تقدم لجنة ElCoM الاكاديمية

دوسية لمادة:

مختبر تحكم الي

اعداد وكتابة:

اسلام حسن

براءة القرارعه

حلا بداوي

بسم الله الرحمن الرحيم

بسم الواحد الأحد، الفرد الصمد، رفع السماء بلا عمد،نحمدك ربي حمدا لا بلوغ لمنتهاه على ما أنعمت علينا من فضلك، نحييكم بتحية الاسلام تحية أهل الجنة في الجنة فالسلام عليكم ورحمة الله ...

قال تعالى: "فمن تطوع خيرا فهو خير له"

ومن منطلق حاجة البشرية الى بعضهم البعض والسعي دائمًا إلى التقدم، نقدم لكم هذه الدوسية عن روح :(سميح ابراهيم حسن، احمد رياض البداوي، فيصل مرزوق الغويري) سائلين المولى عز وجل أن يرحمهم وأن يتقبل منا هذا العمل خالصا لوجهه الكريم .

نقدم لكم في هذه الدوسية شرح بسيط عن مادة مختبر تحكم آلي ، التي ستمكنكم بإذن الله بالنجاح والعلامات العالية ، يوجد في اخر مادة المختبر جزء غير مشروح بالدوسية لعدم مقدرتنا على التمكن منه ومن افكاره نعتذر عن تقصيرنا بذلك بالإضافة أن التجربة الخامسة لم تكن مطلوبة على وقتنا لذلك لم يتم شرحها ، يجب اعتماد المانيوال مع الدوسية لأنه يتم اضافه او حذف تجارب .

وكما نتمنى أن تنال الدوسية بعض من الرقي والإعجاب الذي يليق بكم،فإن وُفقنا فذلك من الله، وإن اخفقنا فمنا .

*** ننتظر ملاحظاتكم وتعليقاتكم ***

دعواتكم لنا بالنجاح والتوفيق ♥

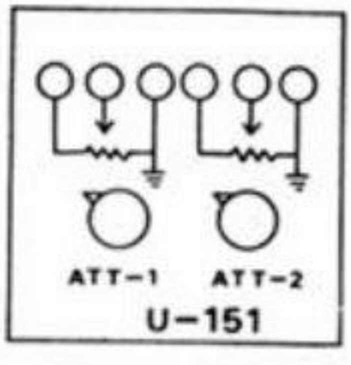
Servo system

تم وضع اهم المعلومات عن الاجهزة .

اذا انت حاب تكون ضامن مية بالمية ارجع للمانيوال واحفظ كل التفاصيل .

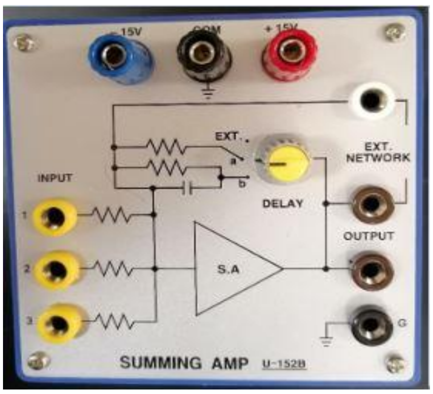
Component:

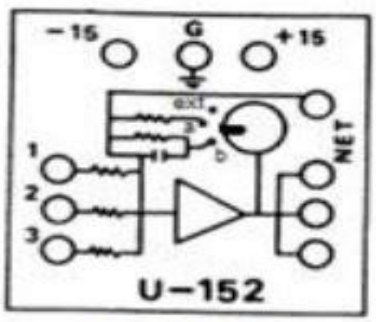
1) Attenuator (u-151): provide gain between (0-1).



Attenuator

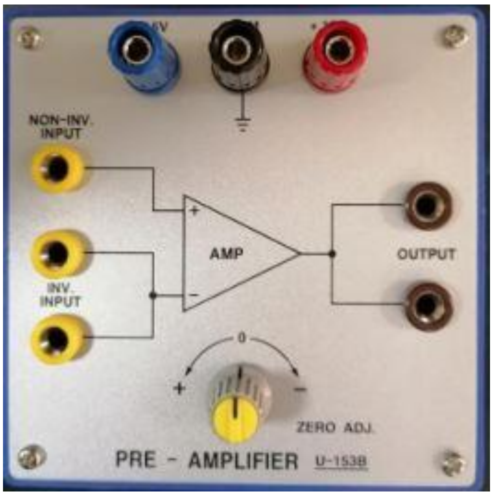
2) Summing Amplifier (u-152): calculate error between setpoint and feedback.

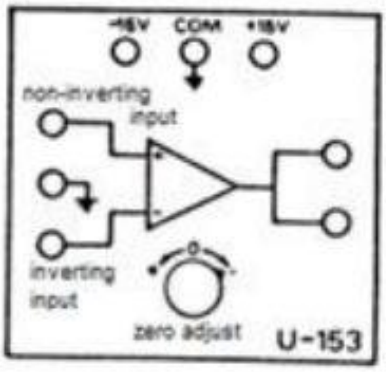




Summing amp

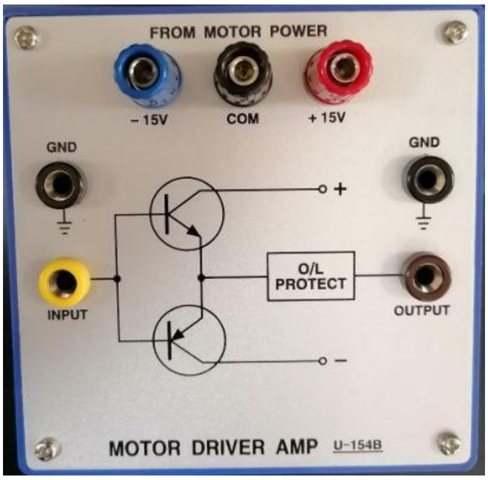
3) Pre-amplifier (u-153): is required in position system , it has two input [inverting and non-inverting] , it provides gain (negative) if the inverting input used .

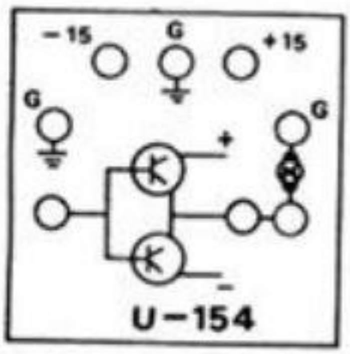




Pre-amp

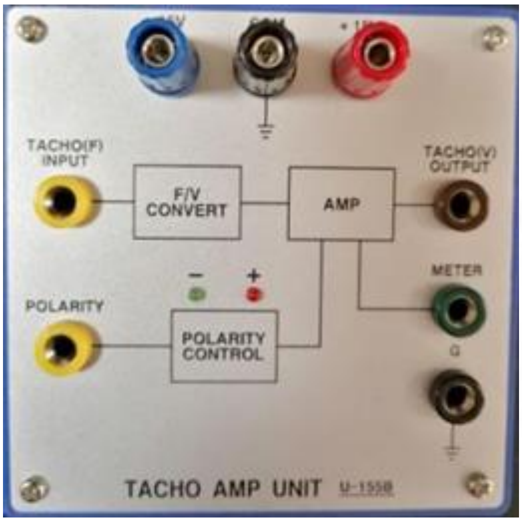
4) Motor drive amplifier (u-154) : provide current gain to be enough to drive the motor .

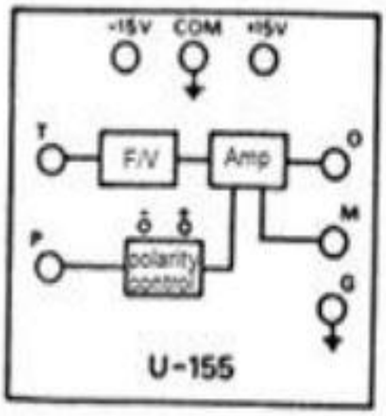




Motor Driver Amp

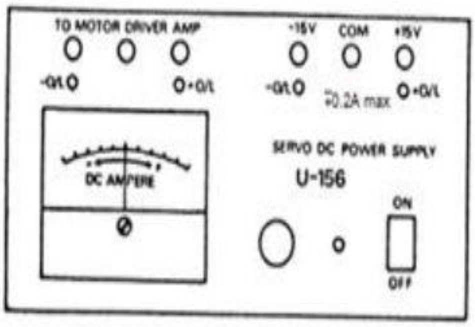
5) Tacho amplifier (u-155) : conversion of digital frequency signal to analog output voltage , convert the input frequency into output voltage .





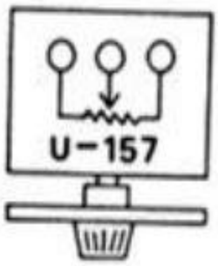
Tacho. Amp. Unit

6) Power supply (u-156) : it has two side , in the right side is low current and power , in the left side is high current and power .



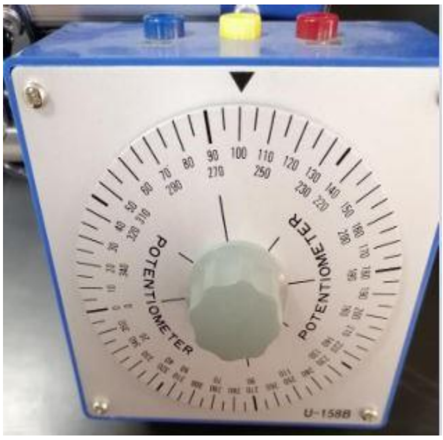
Dc Power Supply

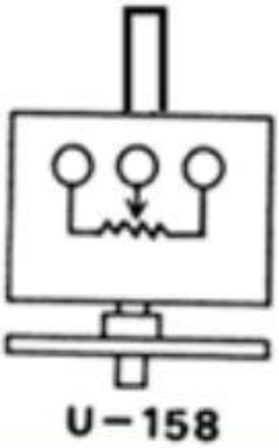
7) Input Angular potentiometer (u-157) : used as set point in position .



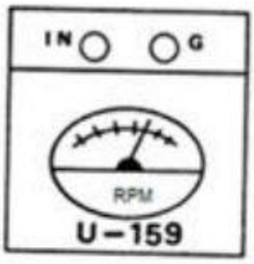
Input Potentiometer

8) Output angular potentiometer (u-158) : used as sensor .





9) Tacho meter (u-159) : used to monitor the speed .

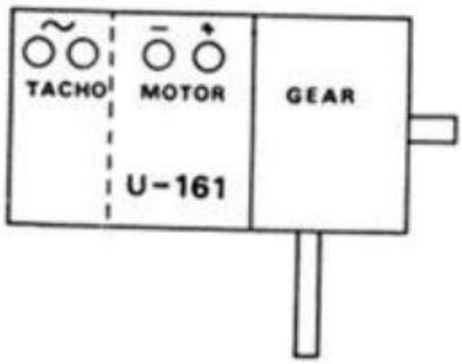


Tacho. Meter

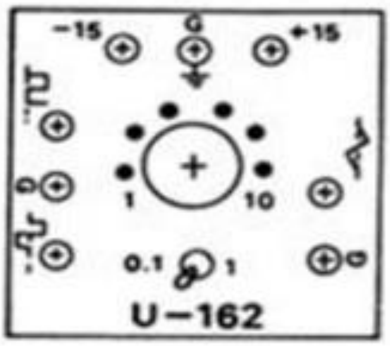
10) Dc motor (u-161) :

[motor part] :is permanent magnet that produce a torque .

[tacho part] : gives output frequency signal to the motor speed .



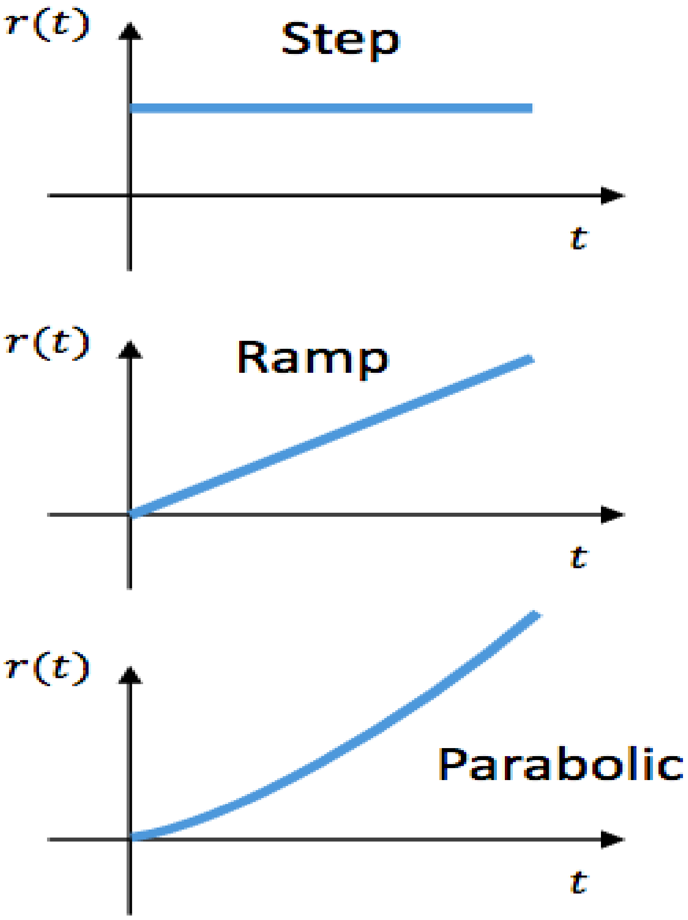
11) function generator (u-162) : provide step input signal to system , and control the frequency of signal.



Function Generator

- **Test input signal :**

- Step input , ramp input, parabolic input, and unit-impulse input .



R(t)

$$\frac{A}{s}$$

$$\frac{A}{s^2}$$

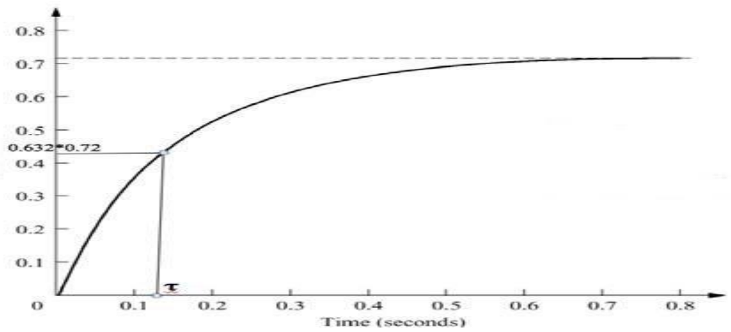
$$\frac{2A}{s^3}$$

Speed Control System

(First order)

"يوجد فيديو شرح توصيلة لهذه التجربة"

* $\frac{Y(s)}{R(s)} = \frac{K}{\tau s+1}$
* $Y(\tau) = 0.63\ y_{ss}$
* Settling time : $Ts = 4\tau$
* $Y(t) = K\left(1 - e^{-\frac{t}{\tau}}\right)$ (For unit step input)



1) Sensitivity : $S_G^T = \frac{dt}{dG} \times \frac{G}{T}$

- In open loop system there is high sensitivity.
- In closed loop system there is low sensitivity.

2) Erorr signal : $E(s) = R_{ss} - Y_{ss}$

$$E(s) = R_{ss} - T(s)(R_{ss})$$

3) Disturbance :

- represents the load of the Dc motor and is added as extra input of the system .
- The electromagnetice break device is used express this load

$$D\% = \frac{output\ due\ to\ D}{total\ output}$$

Notes :

1) If the error increase the accuracy will decrease .

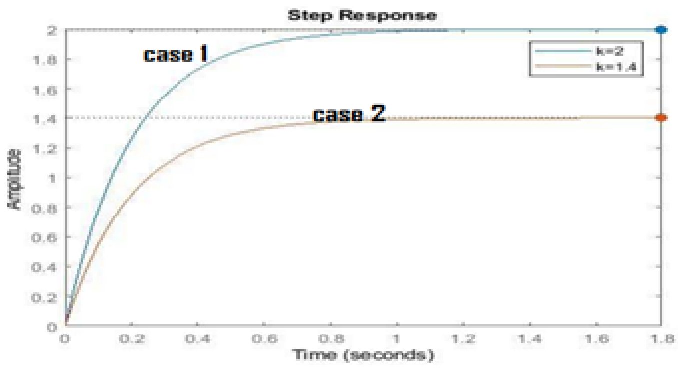
2) Erorr in closed loop < Erorr in open loop .

3) If the gain > 1 In most cases open loop .

4) Closed loop faster than open loop .

5) The one closest to the y-axis is the open loop system.

Case (2) faster than Case (1) / Case (1) The one closest to the y-axis



$$\Delta T = 1.4 - 2 = -0.6$$

$$\Delta K = 1.4 - 2 = -0.6$$

$$S_K^T = \frac{-0.6}{-0.6} = 1$$

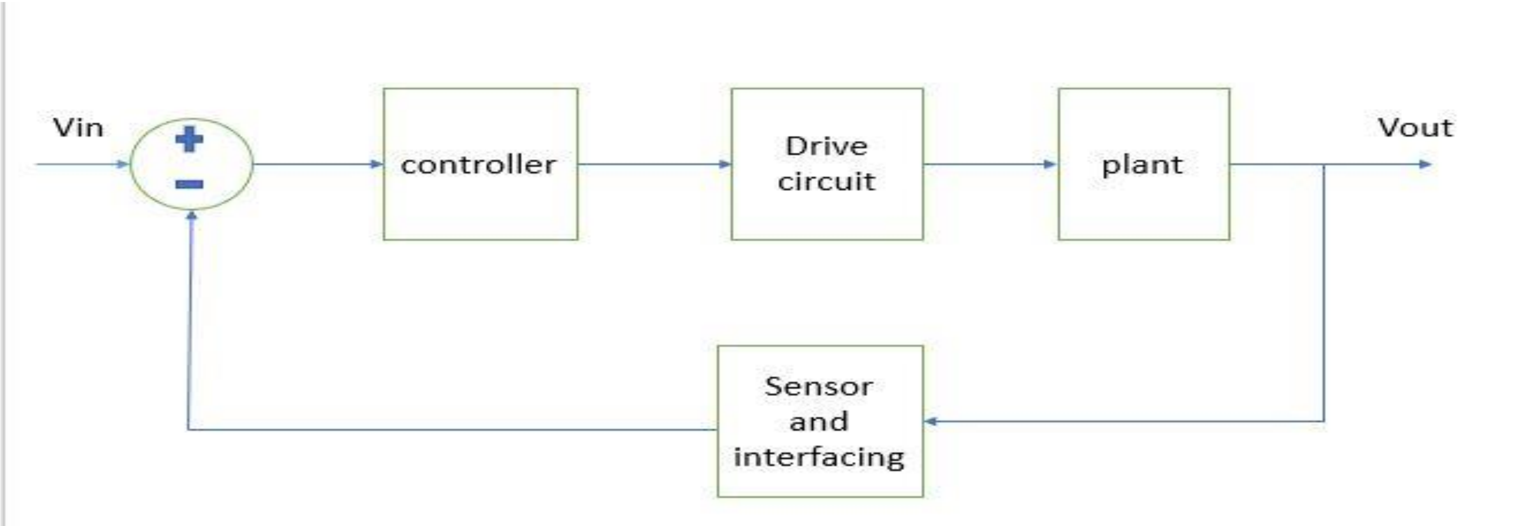
6) If the gain increase the sensitivity will increase .

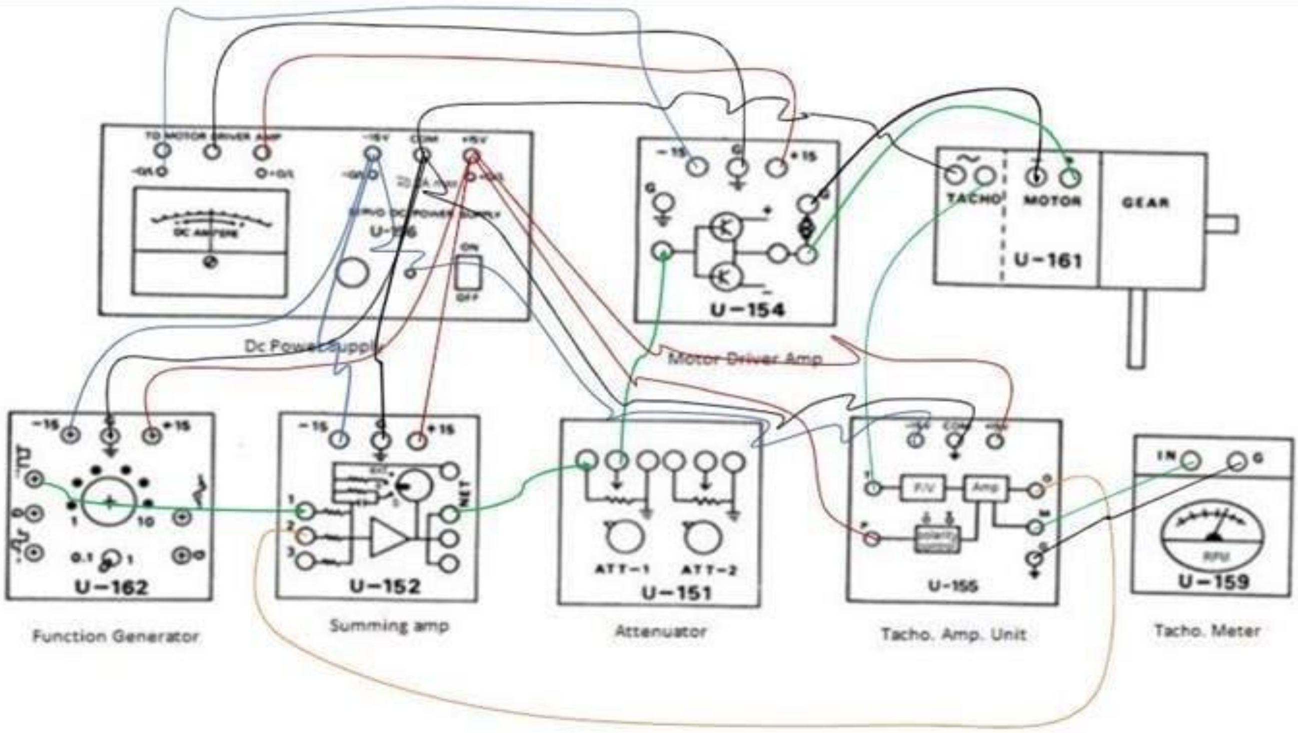
7) If the gain increase the time constant will decrease .

8) The closed loop will decrease disturbance .

9) The feedback will decrease disturbance .

Open loop	Closed loop
Gain ↑ E(s) ↑ τ is constent	Gain ↑ E(s) ↓ τ ↓ Speed ↑

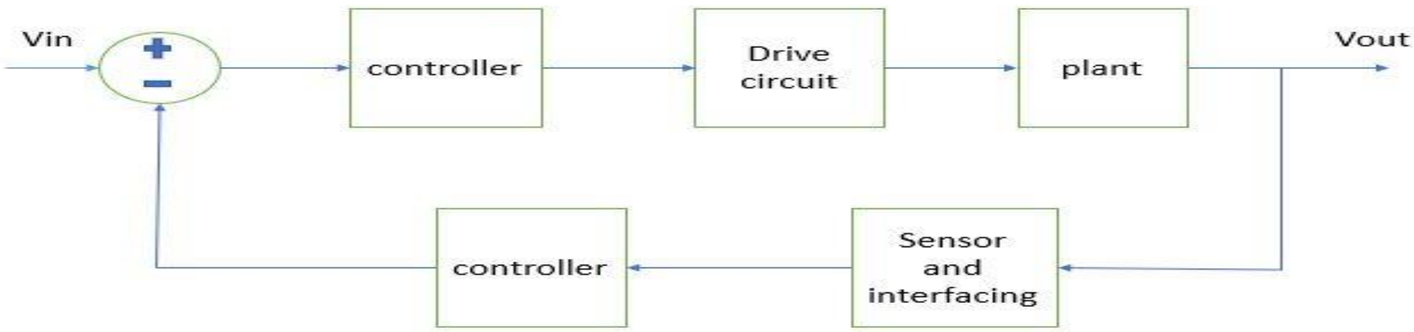


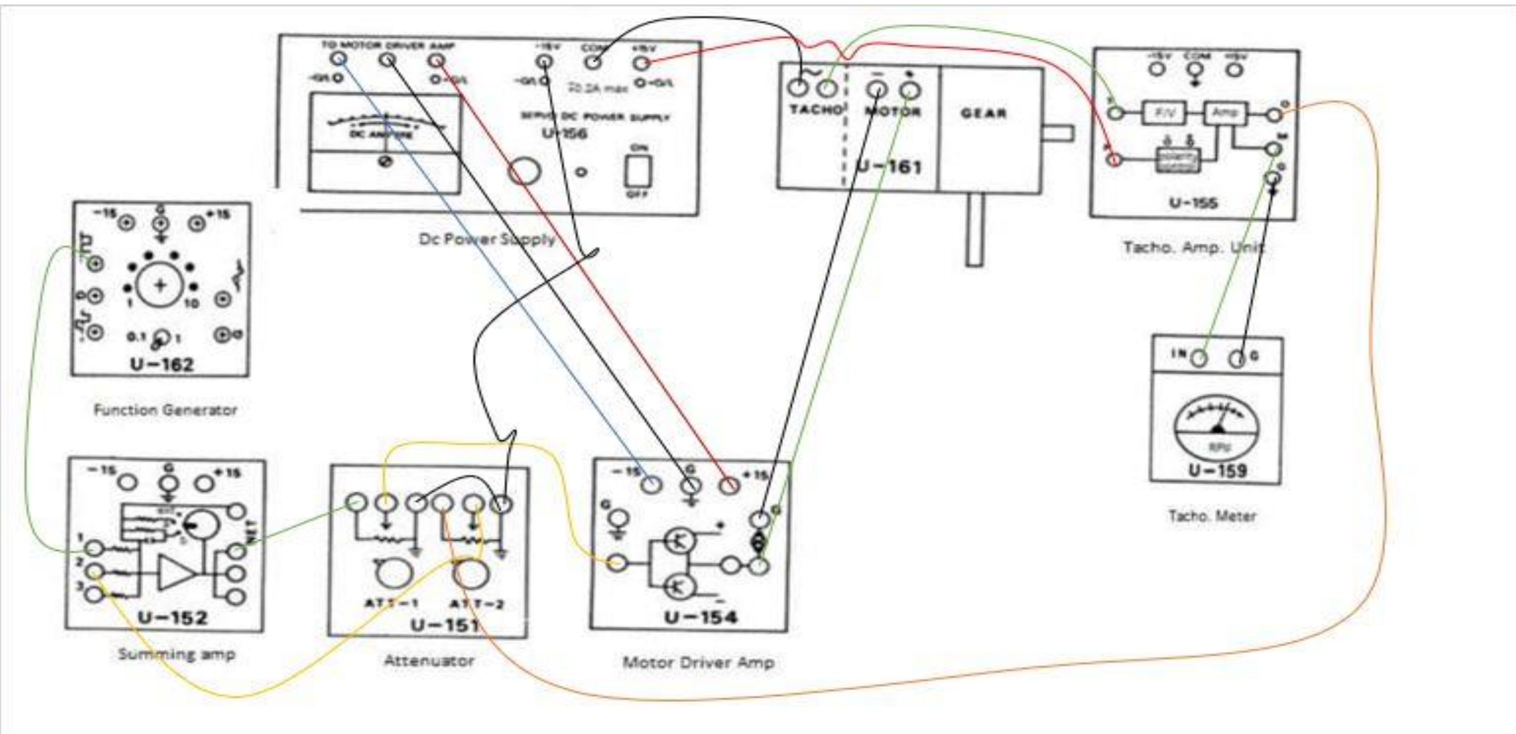


Please 😱 don't forget connect power wire،

Motor drive will take high power from left side of power supply component , each of other component will take low power from right side of power supply component .

"لا تنسى انه في فيديو توصيل, عشان تفهم اكثر روح احضره"





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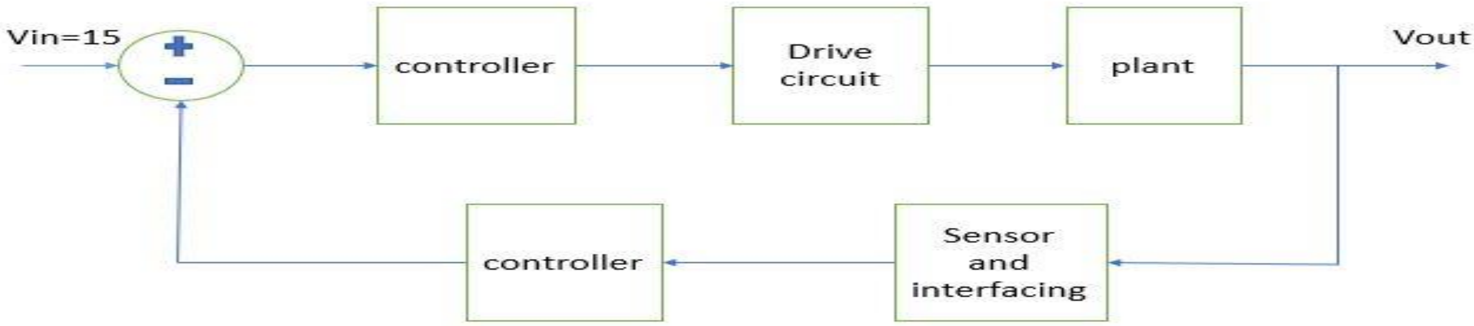
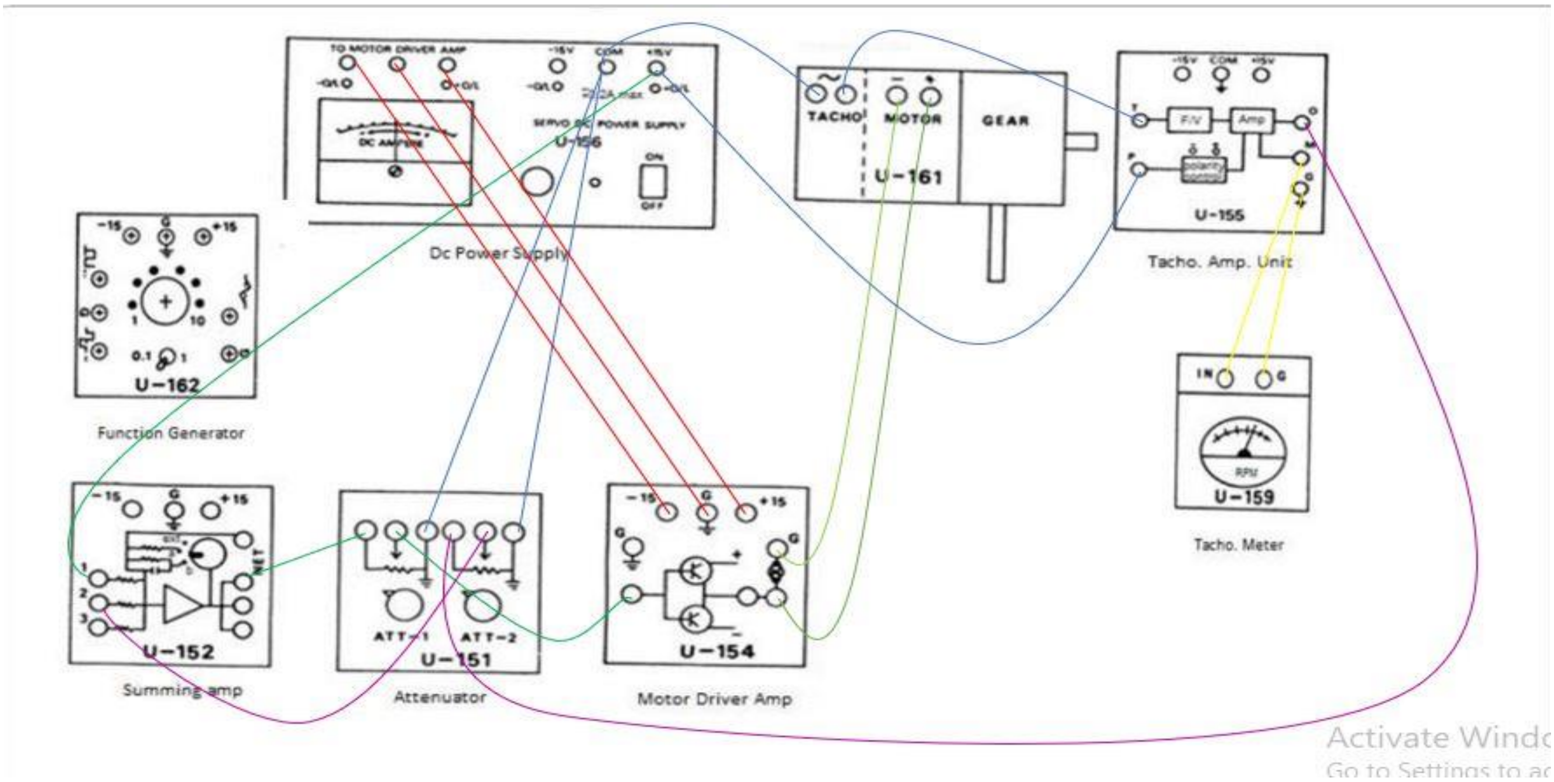
"لا تنسى انه في فيديو توصيل, عشان تفهم اكثر روح *احضره"*



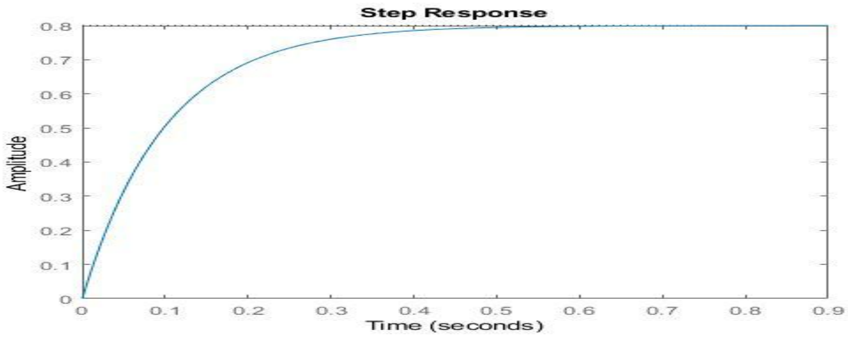


Please 🙈 don't forget connect power wire،

Motor drive will take high power from left side of power supply component , each of other component will take low power from right side of power supply component .

"لا تنسى انه في فيديو توصيل, عشان تفهم اكثر روح احضره"

Example (1):



1) **dc gain :** $k = \frac{y_{ss}}{R_{ss}} = \frac{0.8}{1} = 0.8$

2) **time constant :** $Y(\tau) = 0.63 \times Y_{ss} = 0.63 \times 0.8 = 0.5$

3) $\tau = 0.1$ نقوم بعمل إسقاط عند القيمة 0.5 في محور الصادات على محور السينات لإيجاد قيمة

4) **settling time :** $T_s = 4\tau = 4 \times 0.1 = 0.4$

5) **general form :** $\frac{8}{10\times(\frac{s}{10}+1)}$

Example (2) : $T(s) = \frac{3}{s+3}$

$\frac{Y(s)}{R(s)} = \frac{K}{\tau s+1}$ قبل البدأ بالحل يجب ان نتأكد انه على الصوره العامه وهي

$T(s) = \frac{3}{s+3}$ ➡ $T(s) = \frac{1}{\frac{s}{3}+1}$

1) $K = \frac{Y_{ss}}{R_{ss}} = \frac{1}{1} = 1$

2) $\tau = \frac{1}{3}$

3) $T(s) = \frac{4}{3}$

4) Response $Y(t)$? $Y(t) = K(1 - e^{-\frac{t}{\tau}})$ $= 1 - e^{-3t}$

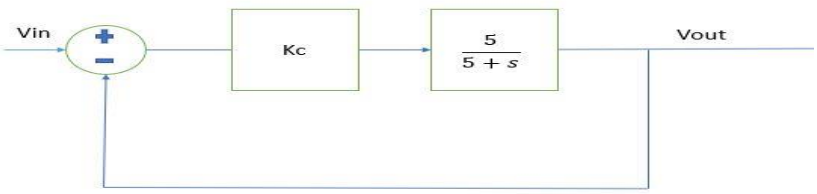
Example (3) :

If the response has a value 3 units at (1min) and 4 unit at stead state find transfer function ?

$Y(t) = 3$ $\quad 3 = 4(1 - e^{-\frac{t}{\tau}})$ $\quad 0.25 = e^{\frac{-60}{\tau}}$ $\quad \frac{-60}{\tau} = \ln 0.25$ $\quad \tau = 43.2 \approx 43$

$$Tf = \frac{4}{43s + 1}$$

Example (4) :



A) Find Tf interm Kc ?

$$Tf = \frac{\frac{5Kc}{s+5}}{1+\frac{5Kc}{s+5}} = \frac{5Kc}{s+5+5Kc}$$

B) What is the value of Dc gain if Kc=2 ?

$$Tf = \frac{10}{s+15} = \frac{10}{15(\frac{s}{15}+1)} \qquad Dc\ gain = \frac{10}{15}$$

C) What is the value of Kc to have pole S=4 ?

pole =4 / s=4

S+5+5Kc=0

4+5+5Kc=0 $\qquad Kc = \frac{-9}{5}$

D) What the effect of increase Kc on system sensitivity ?

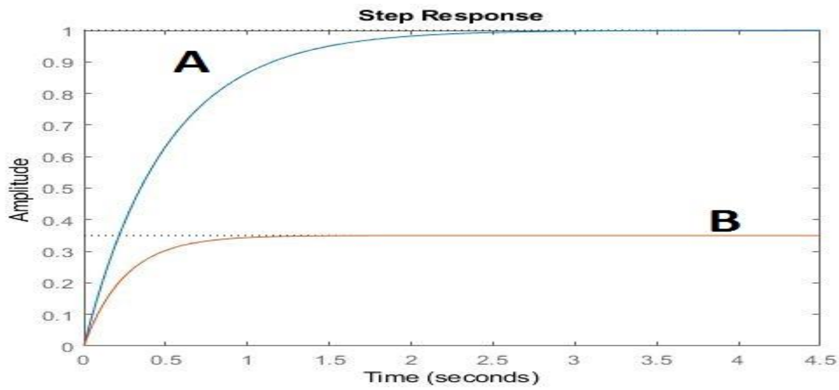
If Kc increases sensitivity increases .

E)Calculate the system sensitivity interm of Kc ? (for unit step input)

$$S_{kc}^{T} = \frac{(5+s+5Kc)5 - 5kc \times 5}{(5+s+5kc)^2} \times \frac{\frac{Kc}{5Kc}}{5+s+5Kc}$$

$$S_{kc}^{T} = \frac{5+s}{5+s+5kc}$$

Example (5) :



1) What is the value of time constant curve B ?

time constant : $Y(\tau) = 0.63 \times Y_{ss}$ = 0.63 × 0.36 =0.22

نقوم بعمل إسقاط عند القيمة 0.22 في محور الصادات على محور السينات لإيجاد قيمة $\tau = 0.25$

2)What is the value of time constant curve A ?

time constant : $Y(\tau) = 0.63 \times Y_{ss}$ = 0.63 × 1 =0.63

نقوم بعمل إسقاط عند القيمة 0.63 في محور الصادات على محور السينات لإيجاد قيمة $\tau = 0.5$

3) Which curve is consideras open loop system ?

If the gain > 1 In most cases open loop , Closed loop faster than open loop .

The one closest to the y-axis is the open loop system.

4) What is the value ofsystem pole ?

A : $0.5s + 1 = 0$

$s = -2$

B: $0.25\,s + 1 = 0$

$s = -4$

Position Control System

Experiment (2)

(Second Order)

"يوجد فيديو شرح توصيلة لهذه التجربة"

- **Dc gain** : $K = \frac{Y_{ss}}{R_{ss}}$
- **Natural frequency** : w_n
- **Damping frequency** : w_d

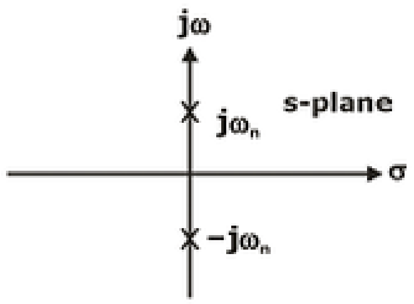
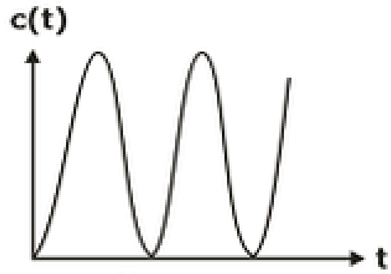
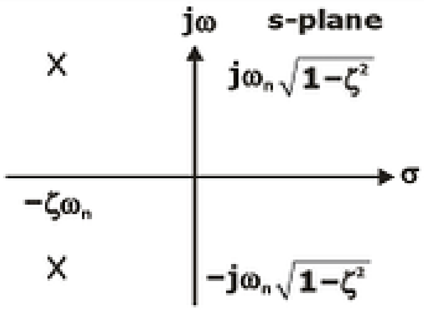
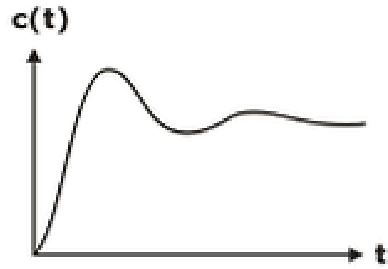
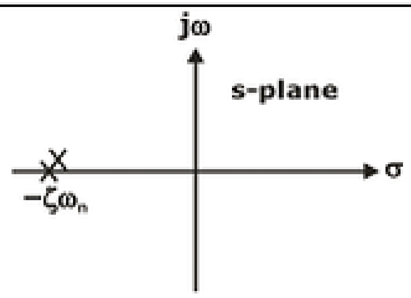
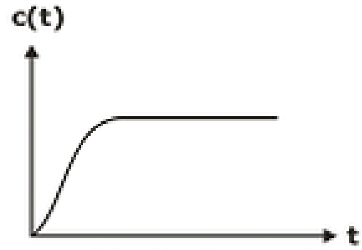
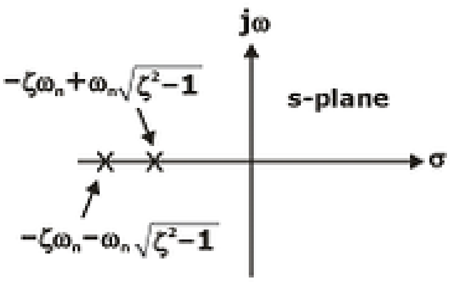
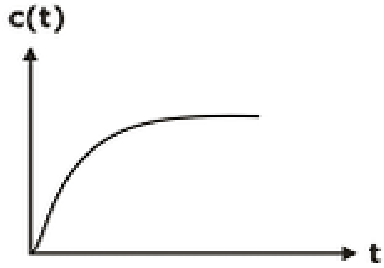
$$w_d = w_n\sqrt{1-\zeta^2}$$

- **Damping ratio** : ζ

Second Order : $\frac{Kw_n{}^2}{S^2+2\zeta w_n S+w_n{}^2}$

Undamped	$\zeta = 0$	$S_{12} = \mp jw_n$	Y(t)=1- $\cos(w_n t)$
θ = 90 **Critically Damped**	$\zeta = 1$	$S_{12} = -w_n$	Y(t)=1-$e^{-w_n t}(1+w_n t)$
θ = 0 **Underdamped**	$0<\zeta<1$	$S_{12} = -\zeta w_n \mp jw_n\sqrt{1-\zeta^2}$	Y(t)=1-$\frac{e^{-\zeta w_n t}}{\sqrt{1-\zeta^2}}\sin(w_n\sqrt{1-\zeta^2}\,t+\cos^{-1}(\zeta))$
Overdamped	$\zeta > 1$	$S_{12} = -\zeta w_n \mp w_n\sqrt{\zeta^2-1}$	Y(t)=1-$\frac{w_n}{2\sqrt{\zeta^2-1}}(\frac{e^{-S_1 t}}{S_1}-\frac{e^{-S_2 t}}{S_2})$

- **All poles is Real then :** Critically damped ζ=1
- **All poles is img then :** Undamped $\zeta = 0$

ζ	Poles	Step response
0		 Undamped
0 < ζ < 1		 Underdamped
ζ = 1		 Critically damped
ζ > 1		 Overdamped

- **Peak time** : $T_p = \frac{\pi}{w_n\sqrt{1-\zeta^2}}$ أو من خلال الرسمه نقوم بالذهاب لأعلى قمة ونقوم بعمل إسقاط على محور السينات

- **Over shot :** $O.V = \frac{Y(T_p)-Yss}{Yss} \times 100\%$

$$O.V = 100\, e^{-\pi\zeta/\sqrt{1-\zeta^2}}$$

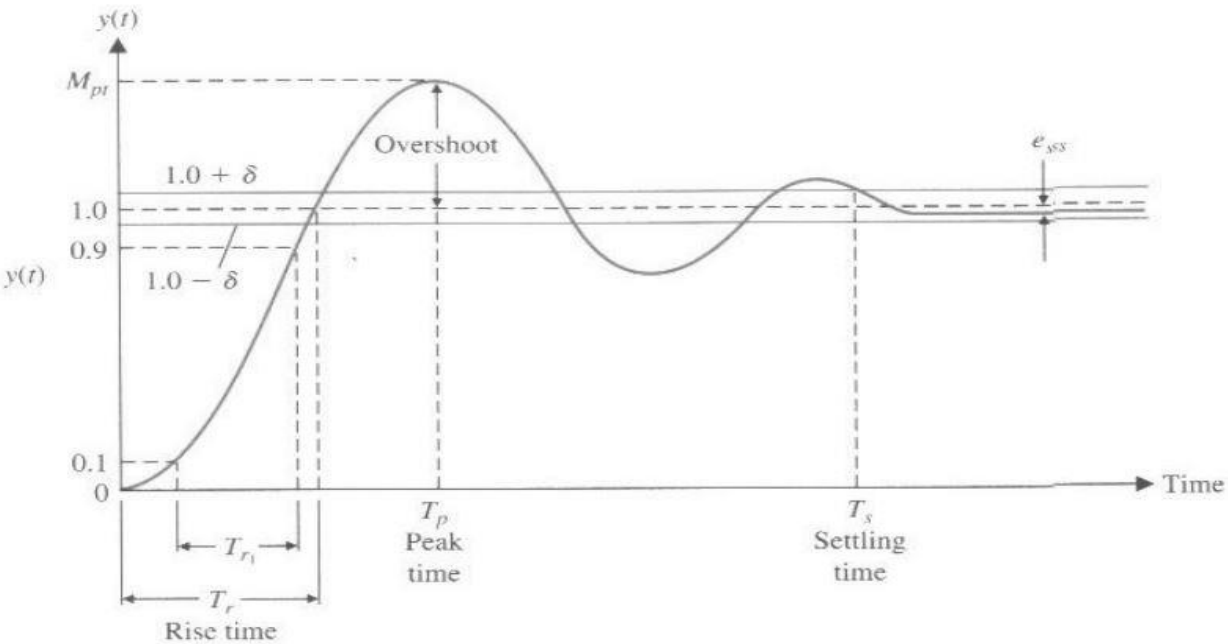
What is the system that have the highest over shoot from this system
1-overdamped / 2-underdamped / 3-critically damped
Answer:
Underdamped/because the overshoot depend on oscillations and the only one has oscillations is under damped system
Note: overdamped and critically damped system don't have over shoot value because they don't have oscillations.

- **Settling time :** $T_s = \frac{4}{\zeta w_n} \rightarrow 2\%$ $T_s = \frac{3}{\zeta w_n} \rightarrow 5\%$

$T_s = y_{ss} + 0.02$ ونقوم بعمل إسقاط على محور السينات

- **Rise time :** $y_{ss} \times 90\% - y_{ss} \times 10\%$ ونقوم بعمل إسقاط على محور السينات

$$T_r = \frac{2.16\zeta + 0.64}{w_n}$$



- **Stability:**

➢ **Stable:** all poles on the left side of (S-plane).

➢ **Unstable:** one poles or more in the right side of (S-plane).

➢ **Marginally Stable:** there is pole in (IMG) axis.

If damping ratio increase then natural frequency decrease so rise time decrease and over shot decrease.

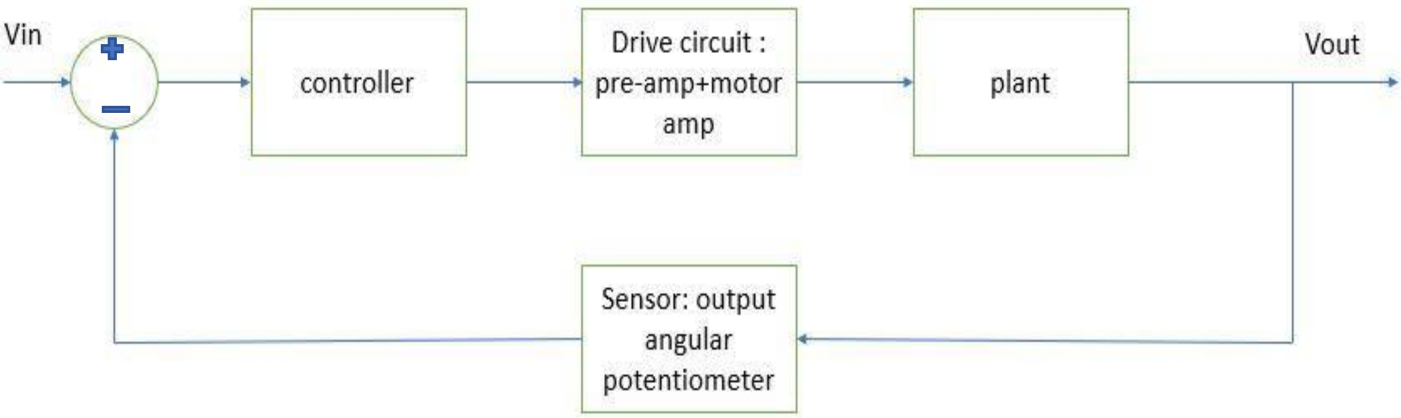
- ***Position Control System Component:***

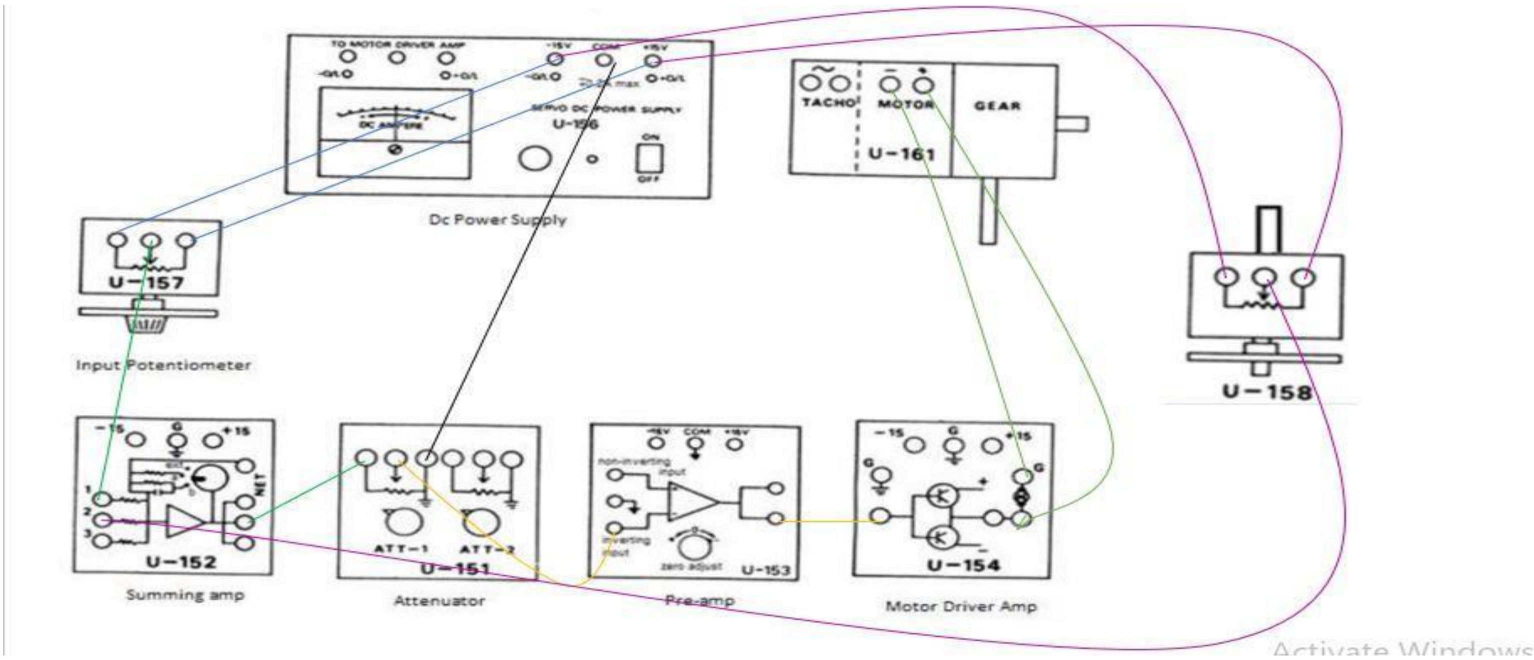
1. **Pre-Amplifier(u-153).**
2. **Summing Amplifier(u-152).**
3. **Attenuater(u-151).**
4. **Power Supply(u-156).**
5. **Dc Motor(u161).**
6. **Motor Drive Amplifier(u-154).**
7. **Input Angular Potentiometer(u-157) Or Function Generator(u-162).**
8. **Output Angular Potentiometer(u-158).**

- **Question:** ***What is the diffirence between speed and position system in component?***

Speed: Use Tacho (u-161) , Tacho Meter (u-159) and Tacho amplifier (u-155)

Position: Use Input Angular Potentiometer (u157) , Output Angular Potentiometer(u-158) and Pre-Amplifier(u-153).

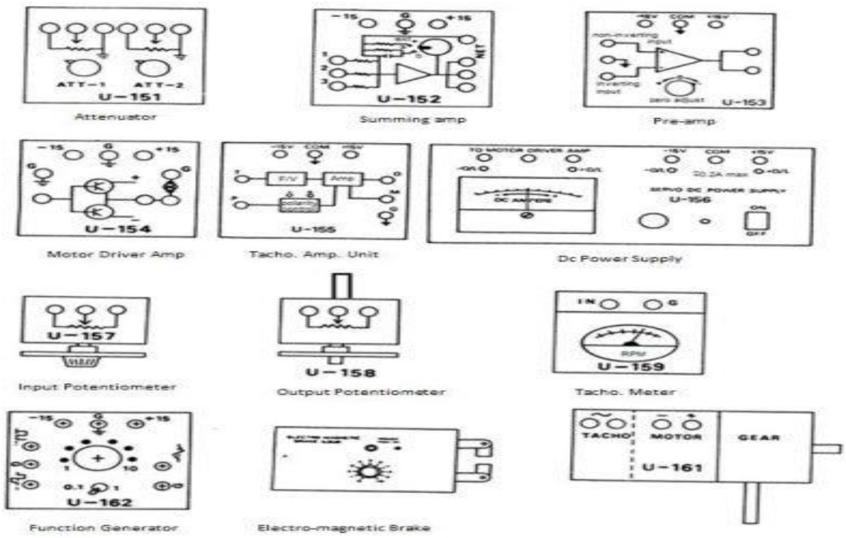




Please 🙈 don't forget connect power wire،

Motor drive will take high power from left side of power supply component , each of other component will take low power from right side of power supply component .

"لا تنسى انه في فيديو توصيل, عشان تفهم اكثر روح احضره"



- ***Question:***

1) **Which unit used as a position sensor?**

Output Angular Potentiometer(u-158).

2) **Which units are used as drive circuit?**

1] Motor Drive(u-154)
2] Pre-Amplifier(u-153).

3) **Which units are not used in position system?**

1]Tacho Meter (u-159)

2]Tacho Amplifier (u-155)

3]Tacho part (u-161).

4) **Which unit is controller?**

Attenuater(u151).

5) **Which unit require high power supply?why?**

Motor Drive (u-154)\to provide enough power to motor to work.

6) **From where we can get the ground part of the motor(u-161)?**

From ground of Motor Drive (u-154) **Or** *ground of high power part from left side of power supply .*

Example (1) : $T(s) = \frac{16}{S^2+8S+16}$

عند الحل ساوي بسط السؤال ببسط القانون وكل جزء بمقام السؤال بمقام القانون :

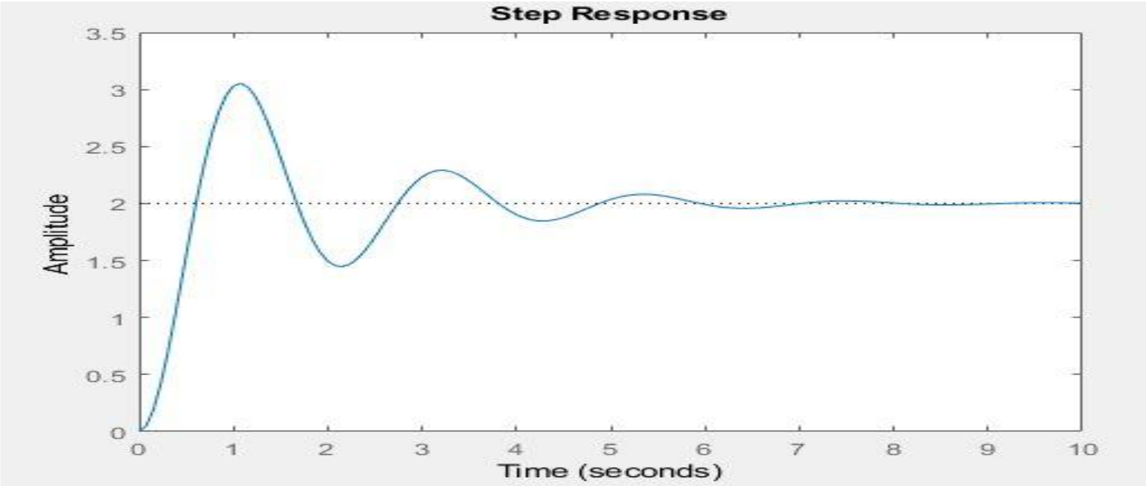
$\frac{Kw_n{}^2}{S^2+2\zeta w_n S+w_n{}^2}$

1. **Dc gain?** 1
2. **Nutural frequency?** Wn=4
3. **Damping ratio?** $2\zeta w_n S = 8S$

   $8\zeta = 8 \qquad \zeta = 1$
4. **Damping frequency?** $w_d = w_n\sqrt{1-\zeta^2} = 0$
5. **Poles?** $S = -w_n = -4$
6. **Response y(t)?** $Y(t)=1-e^{-w_n t}(1+w_n t)$

   $Y(t)=1-e^{-4t}(1+4t)$
7. **Settling time?** $T_s = \frac{4}{\zeta w_n} = \frac{4}{4} = 1$

Example (2) :



1) Dc gain ? K=2

2) Peak time? $T_p \approx 1.08$ نقوم بالذهاب لأعلى قمة ونقوم بعمل إسقاط على محور السينات

3) Over shot ? $O.V = \frac{Y(T_p)-Yss}{Yss} \times 100\%$

$O.V = \frac{3-2}{2} \times 100\% = 50$

4) Settling time ? $T_s = \frac{4}{\zeta w_n} \rightarrow 2\%$ $T_s = Yss + 0.02$ ثم نقوم بعمل إسقاط

$T_s = 6.5$

5)Rise time ? $y_{ss} \times 90\% - y_{ss} \times 10\%$ ونقوم بعمل إسقاط على محور السينات $T_r = 0.4$

6)Damping ratio ? $O.V = 100\, e^{-\pi\zeta\sqrt{1-\zeta^2}} \rightarrow 50 = 100\, e^{-\pi\zeta\sqrt{1-\zeta^2}}$

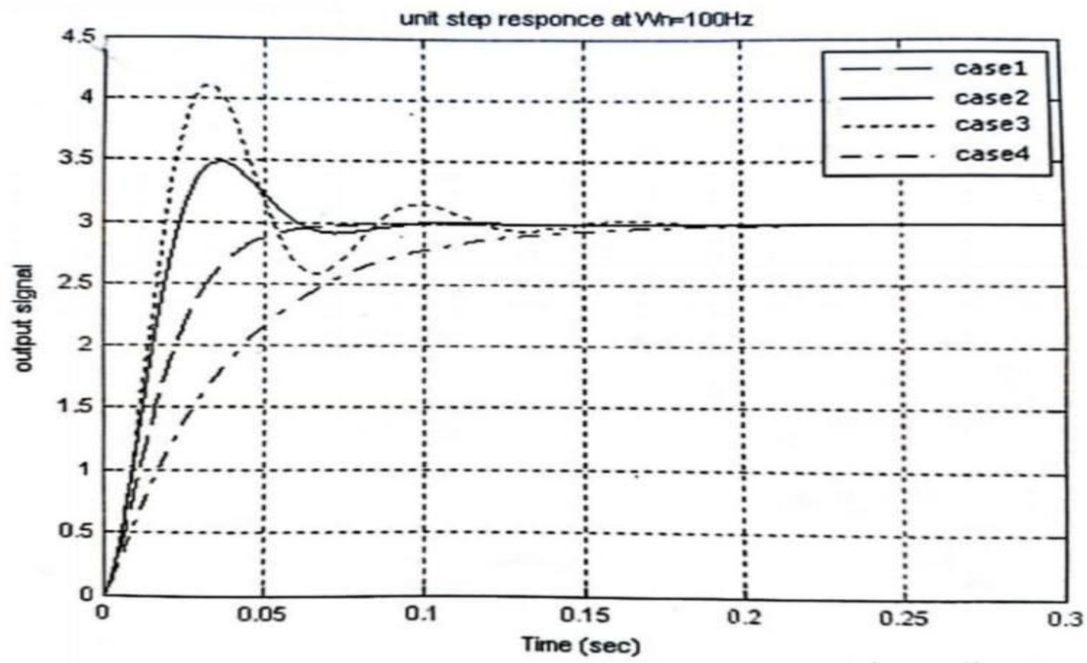
$ln\,(0.5) = -\pi\zeta\sqrt{1-\zeta^2} \rightarrow \zeta = 0.2$

7) Nutural frequency?

$$T_p = \frac{\pi}{w_n\sqrt{1-\zeta^2}}$$

$$w_n = \frac{\pi}{T_p\sqrt{1-\zeta^2}} \rightarrow w_n = 3$$

Example (3) :



1) What is the dc gain of case 2? $K=\frac{Y_{ss}}{R_{ss}}=3$

2) Which case\s considered as Underdamped system?

Case 3 / Case 2

3)Which case has highest damping ratio ?why?

Case 4 , because it is Overdamped system and damping ratio >1

4) Is case 4 considered as Criticallydamped system?

No, because case 1 is faster than case 4

Example (4) :

For the following 2^{nd} order systems,answer the following question ,assume the input is unit step.

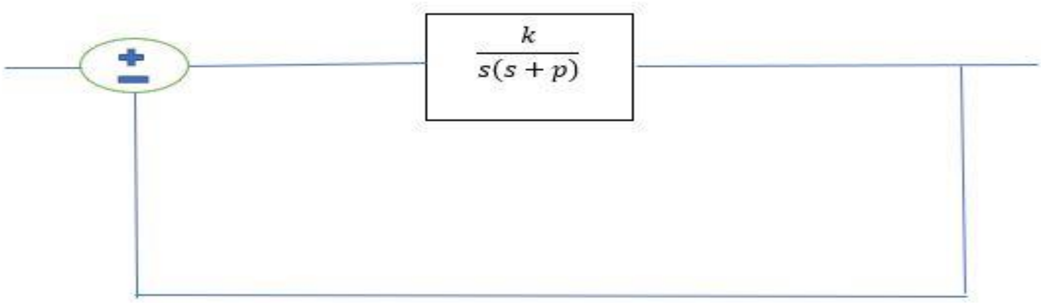
Transfer function	Nutural frequency	Damping ratio	Dc gain
$T_1(s) = \frac{1}{S^2+3S+2}$	$w_n{}^2 = 2$ $w_n = \sqrt{2}$	$2\zeta w_n S = 3S$ $\zeta = \frac{3}{2\sqrt{2}}$	$K = \frac{1}{2}$
$T_2(s) = \frac{1}{S^2+4S+4}$	$w_n{}^2 = 4$ $w_n = 2$	$2\zeta w_n S = 4S$ $\zeta = 1$	$Kw_n{}^2 = 1$ $K = \frac{1}{4}$

- **Complete the table .**
- **Which system is Criticallydamped system?why?**

  T_2 / $\zeta = 1$
- **Which system is un stable?why?**

  No one , because no poles in right side .

Example (5) : **Find (K , P) where $T_s < 4$ $\zeta = 0.4$**



$$T = \frac{\frac{K}{s(s+p)}}{1 + \frac{K}{s(s+p)}} = \frac{K}{S^2 + ps + K}$$

$$T_s = \frac{4}{\zeta w_n} = \frac{4}{0.4\, w_n} = 4$$

$$w_n = \frac{1}{0.4} = 2.5$$

$$K = {w_n}^2 = 6.25$$

$$p = 2\zeta w_n = 2 \times 0.4 \times 2.5 = 2$$

Example (6) :

System 1	System 2	System 3	System 4
$T_1(s) = \frac{1}{s^2+3s+2}$	$T_2(s) = \frac{1}{s^2+4s+4}$	$T_3(s) = \frac{1}{s^2-s-6}$	$T_4(s) = \frac{1}{-s^2-4s-3}$

A. What is the order of system 1?

Two

B. What is the the value of damping ratio of system 1?

$w_n = \sqrt{2}$

$2\zeta w_n = 3$

$\zeta = \frac{3}{2\sqrt{2}}$

C. Which system is unstable?

System 3

D. Which system is Criticallydamped system?

$2\zeta w_n = 4$
$w_n = 2$

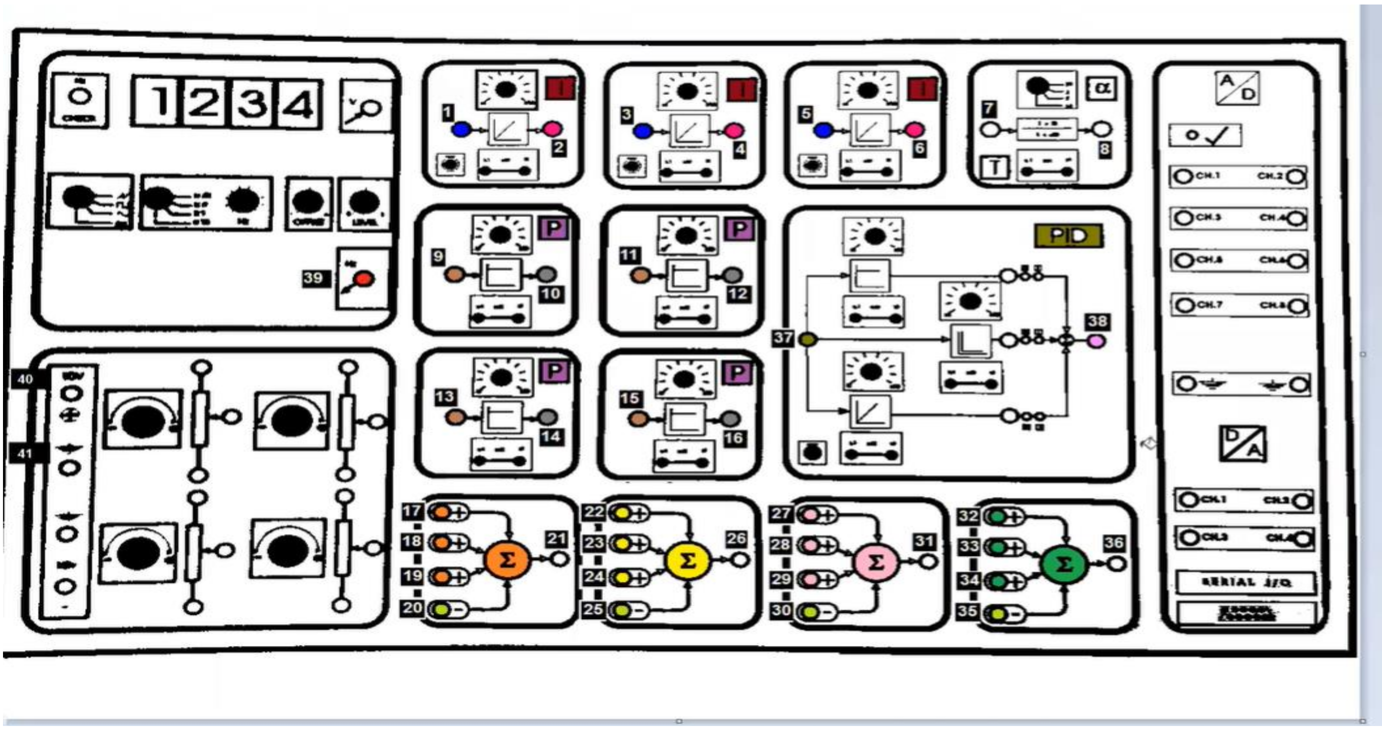
$\zeta = 1$

System 2

Design and Tuning of PID Controller

"يوجد فيديو شرح توصيلة لهذه التجربة" *Experiment (7)*

$$\text{PID} = \frac{S^2K_d + SK_p + K_i}{S}$$



F	Function generator
V	Dc power supply (±10V)
I	Integrator
P	Proportional
PID	Proportional , integral, derivative Controller
S	Summing point
A	Attenuator (Potentiometer)

Term	Math Function	Effect on Control System
P Proportional	KP x Verror	Typically the main drive in a control loop, KP reduces a large part of the overall error.
I Integral	KI x ∫ Verror dt	Reduces the final error in a system. Summing even a small error over time produces a drive signal large enough to move the system toward a smaller error.
D Derivative	KD x dVerror / dt	Counteracts the KP and KI terms when the output changes quickly. This helps reduce overshoot and ringing. It has no effect on final error.

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

K_p , K_i , K_d : **depends on each other**

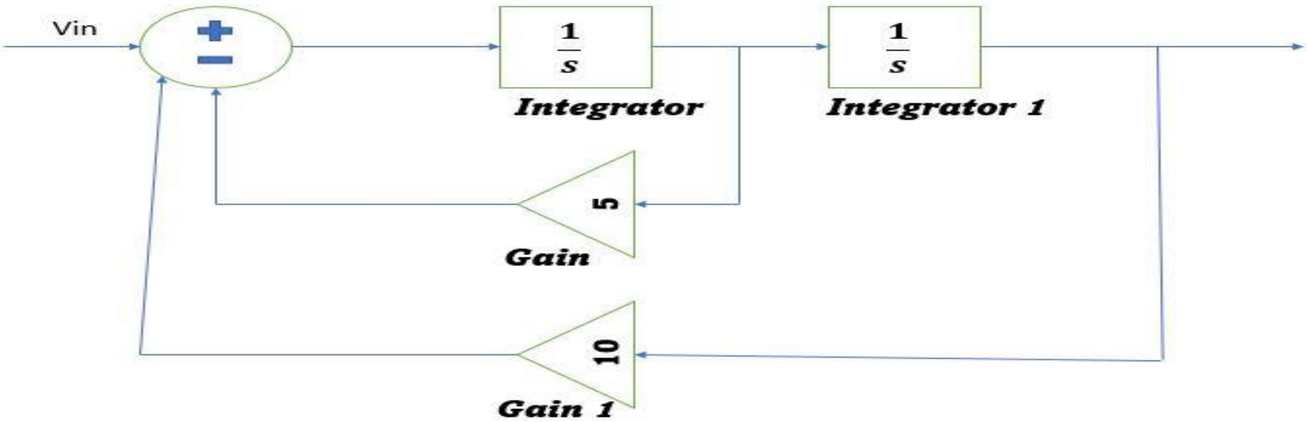
Example (1) :

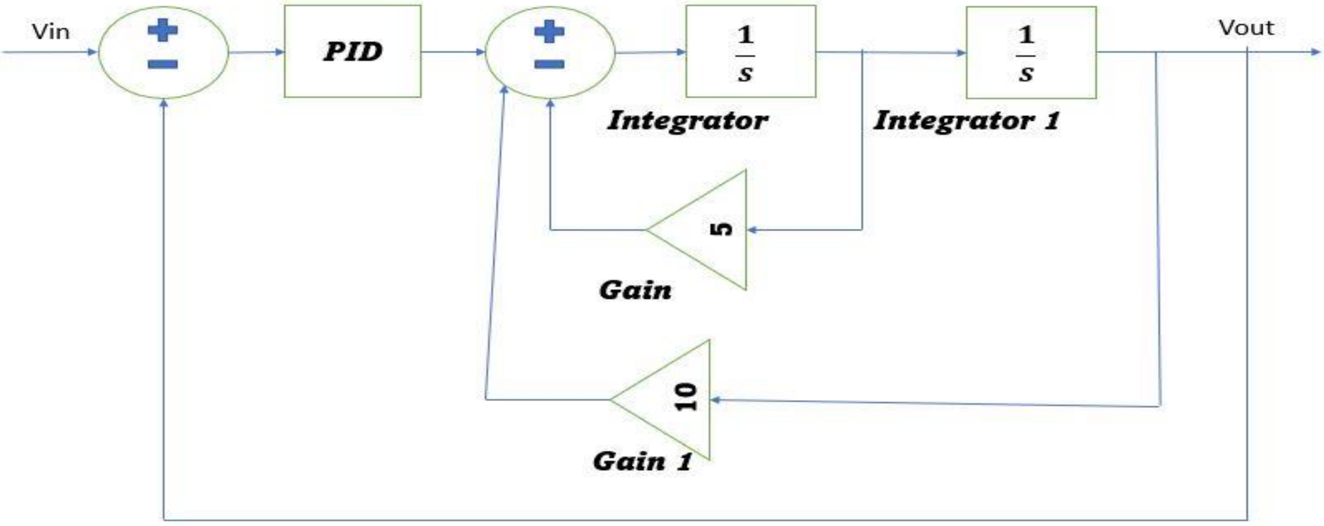
connect the open loop transfer function T(s) , then use the PID controller to control the performance of that system ?

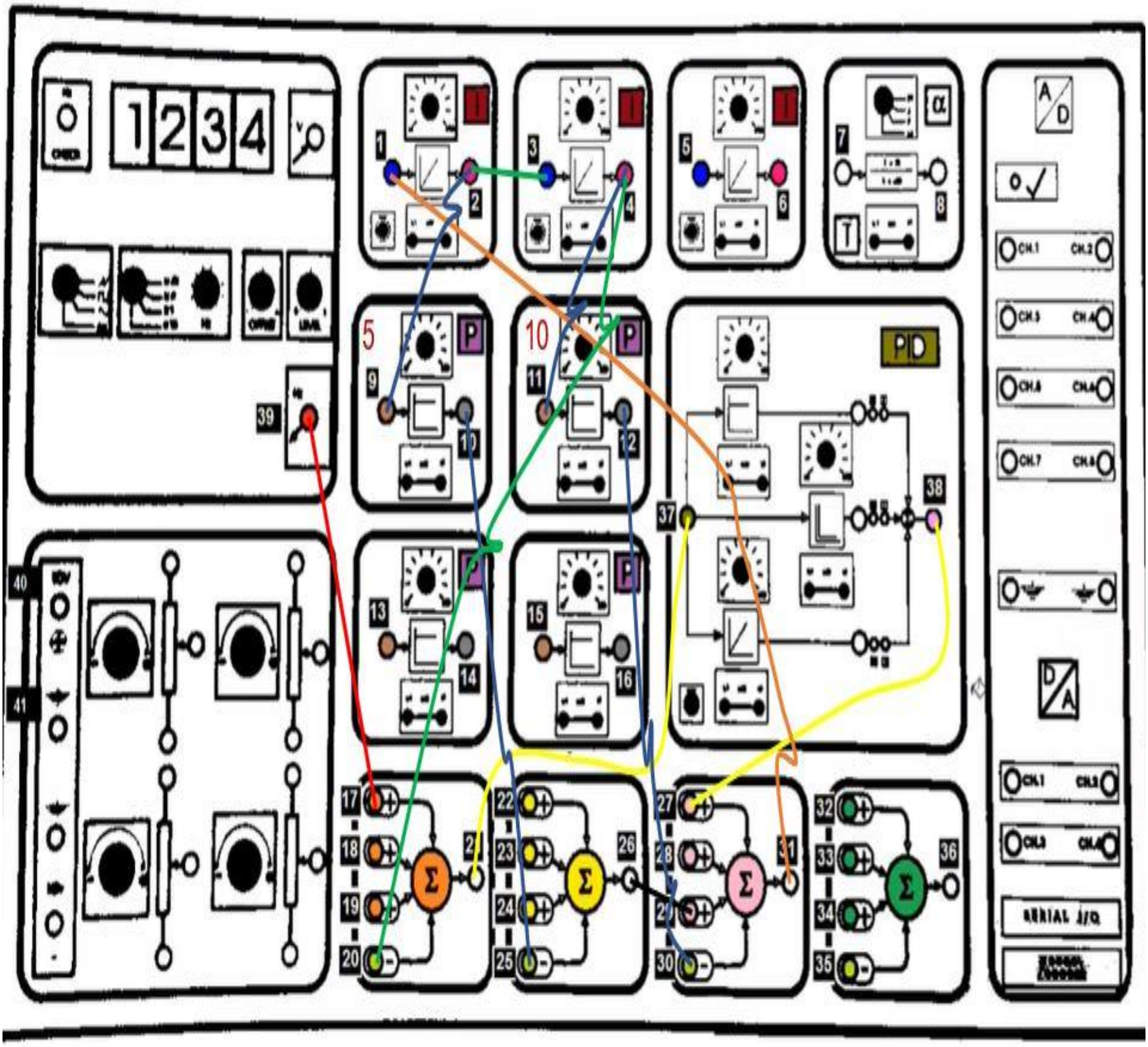
$$\mathbf{T(s)} = \frac{1}{S^2+5S+10} = \frac{V_o}{V_i}$$

$$V_i = V_o S^2 + V_o 5S + V_o 10$$

$$V_o{''} = V_i - 5V_o{'} - 10$$






1234
PID
A/D
D/A
SERIAL I/O

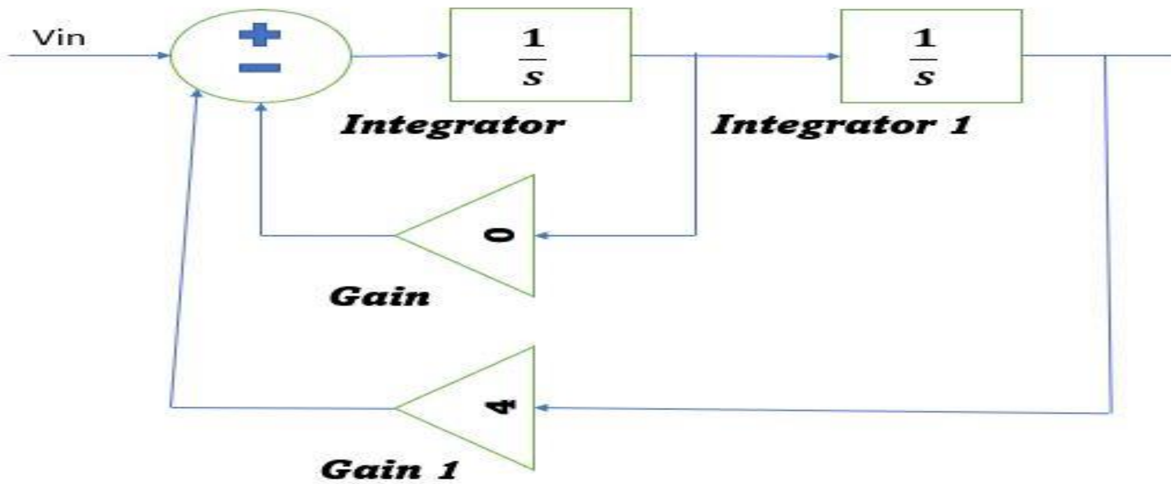
Example (2) :

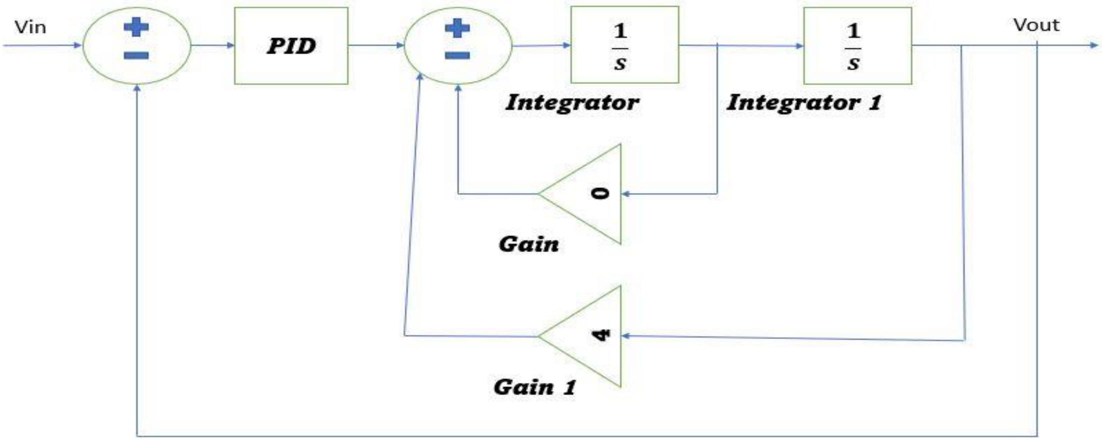
connect the open loop transfer function T(s) , then use the PID controller to control the performance of that system ?

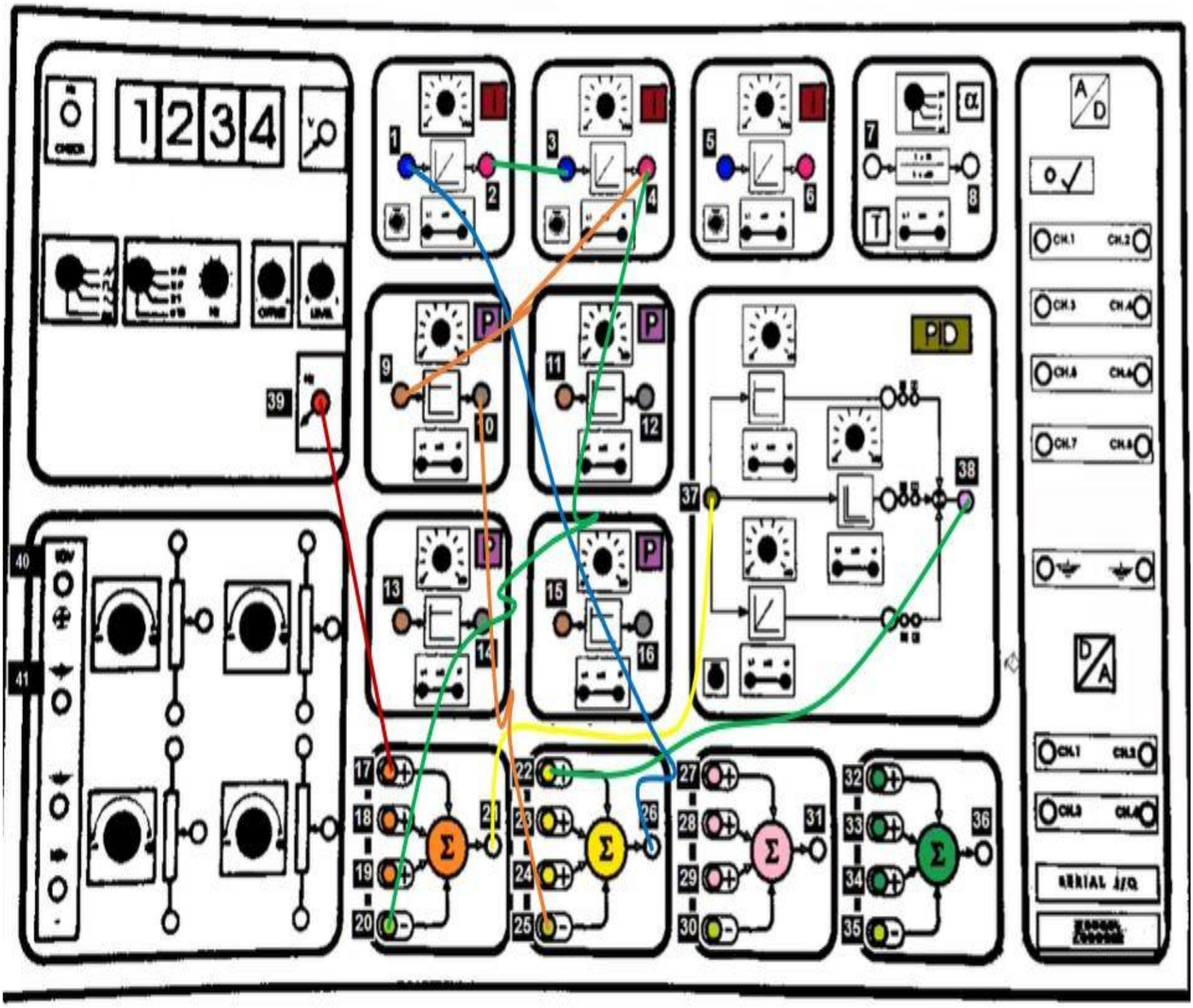
$$\mathbf{T(s)} = \frac{1}{S^2+4} = \frac{V_o}{V_i}$$

$$V_i = V_o S^2 + V_o 4$$

$$V_o'' = V_i - 4V_o$$



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35
36
37
38
39
40
41
PID
A/D
D/A
CH.1
CH.2
CH.3
CH.4
CH.5
CH.6
CH.7
CH.8
OFFSET
LEVEL
CHECK
1234

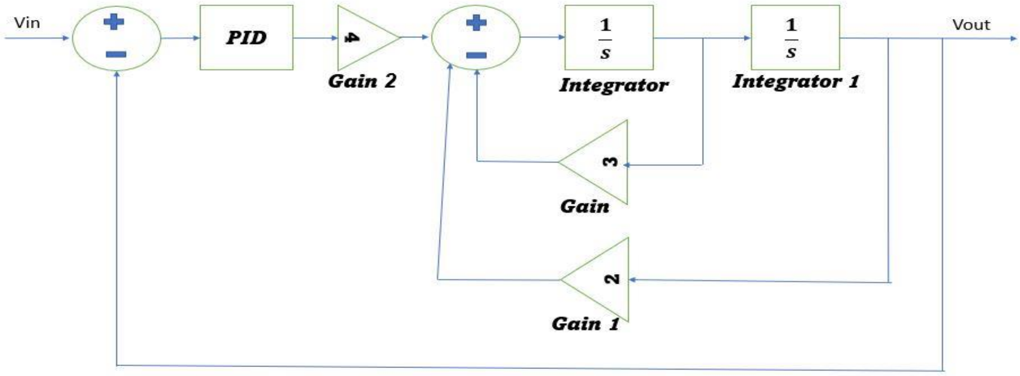
Example (3) :

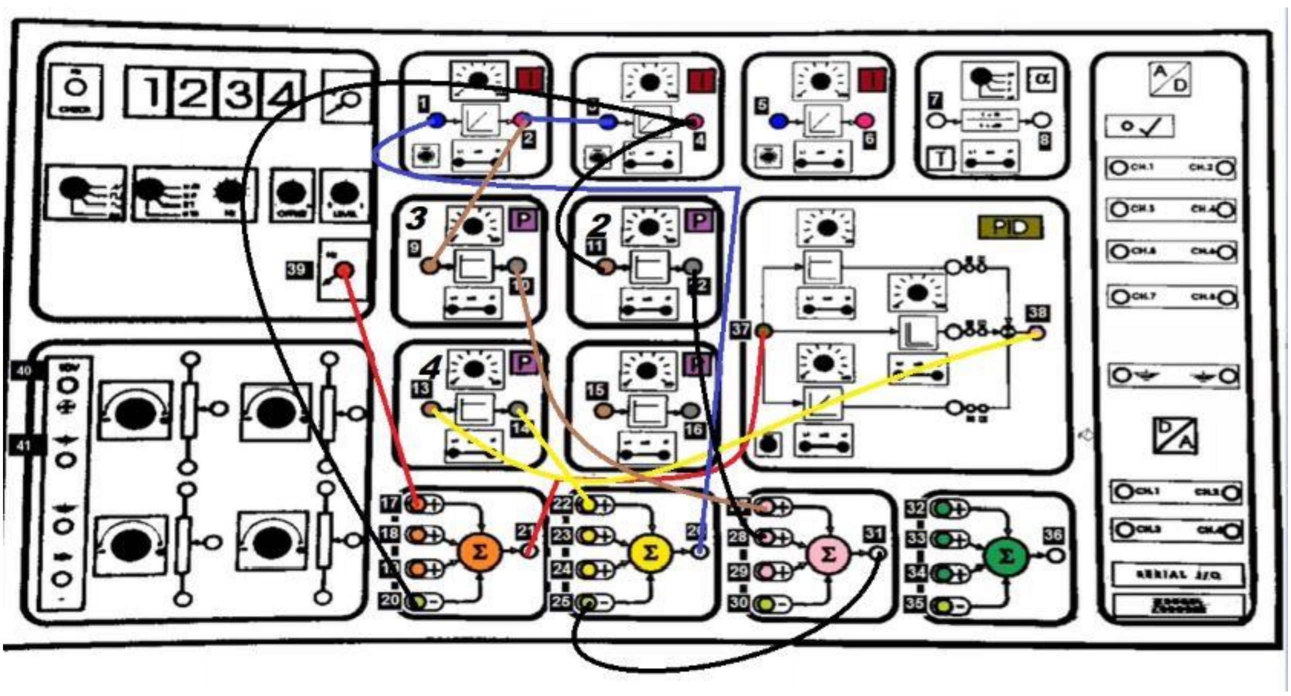
connect the open loop transfer function T(s) , then use the PID controller to control the performance of that system ?

$$\mathbf{T(s)} = \frac{4}{S^2+3S+2} = \frac{V_o}{V_i}$$

$$4V_i = V_oS^2 + V_o3S + V_o2$$

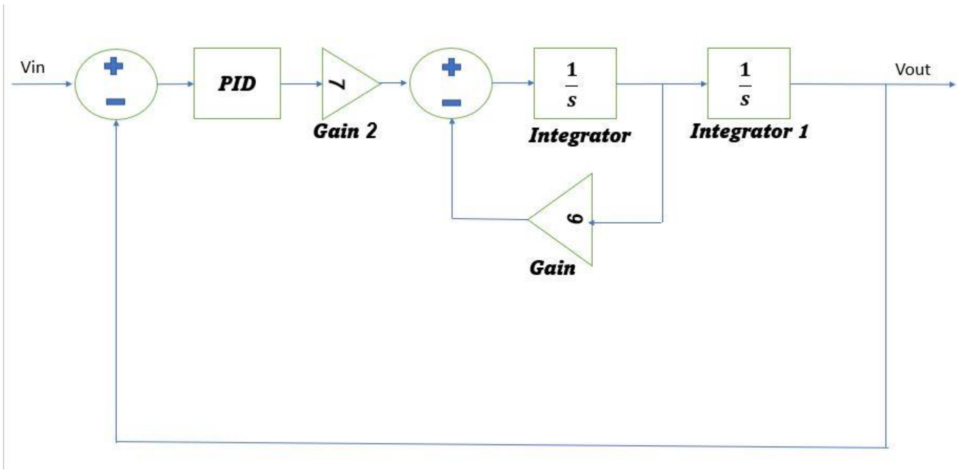
$$V_o'' = 4V_i - 3V_o' - 2V_o$$





Example (4) :

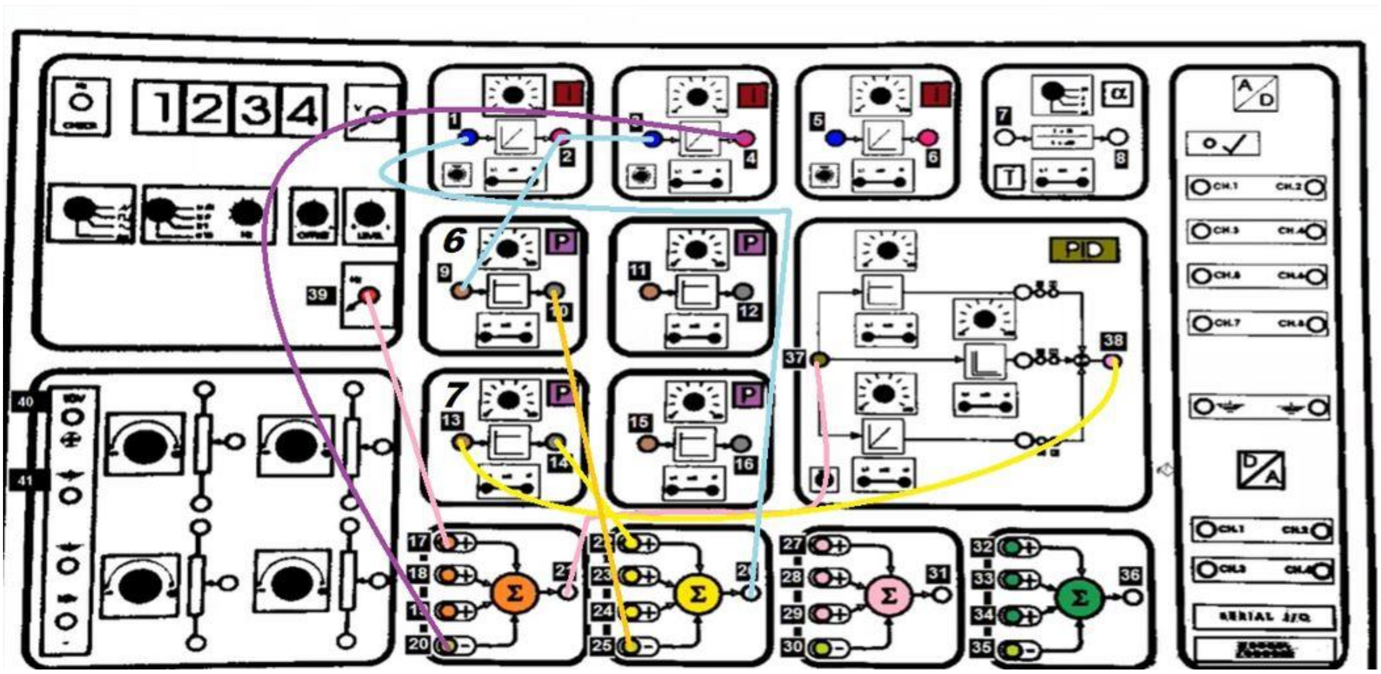
If you now that the following PID block digram answer the question :



1) What is yhe T(s) ?

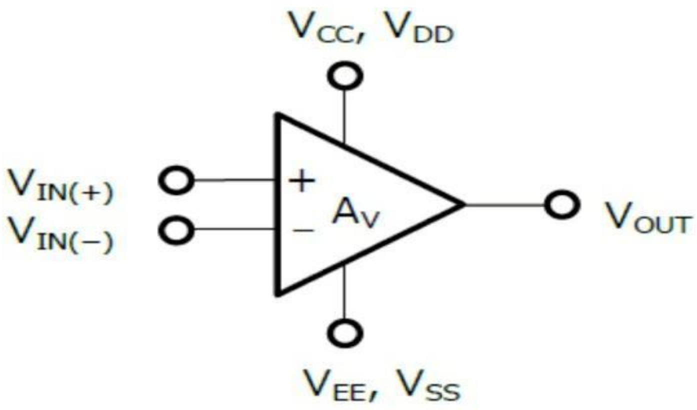
$$T(s) = \frac{7}{S^2 + 6S}$$

2) build the PID block digram on PID kit .



Experiment (8)

Operational Amplifier



V_{CC}, V_{DD}: Positive power supply
V_{EE}, V_{SS}: Negative power supply
$V_{IN(+)}$: Noninverting input
$V_{IN(-)}$: Inverting input
V_{OUT}: Output

*** Ideal operational amplifier has the following specifications:**

1. Infinite input resistance.

2. Zero output resistance.

3. Infinite common mode rejection ratio (CMRR).

4. Zero input current and input voltage offsets.

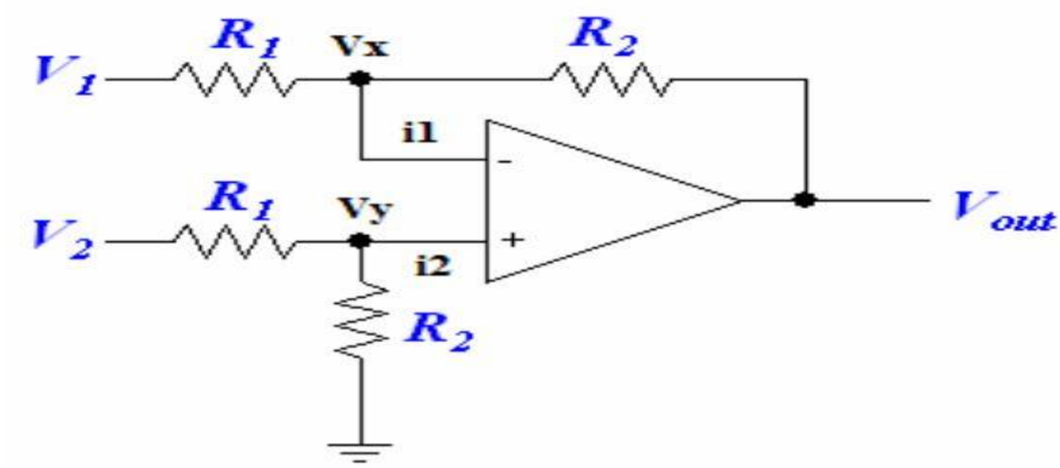
*** To derive the input/output relation of an op-amp applies the following three rules:**

1. Zero input current (i1= i2=0)

2. Virtual short between the inverting and non-inverting terminals.(Vx=Vy)

3. KCL at each node.

Example :



KCL at node X :

$$\frac{V_x - V_1}{R_1} + \frac{V_x - V_o}{R_2} = 0$$

$$V_x = \frac{R_2 V_1 + R_1 V_o}{R_1 + R_2}$$

KCL at node Y :

$$\frac{V_y - V_2}{R_1} + \frac{V_y}{R_2} = 0$$

$$V_y = \frac{R_2}{R_1 + R_2} \times V_2$$

$$\boldsymbol{V_x = V_y}$$

$$\frac{R_2 V_1 + R_1 V_o}{R_1 + R_2} = \frac{R_2}{R_1 + R_2} \times V_2$$

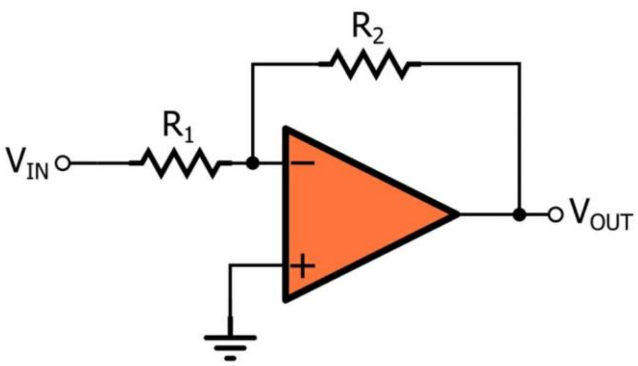
$$\boldsymbol{V_o = (V_2 - V_1)\frac{R_2}{R_1}}$$

- **Applications of the op-Amp:**

Note : $\frac{V_o}{V_{in}} = \frac{-Z_{out}}{Z_{in}}$

Note : $Z_c = \frac{1}{cs}$ / $Z_R = R$

1) Inverting amplifier :

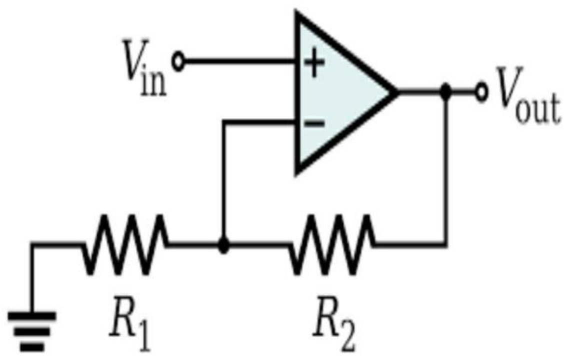


$$T.F = \frac{V_o}{V_{in}} = \frac{-Z_{out}}{Z_{in}}$$

$$T.F = -\frac{R_2}{R_1}$$

$$K_p = -\frac{R_2}{R_1}$$

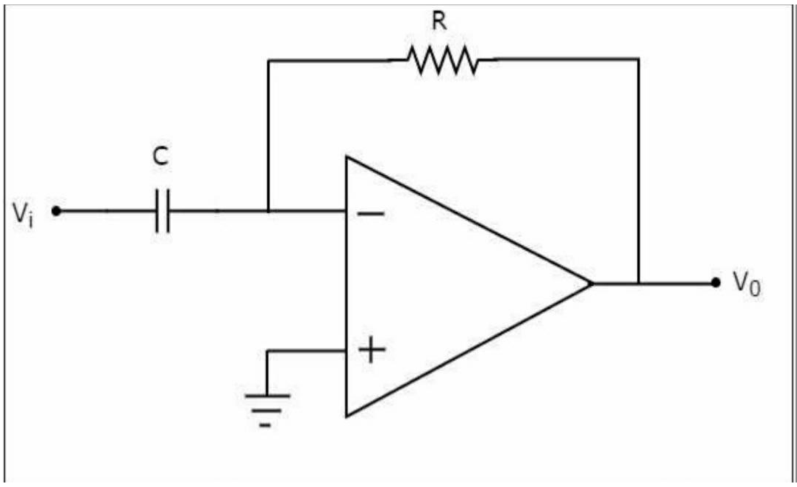
2) Non inverting amplifier :



$$T.F = \frac{V_o}{V_{in}} = \frac{-Z_{out}}{Z_{in}}$$

$$T.F = 1 + \frac{R_2}{R_1}$$

3)Differentiator amplifier :

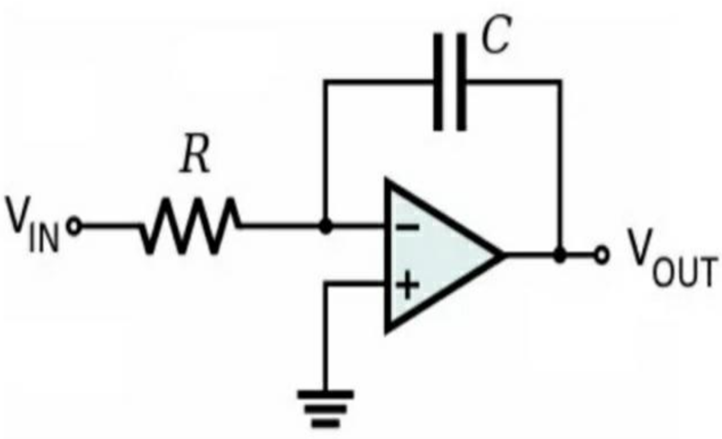


$$T.F = \frac{V_o}{V_{in}} = \frac{-Z_{out}}{Z_{in}}$$

$$T.F = \frac{-R}{\frac{1}{cs}} = -RCS$$

$$K_d = -RC$$

4) Integration amplifier :

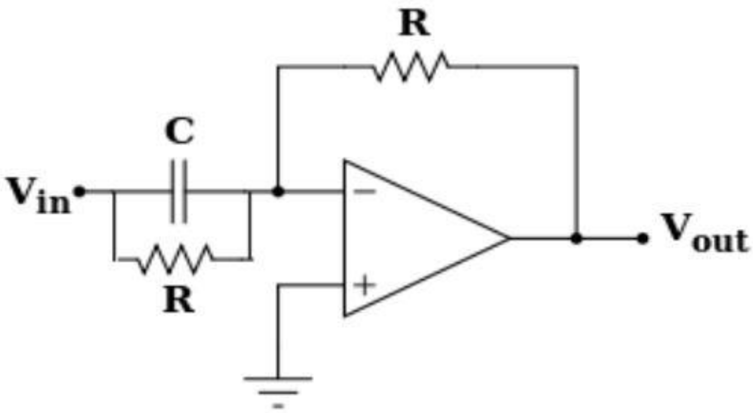


$$T.F = \frac{V_o}{V_{in}} = \frac{-Z_{out}}{Z_{in}}$$

$$T.F = \frac{\frac{-1}{cs}}{R} = \frac{-1}{RCS}$$

$$K_I = \frac{-1}{RC}$$

Example : **Find the T.F , K_d , K_I , K_p :**



$$T.F = \frac{V_o}{V_{in}} = \frac{-Z_{out}}{Z_{in}}$$

$$T.F = \frac{-R_1}{(R_2//Z_c)}$$

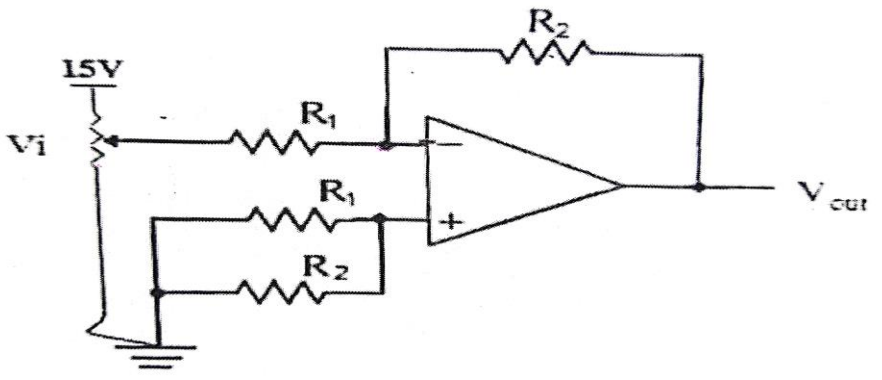
$$R_2//Z_c = \frac{R_2 \times Z_c}{R_2 + Z_c} = \frac{R_2 \times \frac{1}{cs}}{R_2 + \frac{1}{cs}}$$

$$R_2//Z_c = \frac{R_2}{R_2CS + 1}$$

$$T.F = \frac{-R_1}{(\frac{R_2}{R_2CS+1})} = \frac{-R_1R_2CS - R_1}{R_2}$$

$$K_I = 0 \quad ,, K_d = -R_1C \quad ,, K_p = \frac{-R_1}{R_2}$$

Example : **For the op-amp circuit below .**



1) Find the T.F of the system :

KCL at node X :

$$\frac{V_x - 15}{R_1} + \frac{V_x - V_o}{R_2} = 0$$

$$V_x = \frac{R_2 15 + R_1 V_o}{R_1 + R_2}$$

KCL at node Y :

$$\frac{V_y}{R_1} + \frac{V_y}{R_2} = 0$$

$$V_y = 0$$

$$\boldsymbol{V_x = V_y}$$

$$R_2 15 + R_1 V_o = 0$$

$$\boldsymbol{V_o = \frac{-15R_2}{R_1}}$$

2)What is the value of each control gain (K_I , K_d , K_p) .

$\boldsymbol{K_I = 0}$,, $\boldsymbol{K_d = 0}$,, $\boldsymbol{K_p = \frac{-15R_1}{R_2}}$

MATLAB Tutorial

Experiment (4)

"يوجد فيديو شرح ماتلاب لهذه التجربة"

1- To enter a polynomial to matlab, use matrices:

a=[1 2 3]

2- To convert the polynomial into a string (just to view it but you CAN'T substitute in it):

b=poly2str(a,'t')

3- To substitute in the polynomial a and find a value:

polyval(a,3)

4- To find the roots of the polynomial a:

roots(a)

5- To find the polynomials from the roots:

poly(a)

6- To multiply 2 polynomials a and b (find convolution), use:

c=conv(a,b)

7- If you have a numerater (a) and a denomenator (b), you can find the transfer function T=a\b using:

T=tf(a,b) or: T=tf([num parameters], [denum parameters])

8- if you have a transfer function and you want to have it in the form T1=Gain*zeroes\poles, you can use:

T1=zpk(the name of the original tf)

9- if you have the transfer function's zeroes, poles and gain, and you want to convert it into a transfer function, use:
T2=zpk([zeroes],[poles],gain).
ex.: zpk([-1],[-i,i],2)

10- to find the transfer function equivalent to 2 transfer functions T1 and T2 in series, use:
G=series(T1,T2)
this gives the same result as:
G=T1*T2

11- to find the transfer function equivalent to 2 transfer functions T1 and T2 in parallel, use:
G=parallel(T1,T2) ،if it is +,

or:

G=parallel(T1,-T2) ،if it is -

12- to find the transfer function equivalent to a feedback system:
G=feedback(T1,T2) (by default a – feedback)

or:

G=feedback(T1,T2,-1) for -

and:

G=feedback(T1,T2,+1) for +

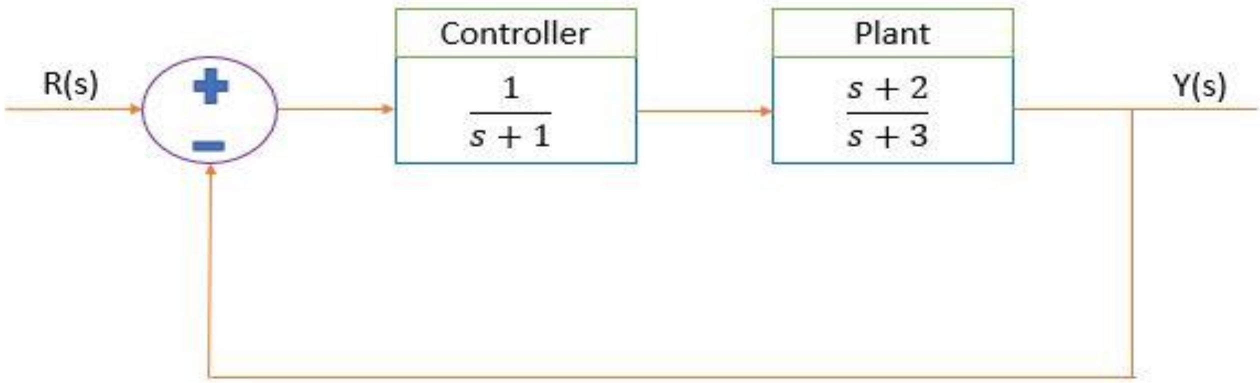
13- to find the poles of the TF "G":
pole(G)
14- to find the zeroes of the TF "G":
zero(G)
15- to draw (map) the poles and zeroes of system (Tf "G") in the S plane:
pzmap(G)

16- to find the response of a TF "G" to a unity step input:
step(G)

17- to find the value of a TF "G" at steady-state "dc-gain", where "dc-gain" is defined as the value of the TF when s→0:
dcgain(G)
18- to find information about a step response:
stepinfo(G)
19- to find a transfer function "G" in its most simple form:
minreal(G)
20- to find the natural frequency and the damping ratio for "G":
damp(G)

21- to find laplace transform:
symst;
enter the time domain function like:
r=5*t;
laplace(r)

Example(1) :Consider the feedback system shown in figure below then answer the following :



1. ***Transfer function of controller?*** *A=tf(1,[1 1])*

2. ***Transfer function of plant?*** *B=tf([1 2],[1 3])*

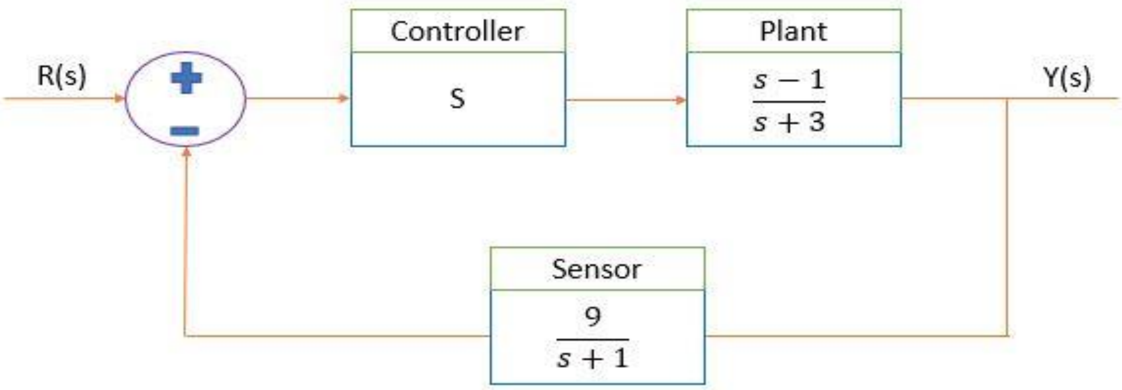
3. ***Transfer function of cascade?*** *C=series(A,B)*

4. ***Over all Transfer function?*** *F=feedback(C,1)*

5. ***Steady state value or Find final value of the output if the input is unit step?*** *D=dcgain(F)*

6. ***Find the steady state error ?*** *E=1-D*

Example(2) :Consider the feedback system shown in figure below then answer the following :



A. ***Transfer function of controller?*** *A=tf([1 0],1)*

B. ***Transfer function of plant?*** *B=tf([1 -1],[1 3])*

C. ***Transfer function of cascade?*** *C=series(A,B)*

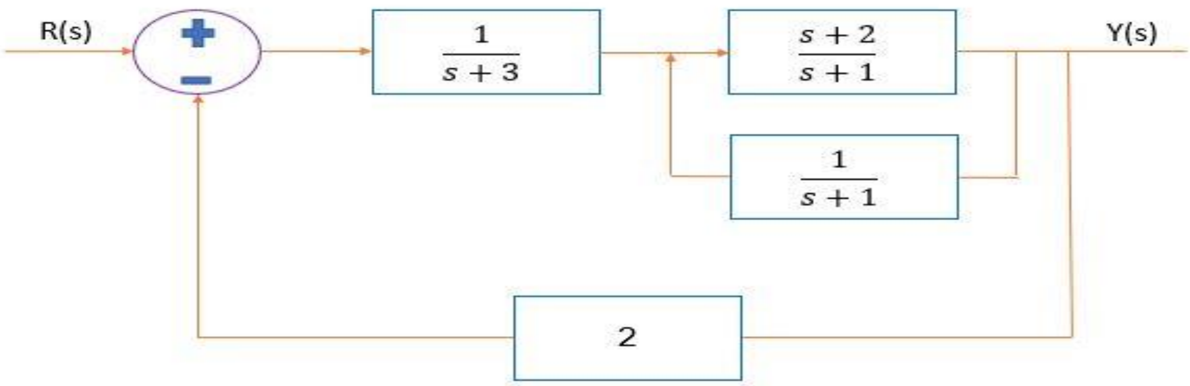
D. ***Transfer function of sensor?*** *K=tf(9,[1 1])*

E. ***Over all Transfer function?*** *F=feedback(C,K)*

F. ***Steady state value or Find final value of the output if the input is unit step?*** *D=dcgain(F)*

G. ***Find the steady state error ?*** *E=1-D*

Example(3) :Consider the feedback system shown in figure below then answer the following :



1)Write matlab code for system?

```
R1=tf(1,[1  3])
R2=tf([1 2],[1 1])
 R3=tf(1,[1 1])
 R4=parallel(R2,R3)
 R5=series(R1,R4)
 R6=feedback(R5,2)
```

2) Find the poles of the system? P=pole(R6)

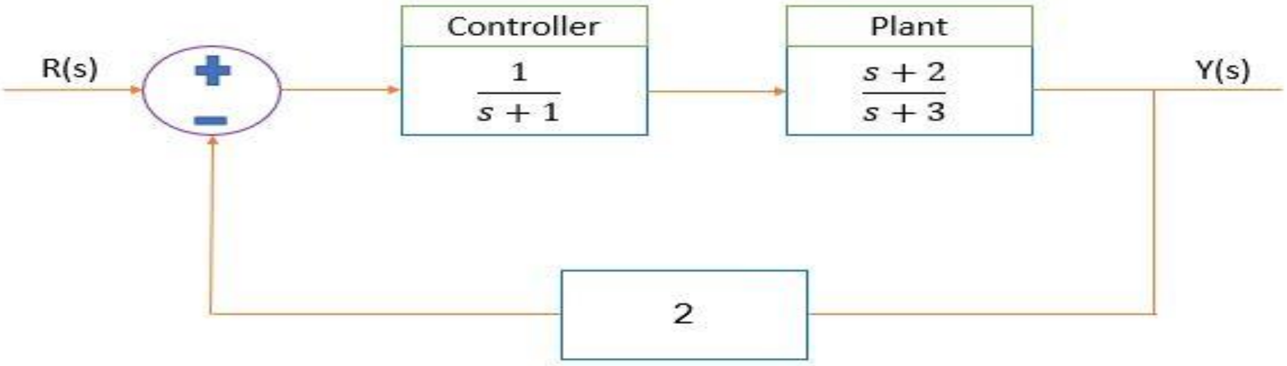
3) There is any pole-zero cancelation? Yes,M=mineral(R6)

4) What is dcgain of the system? D=dcgain(R6)

5) Find the steady state error if the input =5 ? E=5-5*d

6) What is the percentage over shoot value ? W=stepinfo(R6)

Example(4) :Consider the feedback system shown in figure below then answer the following :



1) Write matlab code for system?

```
R1=tf(1,[1  1])
R2=tf([1 2],[1 3])
 R3=series(R1,R2)
 R4=feedback(R3,2)
```

2) Find the poles of the system? P=pole(R4)

3) There is any pole-zero cancelation? M=mineral(R4)

4) What is dcgain of the system? D=dcgain(R4)

5) Find the steady state error if the input =8? E=8-8*d

6) What is the percentage over shoot value ? W=stepinfo(R4)

Root Locus Design

Experiment (6)

"يوجد فيديو شرح ماتلاب لهذه التجربة"

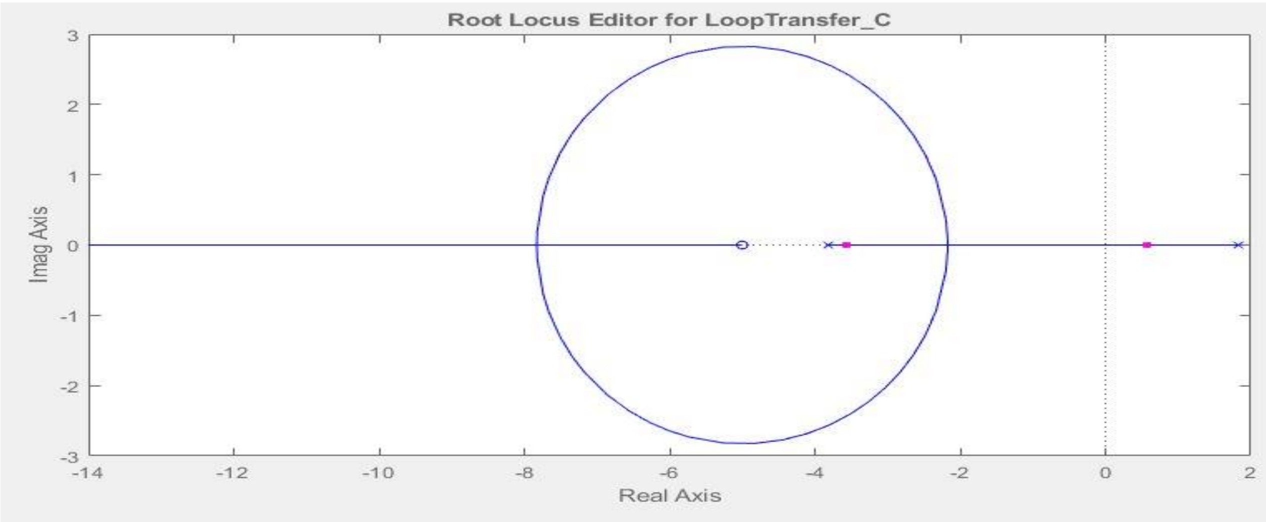
For following open loop transfer function :

$$T(s) = \frac{S + 5}{S^2 + 2S - 7}$$

Use matlab root locus tool to answer the following:

1) Plot the root locus for the system.

```
A=tf([1 5],[1 2 -7])
rltool(A)
```

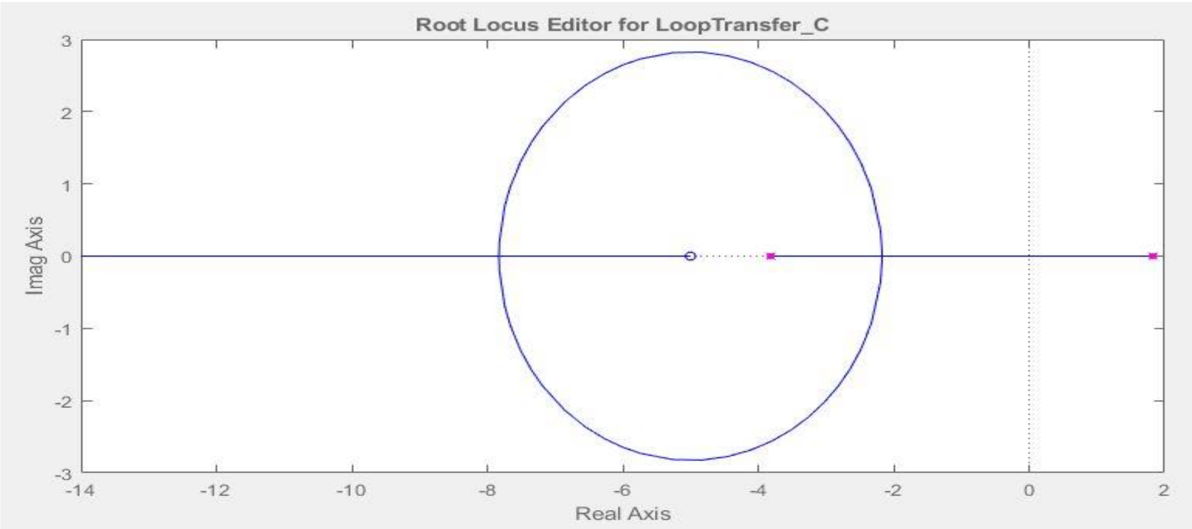


2)How many poles and zeros does the system have? 2poles, 1zero

3) Is the system stable? No,because there is one pole in right *side*

4) For k=0,what is the value of the system pole?what do these poles represent?

S=-3.83 \ S=1.83 , open loop poles (right click - edit compensator) دين بكبس عالمربع الزهري وبقرا قيمته)

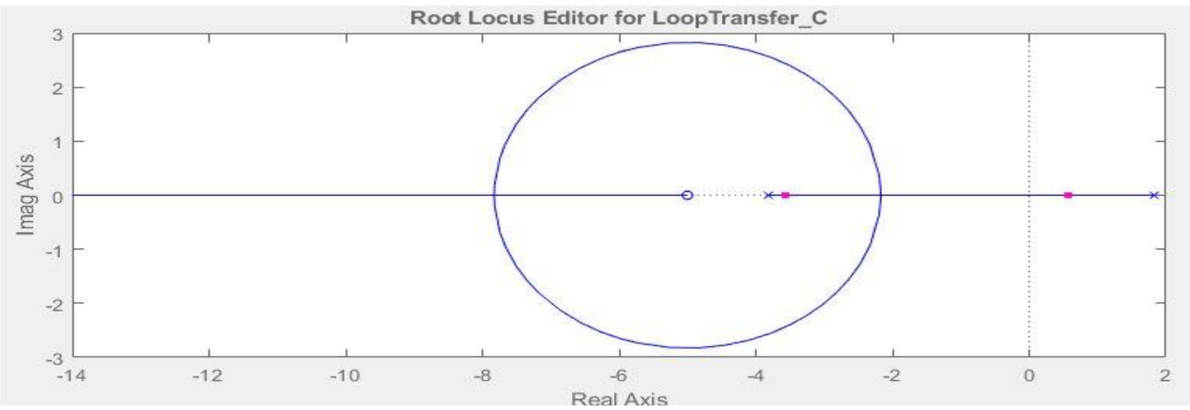


5) For k=1,what is the value of the system poles?

Is the system stable?

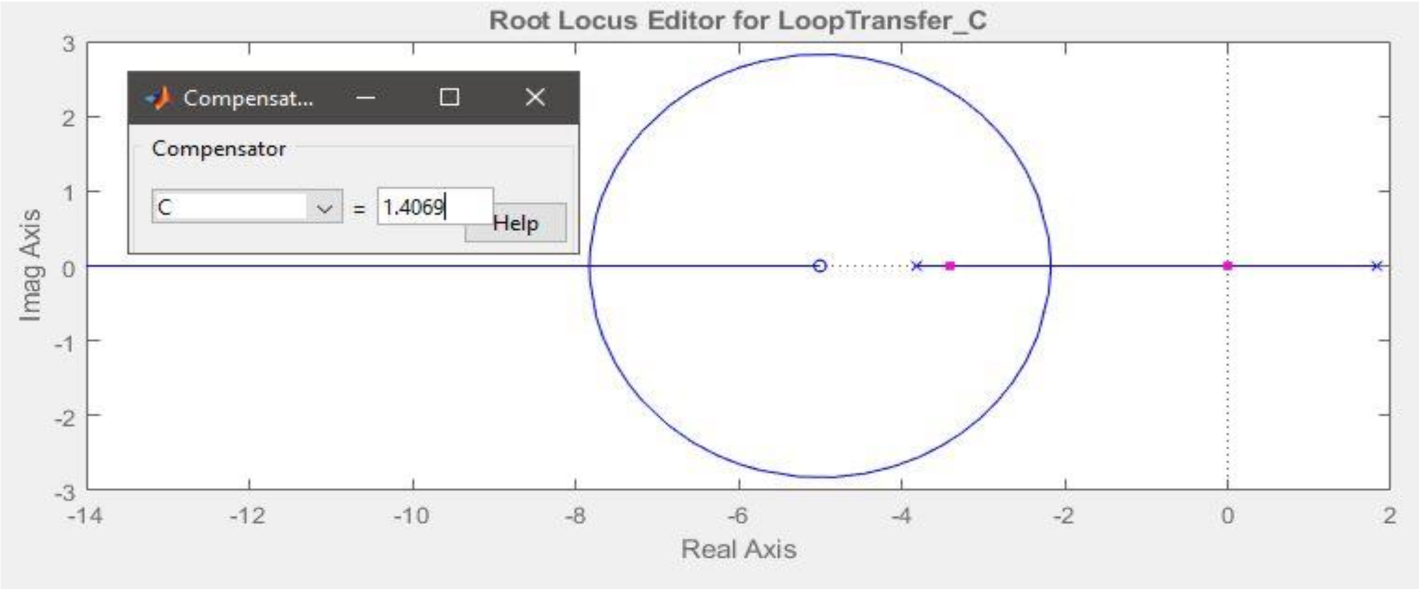
(right click - edit compensator) (بعدين بكبس عالمربع الزهري وبقرا قيمته)

S=-3.56 / S=0.562 , No



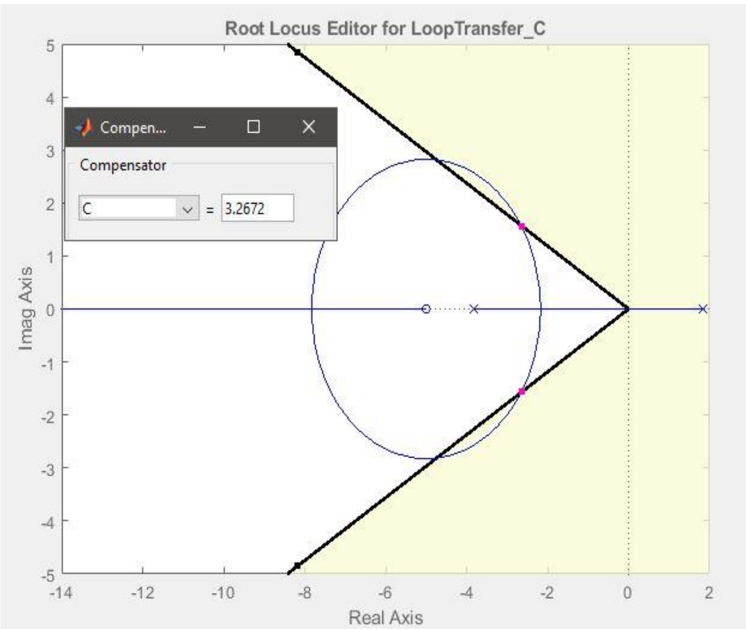
6) What is the range of k to give a stable response ?(1.39,∞)

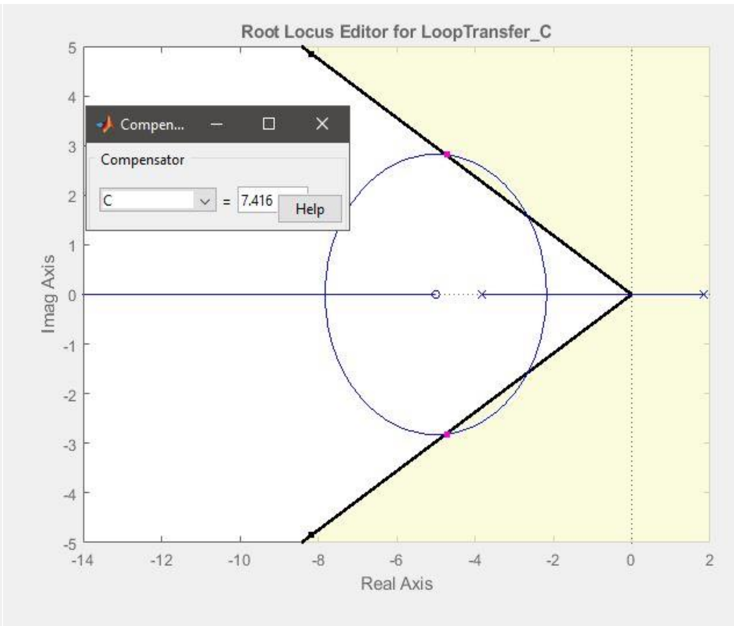
(بتمسك المربع الزهري يلي عاليمين وبتحركه لخط الستيبل وبتشوف كم قيمة k)



7) What is the range of k to give a stable response with $\zeta < 0.86$?

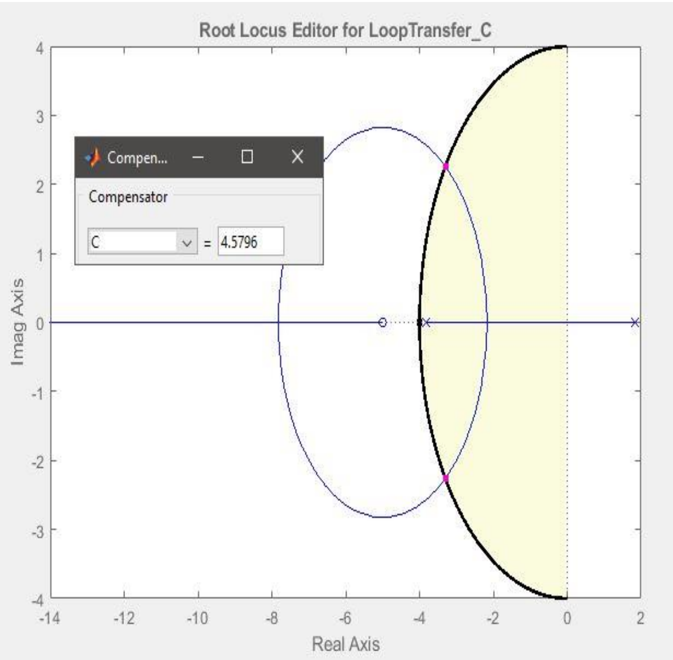
(3.267 / 7.4379)

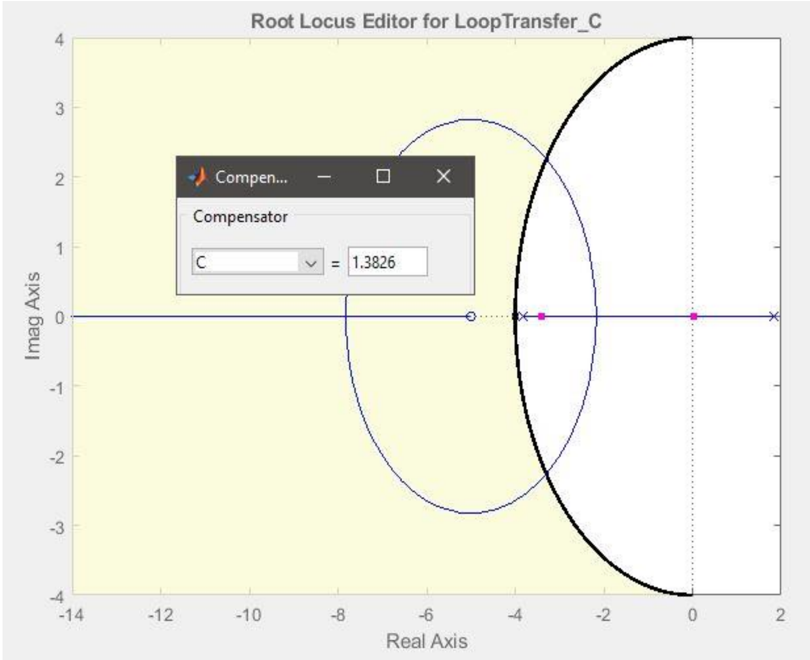




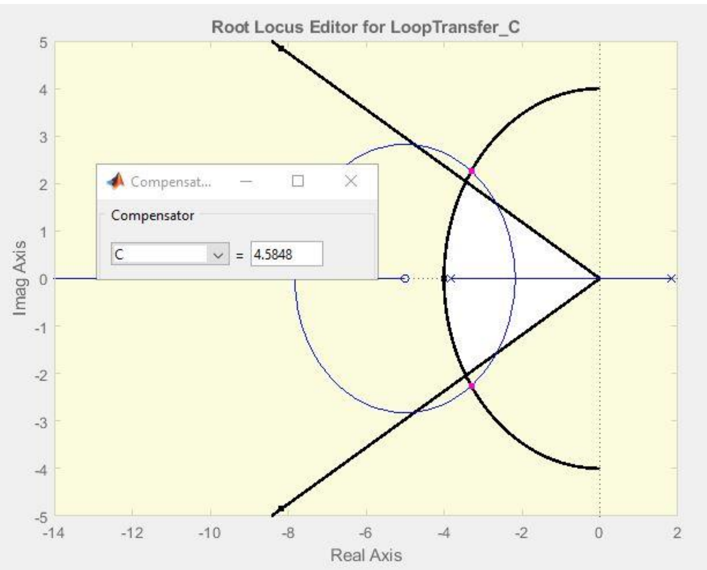
8) What is the range of k to give a stable response with $W_n < 4$?

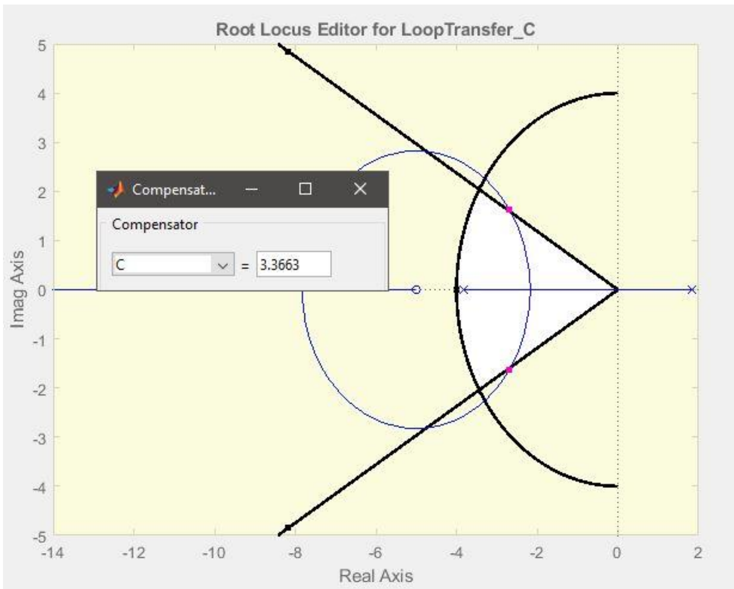
(1.3802 / 4.5901)



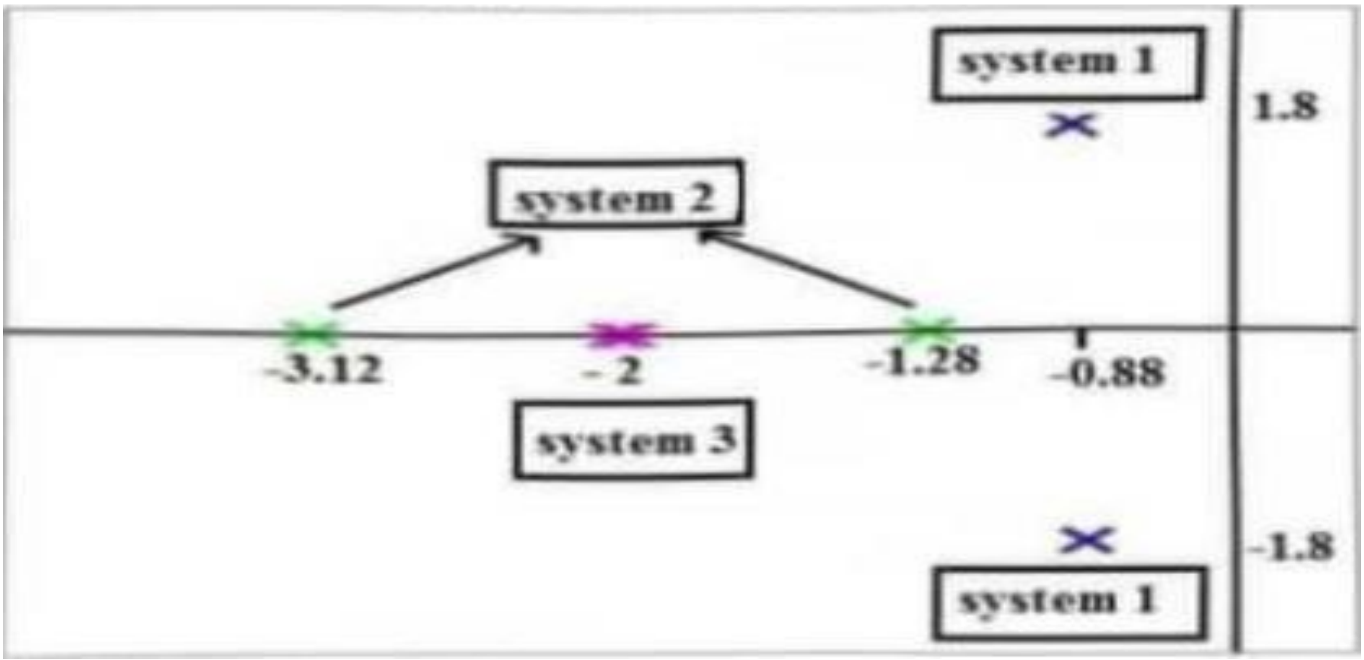


9)What is the range of k to give a stable response with $\zeta < 0.86$ and $W_n < 4$? (3.3398 / 4.590)





Example (1) :This figure shows the pole locations of three different 2nd order systems (each system is assigned unique poles color) . Notice that all 3 different systems share the same natural frequency (= 2 rad / s) , but have .different damping ratios



1) Which system is under - damped ? system 1

2) Which system has the highest damping ratio ? system 2

3) System 2 is critically-damped ? No

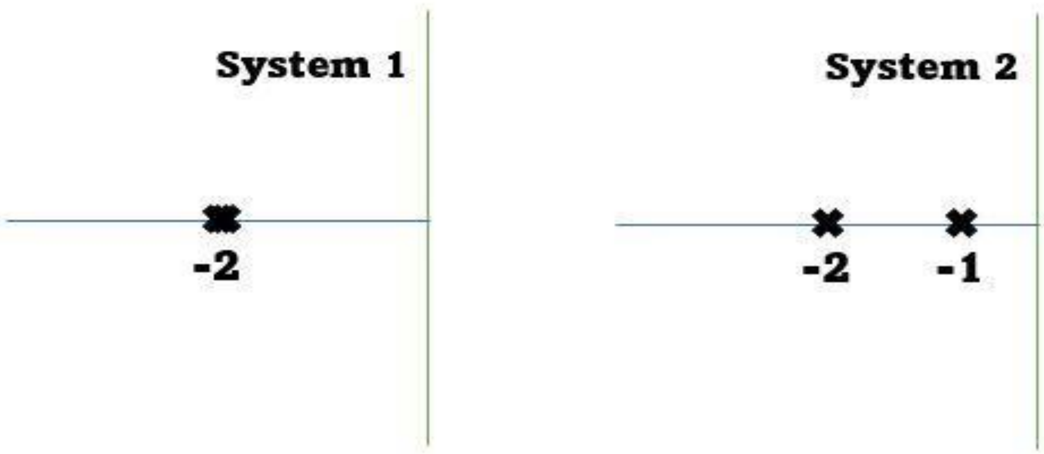
4) The damping ratio for System 1 is ?

$$r = \sqrt{(1.8)^2 + (0.88)^2} = 2$$

$$\zeta = cos\theta = \frac{0.88}{2} = 0.44 \qquad cos\theta = \frac{\text{المجاور}}{\text{الوتر}}$$

5) Which system will have the largest overshoot (deviation from the steady state value) in its step – response ? system 1

Example (2) :Consider the feedback system shown in figure below then answer the following:



1) Does system 1 consider as a speed or position control of motor?why?

Position , because it has two pole its critically damped system .

2)which system is over damped?

System 2

3)what is the damping ratio of system 1?

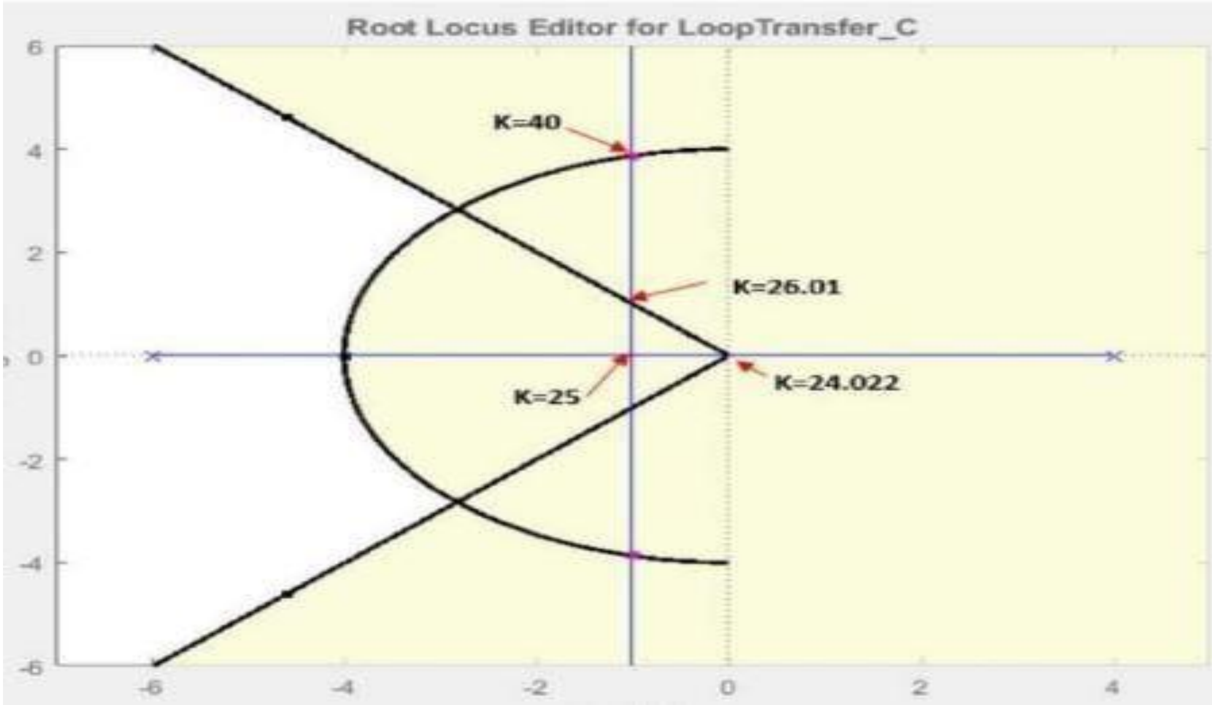
$\zeta = 1$ critically

4)what is the natural frequency of system 1?

$S = -W_n$

$S = 2$

Example (3) : For the following Root Locus plot , answer the following questions :



1)What are the values of the open loop system poles ?

بروح بشوف وين في ✖ بالرسمة وبعمل اسقاط على محور السينات بتطلع معي قيمة وهي

S=4 / S= -6

2)What is the value of natural frequency W_n assigned on the figure ?

$W_n = 4$ بروح عند تقوس الدائرة وبعمل اسقاط على محور السينات بتطلع معي قيمة

3)What is the range of k to give a stable response ?

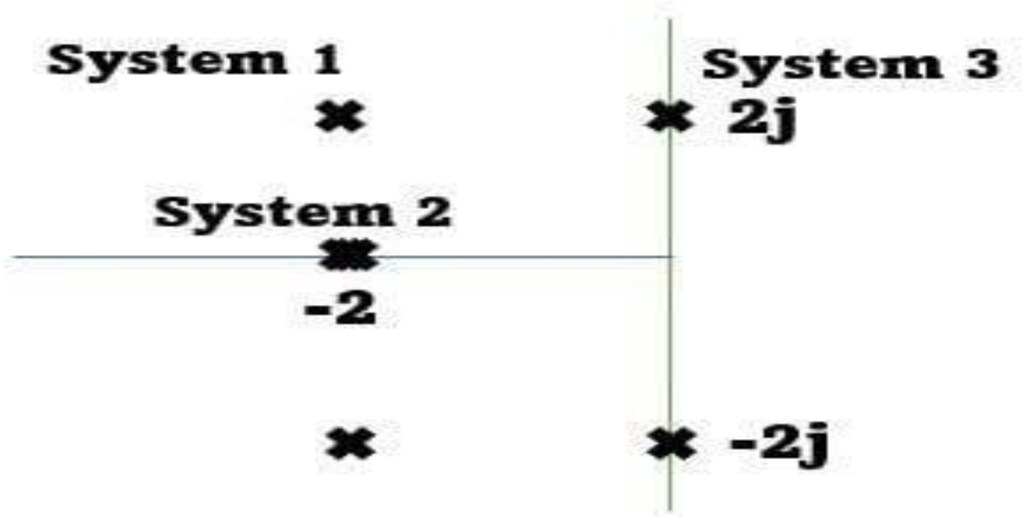
من عند خط الستيبل معطيك القيمة ل ∞

$24.022 \le K < \infty$

4) What is the range of k to give an under damped response ?

$25 \le K < \infty$

Example (4) :Consider the feedback system shown in figure below then answer the following:



1) What the damping ratio and natural frequency for system 3 ?

$\zeta = 0$

$W_n = 2$

2) The response of system 1 ?

Underdamped

3) The settling time of system 3 if the input is unit step (use 2% criterion) ?

$$T_s = \frac{4}{\zeta W_n} = 0$$

- **Center asymptot :**

$$\sigma = \frac{\Sigma\, poles - \Sigma\, zeros}{poles - zeros}$$

- **Angle:**

$$\theta_A = \frac{(2K+1)180}{poles - zeros}$$

- **Break point :** نشتق المقام ونساويه بالصفر

- **Angle dep :** 180 + $\Sigma\, zeros - \Sigma\, poles$

- **number of asymptotes : K=poles – zeros= n-m**

Example (5) : Figure 1 shows the block diagram of a motor position control system, Figure 2 is the root locus of the system G(s)= $\frac{5}{s^2+s}$ its required to select K_p such that the response to a unit step input satisfies:

1) PO ≤ 7.3%　　　2) $T_s \leq$ sec (2% error)

If (K_p1) is the controller gain that corresponds to poles at [A] and (K_p2) is the controller gain that corresponds to pole [B] as shown in Figure 2. Fill the bellow table with √ if performance condition is satisfied and with × if condition is not satisfied.

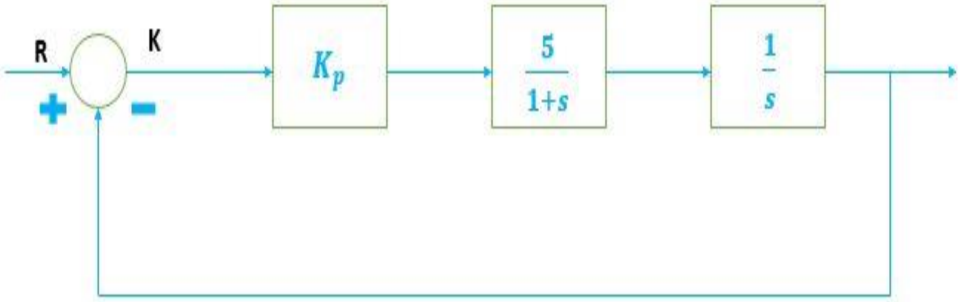


Figure 1

Performance condition	K_p1 A	K_p2 B
$T_s \leq$ sec (2% error)	×	√
PO ≤ 7.3%	×	×

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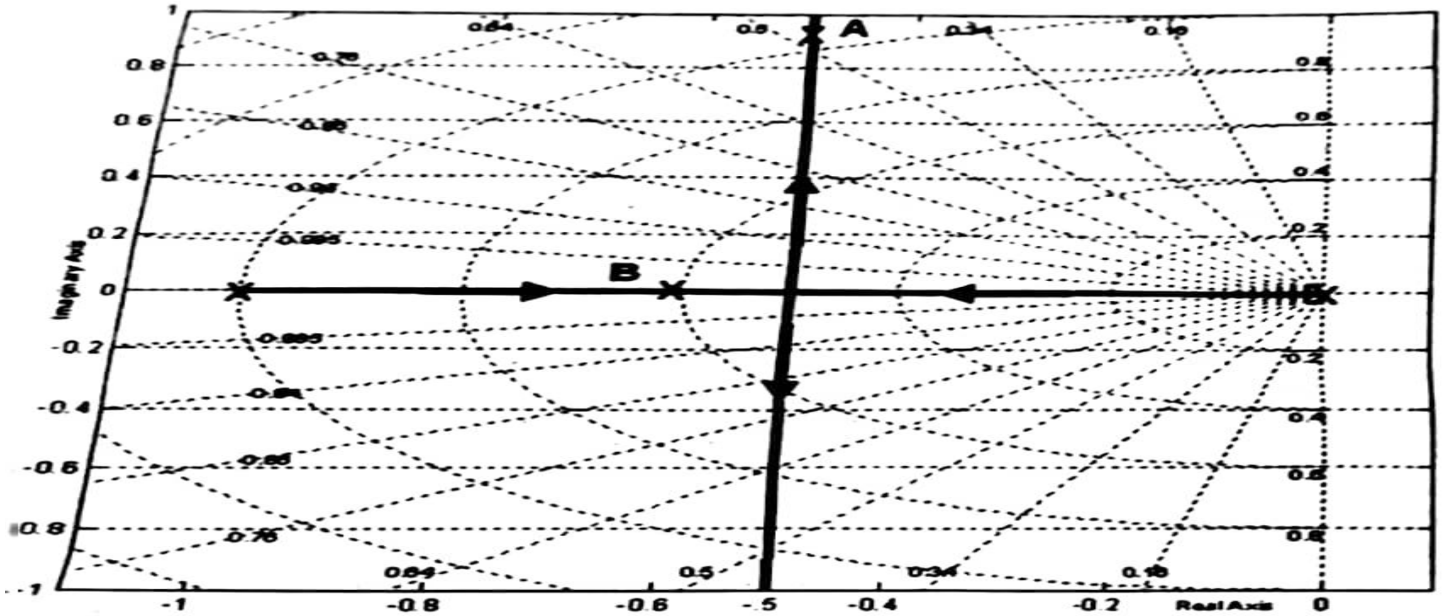

Figure 2: Root locus for the system $G(s) = 5/(s^2 + s)$

من خلال الدوائر بالرسمة بقدر اعرف WN

من خلال ال اشارة الاصغر بتقدر تعرف ζ

For A :

$W_n = 1$, $\zeta = 0.5$

$T_s\, K_p 1 = \frac{4}{\zeta \times W_n} = \frac{4}{0.5 \times 1} = 8$ sec

8 sec > 4 (الشرط لم يتحقق) ×

$\text{PO } K_p 1 = \text{OV} = 100\, e^{\frac{-\pi \zeta}{\sqrt{1-\zeta^2}}} = 16\%$

$16\% > 7.3\%$ (الشرط لم يتحقق) ×

For B:

$W_n = 0.6$, $\zeta > 1$ افرض مثلا انه زيتا بتساوي 2

$T_s\, K_p 2 = \frac{4}{\zeta \times W_n} = \frac{4}{0.6 \times 2} = 3.3$sec

3.3 sec < 4 (الشرط يتحقق) √

its over damped system so ,

no oscillation ,no over shot

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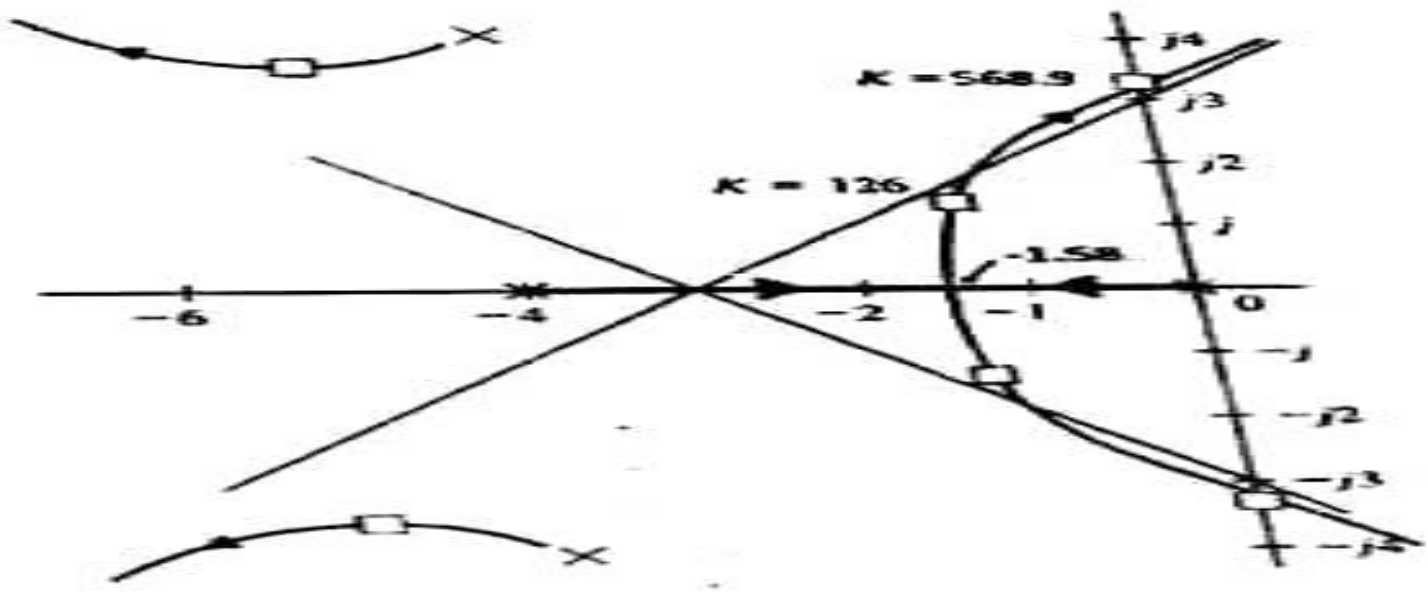
Example (6) : The Figure shown is the root locus of a unity feedback control system .



1)What is the type of the system? Type 1 , one pole at origin.
2)What is the range of K for the system to be stable?0<K<568.9
3)What is the breakaway point of the system? 1.58
4)What is the number of asymptotes of the system?
K=poles – zeros= n-m= 4-0 = 4 asymptotes

رابط شرح التوصيلات والماتلاب :

https://youtube.com/playlist?list=PLjiyR6nPcbxyQuDb8yIiYOLtRrGPJ8WbJ

نتمنى لكم فصل سعيد بكل تفاصيله,فالكم العلامة الطيبة في جميع المواد,نتمنى منكم دعوة خفيفة لطيفة تزهر القلوب 💙