digital.

0V — 5V
[0 — 1024]

Analog.

* Every Arduino "Sketch" has :

```
// variable declarations

const int LED 13 ;

void setup ()
{
  // configuration of pins , etc .
}
void Loop ()
{
// what the program does , in the continuous loop
}
```

Example : blink

```
const int LED = 13 ;

void Setup ()
{
pin Mode (LED, OUTPUT) ;
}
Void Loop ()
{
digital Write (LED, HIGH) ;
delay ( 1000 ) ;
digital Write (LED, LOW) ;
delay (1000) ;
}
```

(Pin 13) وصلة مع

OUTPUT
INPUT

5V

delay (1000)
تأخر ثانية واحدة

button

```
  void Loop (0)
{
val = digitalRead (Button) ;
 if (val == HIGH) {
{
digital Write (LED, HIGH) ;
}
 else {
   digital Write (LED, LOW) ;
   }
}
```

بس لازم أكون قبل معرفة
```
Const int Button = ;
pin Mod (Button, INPUT)
```

Morse code

LED will ligth long. ← الاشارة الطويلة

النقطة ← اشارة قصيرة

```
void dot ()
{ blink (200, 200) ; }

void dash ()
{ blink (600, 200) ; }

void letterspace ()
{ delay (400) ; }

void wordspace ()
{ delay (800) ; }
```

```
void blink (int ontime , int offtime ).
{
 digital Write (LED, HIGH) ;
   delay (ontime) ;
 digital Write (LED, LOW) ;
   delay (offtime) ;
}
```

نعملها

Perhaps letter functions :

```
void morse_s ()
{ dot () ; dot () ; dot () ; letterspace () ; }

void morse_o ()
{ dash () ; dash () ; dash () ; Letter space () ; }
```

Arduino : Temperature Sensors

TMP36


→ مُصمم بطريقة تحديداً عشان يقيس voltage.
يستقبل من الاطراف (Zero & 5 V)

NTC Thermistor


⇒ تتغير المقاومة فيه (بتنزل مع الحرارة)

```
// We'll use analog input 0 to read Temperature Data const int t
void setup()
 { Serial.begin(9600); }
void loop()
{ float voltage, degreesC, degreesF;
voltage = getVoltage(temperaturePin);
 // Now we'll convert the voltage to degrees Celsius.
// This formula comes from the temperature sensor datasheet:
 degreesC = (voltage - 0.5) * 100.0;
 // Send data from the Arduino to the serial monitor window
Serial.print("voltage: ");
Serial.print(voltage);
Serial.print(" deg C: ");
Serial.println(degreesC);
delay(1000);
// repeat once per second (change as you wish!) }
float getVoltage(int pin)
 { return (analogRead(pin) * 0.004882814); }
// This equation converts the 0 to 1023 value that analogRead()
// returns, into a 0.0 to 5.0 value that is the true voltage
// being read at that pin.
```

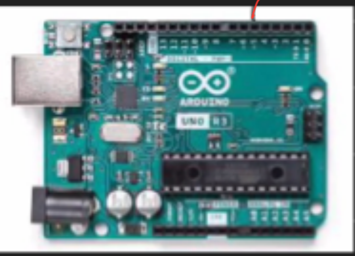
```
// Read Temerature Values from NTC Thermistor
 const int temperaturePin = 0;
 void setup()
{ Serial.begin(9600); }
 void loop()
 { int temperature = getTemp();
Serial.print("Temperature Value: ");
Serial.print(temperature);
 Serial.println("*C");
delay(1000);
 }
 double getTemp()
{
// Inputs ADC Value from Thermistor and outputs Temperature in Celsius int RawADC =
analogRead(temperaturePin);
long Resistance;
 double Temp;
 // Assuming a 10k Thermistor. Calculation is actually: Resistance = (1024/ADC)
Resistance=((10240000/RawADC) - 10000);
 // Utilizes the Steinhart-Hart Thermistor Equation:
// Temperature in Kelvin = 1 / {A + B[ln(R)] + C[ln(R)]^3}
// where A = 0.001129148, B = 0.000234125 and C = 8.76741E-08 Temp = log(Resistance);
 Temp = 1 / (0.001129148 + (0.000234125 * Temp) + (0.0000000876741 * Temp * Temp *
Temp)); Temp = Temp - 273.15;
// Convert Kelvin to Celsius return Temp;
 // Return the Temperature
 }
```

const int temp = 0

Lecture 1

Arduino :

digital [10]
on / off ⇒ on = 5V , off = 0 V



input : Button 1 0

Output LED 1 0 :

منشيلها ما نغير

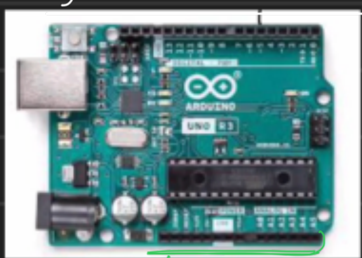
```
const int Button = 10; (1)
        , LED = 9;
void setup( )
{ pinMode( Button , INPUT );
  pinMode( LED , OUTPUT );
{ Void loop( )
  { int X;
    X = digitalRead (Button);
    if (x==1)
    digitalWrite (LED, HIGH);
    else
    digitalWrite (LED, LOW);
  }
```

بالنسبة لـ (LED) دايما في resistance

كيف بدخله بالمعادلة ؟؟

في حال كان على (9)
و Button على (10)

① Digital pins.
بيوخذو قيمة
[0 / 1].



Analog pin

* Analog pin [1024]

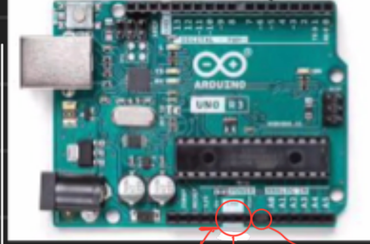
using analogRead
analogWrite
delay (1000);

②

$$R_{total} = 1000 + RT = \frac{V}{I} = \frac{\frac{1024}{V}}{1000}$$

```
float getTemp (int Tpin)
{ int V = analogRead (Tpin);
  float R = (10240000 / V) - 10000
  float logR = log(R);
  return (1/(0.001129148 + 0.000234125 log(R)
         + 8.76741 E8 * logR * logR * logR) }
```

- 273.15 → if it's in (C)



5V   Ground   A0

TMP 36 :

الطرف اليمين مع الـ Ground.
اليسار مع (5V)
الوسط مع A0

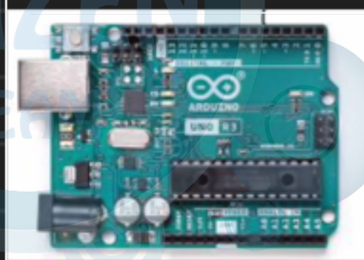
```
Const int Tpin = 0;

Void setup ( )
{ Serial.begin (9600);
}
Void loop ( )
{ float voltage , temprature;
  voltage = getvoltage (Tpin);
  temperature = (voltage - 0.5)*100;
  Serial.print ("T is ");
  Serial.println (temperature);
  delay (1000);
}
```

①

0 → 1024
0V → 5V
⇒ 512 → 2.5V
= * 5/1024

```
float getvoltage (int Tpin)
{ return (analogRead (Tpin) * 5/1024)
```

ثابتة



②

NTC Thermistor

A0   1000Ω   V1   RT   5V

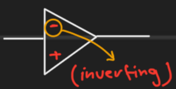
voltage div
5V → 1024

```
const int Tpin = 0;

Void setup ( )
{ Serial.begin (9600);
{ Void loop (
  { float Temp;
    Temp = getTemp (Tpin);
    Serial.Print ("T is ");
    Serial.print (Temp);
    Serial.println (Temp);
    delay (1000);
{
```

Electronic sys., Active circuit. (AC)

$T.f = \frac{\text{output}}{\text{input}}$

Cases: 1] Inverting 2] non-inverting.



,

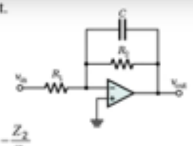
$T.f = \frac{-Z_2}{Z_1} = \frac{\text{out put}}{\text{Input}}$

$T.f = 1 + \frac{Z_2}{Z_1}$ out / in

$Z \Rightarrow$

- Find out the transfer function of the following circuit.

inverting



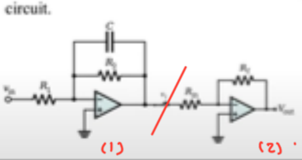
$\frac{V_{out}}{V_{in}} = -\frac{Z_2}{Z_1}$

$Z_2 = \frac{R_2 * \frac{1}{c.s}}{R_2 + \frac{1}{c.s}}$

$T.f = \frac{-Z_2}{Z_1}$

$Z_1 = -R$

- Find out the transfer function of the following circuit.



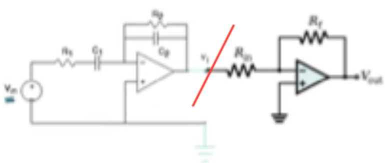
$T.f_{(tot)} = T.f_{(1)} * T.f_{(2)}.$

(1): $\frac{-\frac{R_2}{1+R_2C.S}}{R_1}$

(2): $\frac{-R_f}{R_{in}}$

بعدها منضربهم ببعض

Find out the transfer function of the following circuit.



(2) $\frac{-R_f}{R_{in}}.$

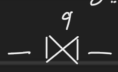
(1) = $\frac{\frac{R_2}{1+R_2C.S}}{\left(R_1 + \frac{1}{C_1.S}.\right)}$

Gear ratio:

$\frac{\text{\# of teeth of input gear}}{\text{" " " output "}} = \frac{\text{Input Torque}}{\text{Output Torque}} = \frac{\text{outp. speed}}{\text{inp. speed.}}$

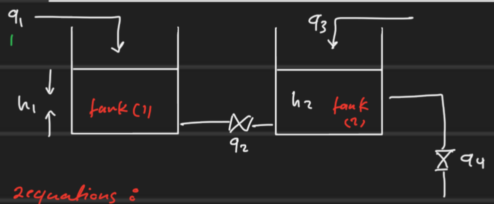
Tanks :

ال (q) الها معادلة خاصة فيها



$$\left[q = \frac{h_{in} - h_{out}}{q_1}\right] \cdots ①$$

$$\left[C \frac{dh}{dt} = q_{in} - q_{out}\right] \cdots ②$$



2equations :

tank (1): $C_1 \frac{dh}{dt} = q_1 - q_2$.

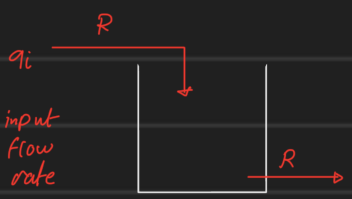
tank (2): $C_2 \frac{dh}{dt} = q_3 + q_2 - q_4$

Step (1).

for (q) → (R).

$$R_1 = \frac{h_{in} - h_{out}}{q_1} = \frac{0 - h_1}{q_1}$$

$$R_2 = \frac{h_1 - h_2}{q_2}, \quad R_3 = \frac{-h_2}{q_3}, \quad R_4 = \frac{h_2}{q_4}$$



R: Resistance of value

qo : output flow rate

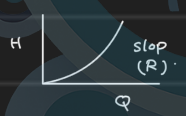
anti proprtional relation ship

$q_o \uparrow \quad R \downarrow$

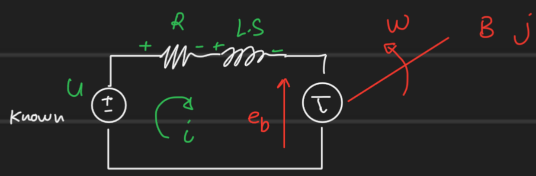
$q_o \propto \frac{1}{R}$

$q_o \uparrow \quad H \uparrow$

$q_o \propto H$



*] DC motor :



$$-u + RI + LSI + e_b = 0$$

$$\tau = K_t * I, \quad I = \tau / K_t, \quad e_b = K_b \omega.$$

$$T = J\dot{\omega} + B\omega$$

$$u = \frac{J\omega s + B\omega}{K_t}(R + LS) + (K_b \omega).$$

$$u = \omega\left(\frac{JLS^2 + (JR + BL) * S + BR + K_b K_t}{K_t}\right)$$

$$\left(\frac{\omega}{u} = \frac{K_t}{JLS^2 + (JR + BL)S + BR + K_b K_t}\right)$$