University of Jordan
Elect. Eng. Dept.
Second Exam
Reg. No.
Exam Duration: 70 min

Control Systems 903441
Student Nam
Answers should be written in ink

Thursday 6/7/2017
Mark out of 30

30

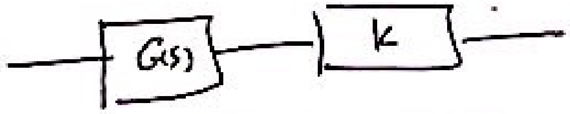
Q1 A system is given by a transfer function *G(s)*.

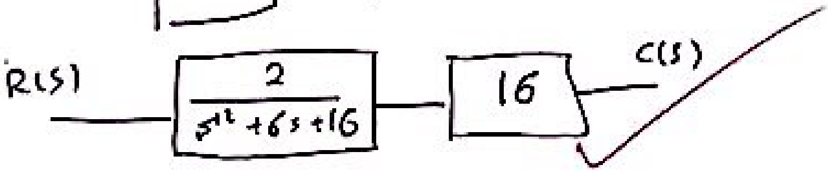
$\frac{9}{16}$ $2\zeta\omega_n = 6$

If possible, introduce **minimum number of components** in order to have:

i) A damping ratio of **0.75**, and a steady state output of **2** given $G(s)=\frac{2}{s^2+6s+16}$.

$\zeta = \frac{3}{4}$, $\omega_n = 4$, $\sqrt{1-\zeta^2} = \frac{\sqrt{7}}{4}$, $\omega_d = \sqrt{7}$



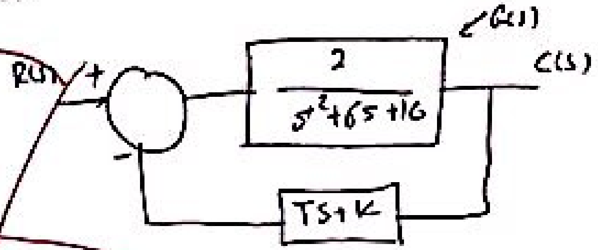


2

ii) a $\zeta = 1$, and $\omega_n = 2$ rad s^{-1} given $G(s)=\frac{2}{s^2+6s+16}$. What is the **time to the first overshoot**.

$\zeta = 1$, $\omega_n = 2$, $\omega_d = 0$, $\sqrt{1-\zeta^2} = 0$

$\frac{1}{s^2+4s+4}$ ⇐ new transfer func. That we want



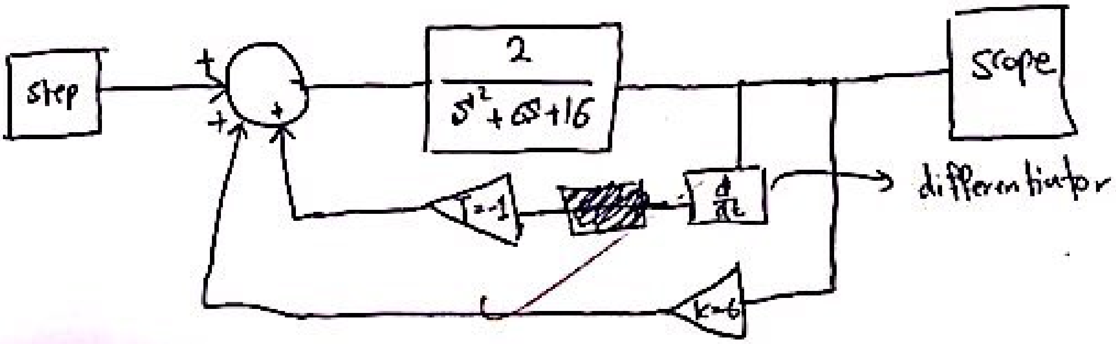
$\frac{2}{s^2+6s+16+2Ts+2K} \Rightarrow \frac{2}{s^2+(6+2T)s+(16+2K)}$

$6+2T=4 \Rightarrow T=-1$ & $16+2K=4 \Rightarrow K=-6$

since for $\zeta=1$ the system is critically damped, there is no over shoot !!!

4

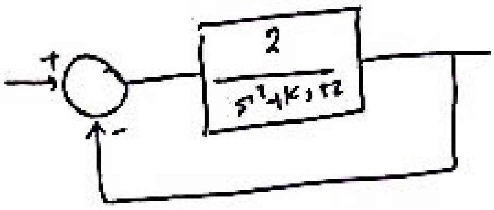
Simulate the system together with the proposed controller using **Simulink**.



2

$\frac{s^2+4+Ks}{s^2+4}=0$ $1+G(s)H(s)$ $1+\frac{A(s)}{B(s)}$ $\frac{2}{A(s)+2}$

Q2 a)A <u>unity negative feedback</u> system has $G(s)=\frac{2}{s^2+Ks+2}$. Represent the characteristic equation in a form suitable for root locus sketching , and <u>determine</u> the poles and zeros involved in the process of sketching the root locus. <u>**Don't sketch the root locus.**</u>



$C(s) = \frac{2}{s^2+Ks+2+2}$ ← The characteristic equation

$C(s) = \frac{2}{s^2+Ks+4}$ ⇒ $1+K\frac{A(s)}{B(s)}=0$

$1+K\frac{s}{s^2+4}=0$

The zero is : $s=0$

The poles are : $s=j2$, $s=-j2$

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b) Classify the following processes as <u>stable</u>, <u>asymptotically stable</u>, or <u>unstable</u>

A nuclear reactor operating normally. asy stable

A ruler just balanced on a finger tip. asymptotically ~~stable~~

Pushing an unmanned unicycle. ~~asymptotically stable~~ unstable

A ball bearing released from the rim towards the inside of a bowl. asymptotically stable

A bridge experiencing moderate non-continuous wind forces. asymptotically stable

The pendulum of a clock. stable

$\frac{K}{A(s)}$: $\frac{K}{A(s)+K}$ $A(s)+K$

2.5

c) A system has $G(s)=\frac{9s+8}{4s^2+2}$. Write down matlab <u>commands</u> (not Simulink blocks) to determine its

$4s^3+2s$

i. <u>open loop poles.</u>

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>> roots([4 0 2])
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ii. open loop output time response due to <u>two</u> signals having Laplace transforms 1 and $\frac{1}{s^2}$.

for 1 ⇒ n=[9 8]; d=[4 0 2]; sys=tf(n,d); impulse(sys)

for $\frac{1}{s^2}$ ⇒ n=[9 8]; d=[4 0 2 0]; sys=tf(n,d); step(sys)

3

Q3 Consider a system having the following characteristic equation $s^4+s^3+s^2+Ks+1=0$.

i) Without using Routh's stability criterion, does there exist values of K which are certain to make the system unstable?.If yes, what are they? State your reasons.

yes, any negative value of K will make the system unstable, due to the changing of sign in the characteristic equ.

also, if K equal to zero, the system would be unstable due to missing power in the characteristic equation.

both cases will produce a poles with positive real part

2

ii)Using Routh's stability criterion determine if any positive value of K make the system stable?.

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

$$\frac{(1-K)K-1}{1-K}$$

$$\frac{K-K^2-1}{1-K}$$

So there is no value of K such that the system is stable

$1-K>0 \rightarrow \boxed{K<1}$

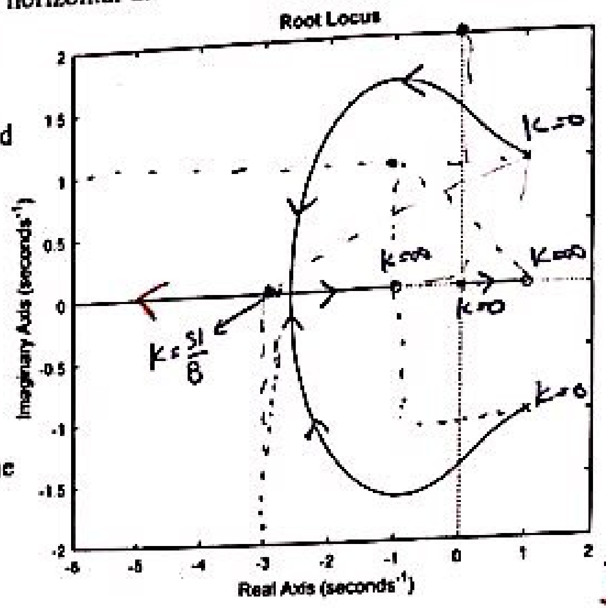
$K-K^2-1>0 \Rightarrow$ This term will never be positive for real value of K

prove

3

$(k-(1+j))(k-(1-j)) = k^2 - k + kj - k - j + 1 + 1$ k^2+2 $k^2 - k + kj - k + 1 - j - jk + j + 1$

Q4 Consider the root locus plot shown. Be careful with the horizontal and vertical scales. They are not equal. Use the root locus sketch to answer the following :



3

Write down *G(s)H(s)* as *K* times a transfer function obtained from the poles – zeros configuration.

Zeros @ : s = -1 , s = 1 , poles @ : s = 1+j, s = 1-j, s = 0

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

Indicate arrows on the root locus with values for K at the poles and zeros.

Calculate the sum of angles due the poles and zeros at the test point $-1+j$.

$\angle$ zero $- \angle$ poles

$(90 + 180 - \tan^{-1}(\frac{1}{2})) - (180 + \tan^{-1}(\frac{1}{1}) + 180 - \tan^{-1}(\frac{2}{1}))$

$243.43^\circ - 450^\circ$

$\boxed{-206^\circ} \neq (2n+1)180^\circ$ 2

Use the **magnitude condition** to determine the value of K which makes the point $s=-3$ a closed loop pole.

$$K \frac{|2|\,|4|}{|\sqrt{17}|\,|3|\,|\sqrt{17}|} = 1 = K\frac{8}{51} \Rightarrow \boxed{K = \frac{51}{8}}$$

1

Use the **angle condition** to decide if $2j$ is a closed loop pole or not.

$(\tan^{-1}(\frac{2}{1}) + 180 - \tan^{-1}(\frac{2}{1})) - (90 + 180 - \tan^{-1}(\frac{1}{1}) + 180 - \tan^{-1}(\frac{3}{1}))$ $\neq (2n+1)180$

$180 - 333 = -153.43 \neq (2n+1)180^\circ$ not a closed loop pole

Using the root locus, write down the value of a point which is a possible closed loop pole.

$s = 0.5$ & $s = -1.5$

Using the root locus, write down the value of a point which is not a possible closed loop pole.

$S = -5 + j$, $S = -6 - 8j$, $S = 2$ 1