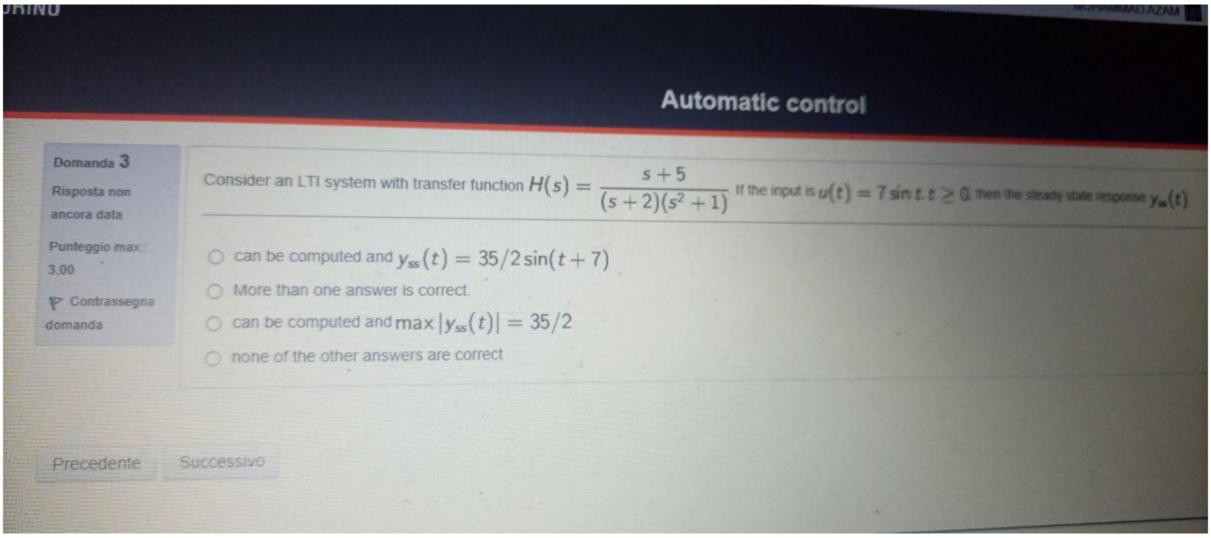


Automatic control

Domanda 3

Risposta non ancora data

Punteggio max.: 3,00

Contrassegna domanda

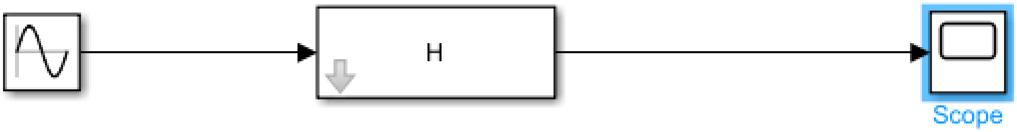
Consider an LTI system with transfer function $H(s) = \frac{s+5}{(s+2)(s^2+1)}$ If the input is $u(t) = 7\sin t,\ t \geq 0$ then the steady state response $y_{ss}(t)$

- can be computed and $y_{ss}(t) = 35/2\sin(t+7)$
- More than one answer is correct.
- can be computed and $\max|y_{ss}(t)| = 35/2$
- none of the other answers are correct

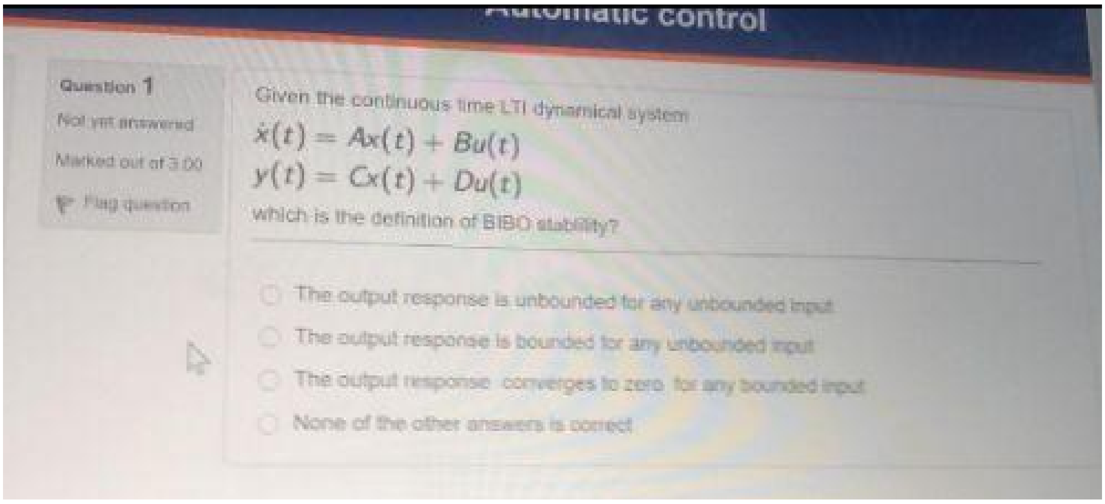
Precedente Successivo

Answer:

```
    H=(s+5)/((s+2)*(s^2+1));
    pole(H); %not all poles have Re<0
%none of the answer is correct => D


can be solved also by simulink
```



for t-> inf, we see the steady state goes to inf, so option d is correct



Automatic control

Question 1

Not yet answered

Marked out of 3.00

Flag question

Given the continuous time LTI dynamical system

$\dot{x}(t) = Ax(t) + Bu(t)$

$y(t) = Cx(t) + Du(t)$

which is the definition of BIBO stability?

- The output response is unbounded for any unbounded input
- The output response is bounded for any unbounded input
- The output response converges to zero for any bounded input
- None of the other answers is correct

Answer:

%the output response is bounded for any bounded input

%none of the other answers is correct => D

Question 2

Risposta non ancora salvata

Marked out of 3.00

Flag question

Given the LTI system

$$\dot{x}(t) = Ax(t) + Bu(t)$$
$$y(t) = Cx(t) + Du(t)$$

with

$$A = \begin{pmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -3 \\ 6 & 0 & 3 & 0 \end{pmatrix}$$

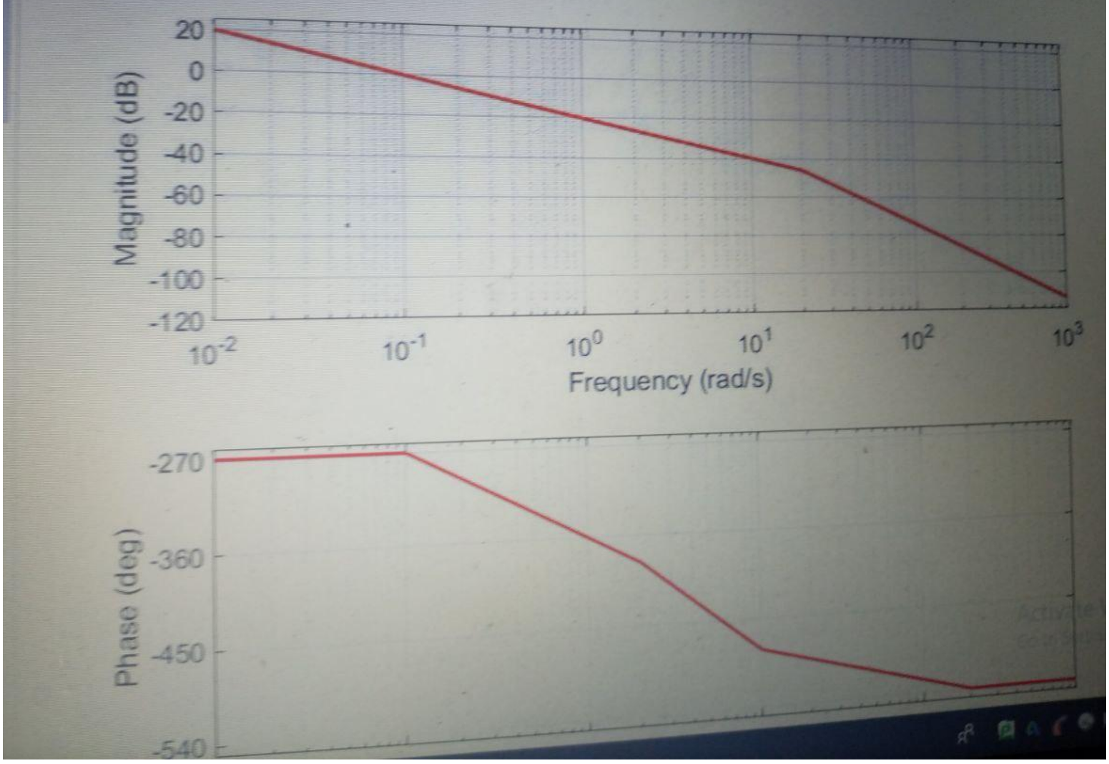
which statement is true?

- (●) The system is internally unstable
- ( ) The system is internally asymptotically stable
- ( ) The system is internally (not asymptotically) stable
- ( ) We cannot evaluate the internal stability of the system as B is not given

Answer:

```
eig(A);

ans =

   0.0000 + 3.0000i
   0.0000 - 3.0000i
   0.0000 + 1.0000i
   0.0000 - 1.0000i

%all different lambdas and all Re(lambda) = 0 => internally stable
%not asymptotically because lambda not all < 0 => C
```

Given the asymptotic Bode diagrams below



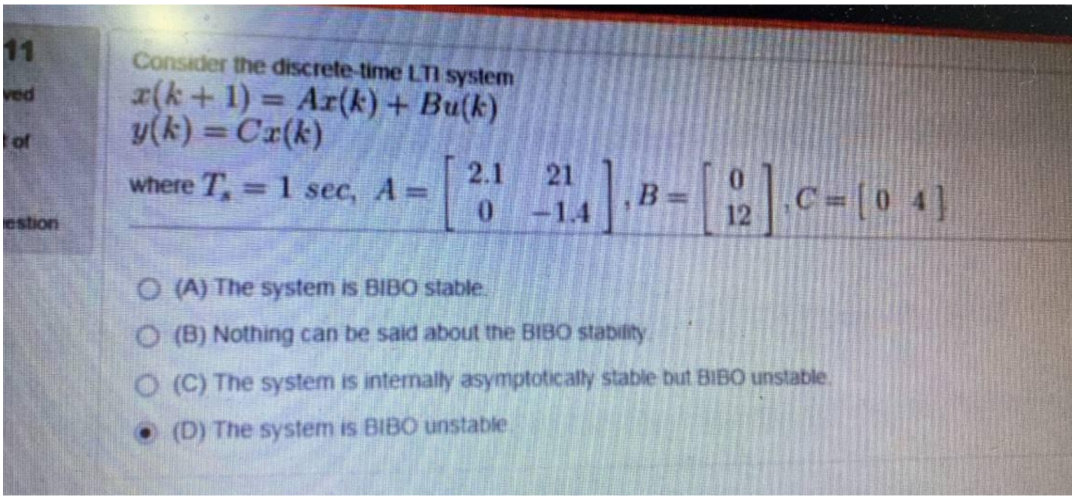
Evaluate the poles, the zeros and the sign of the generalized dc-gain of the corresponding trans minimal).

- ○ The poles are $p_1 = 0, p_2 = -1, p_3 = -20$
  The unique zero is $z = 1$
  The generalized dc-gain is negative
- ● The poles are $p_1 = 0, p_2 = -1, p_3 = -20$
  The unique zero is $z = -1$
  The generalized dc-gain is positive
- ○ The poles are $p_1 = 0, p_2 = 1, p_3 = -20$
  The unique zero is $z = -1$
  The generalized dc-gain is negative
- ○ The poles are $p_1 = 0, p_2 = -1, p_3 = -20$
  The unique zero is $z = 1$
  The generalized dc-gain is positive

Answer:

```
%you can check
   H=(s-1)/(s*(s+20)*(s+1));
   bode(H);
   dcgain(s*H);
%p2=-1,z=1,dc-gain negative => A
```

INF ONLY



11

Consider the discrete-time LTI system

$x(k+1) = Ax(k) + Bu(k)$

$y(k) = Cx(k)$

where $T_s = 1$ sec, $A = \begin{bmatrix} 2.1 & 21 \\ 0 & -1.4 \end{bmatrix}$, $B = \begin{bmatrix} 0 \\ 12 \end{bmatrix}$, $C = \begin{bmatrix} 0 & 4 \end{bmatrix}$

- (A) The system is BIBO stable.
- (B) Nothing can be said about the BIBO stability.
- (C) The system is internally asymptotically stable but BIBO unstable.
- (D) The system is BIBO unstable.

Answer:

```
A=[2.1 21;0 -1.4];
   eig(A); %from eig we cannot conclude anything!
   B=[0;12];
   C=[0 4];
   z=tf('z',1);
   H=minreal(C*inv(z*eye(2)-A)*B);
   pole(H);
  %abs(pole)>1, BIBO unstable
%remember! |p| < 1
% BIBO unstable => D

%alternative solution to find H :
A=[2.1 21;0 -1.4];
B=[0;12]
C=[0 4]
D=[0]
sys=ss(A, B, C, D);
H=tf(sys)
pole(H)
```

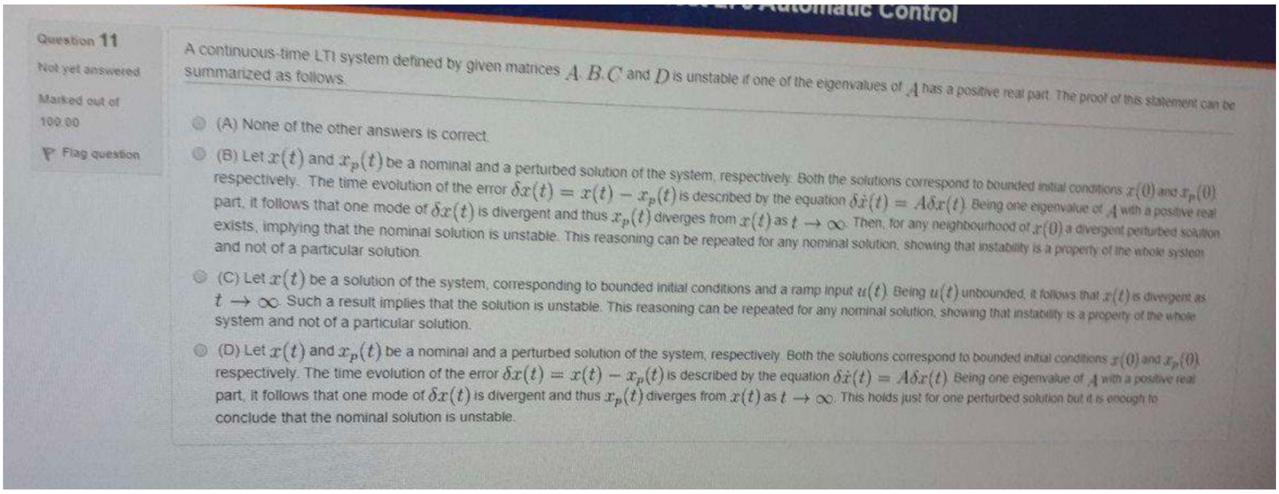
Definition 4. BIBO stability of DT LTI systems

A Single Input Single Output (SISO)* DT LTI system is **bounded-input bounded-output** (BIBO) stable if the zero state output response is bounded for <u>all</u> bounded inputs

$$\forall u_M \in (0,\infty), \quad \exists y_M \in (0,\infty):$$
$$|u(k)| \le u_M, \forall k \ge 0 \quad \Rightarrow \quad |y(k)| \le y_M, \forall k \ge 0$$

Result 4.1 BIBO stability of DT LTI systems

A DT LTI system is **BIBO stable** if and only if all the poles p_i of its transfer function $H(z)$ lie strictly inside the unit circle, i.e., $|p_i| < 1$ for all $i = 1,\dots,n$.



Automatic Control

Question 11

Not yet answered

Marked out of 100.00

Flag question

A continuous-time LTI system defined by given matrices A, B, C and D is unstable if one of the eigenvalues of A has a positive real part. The proof of this statement can be summarized as follows.

(A) None of the other answers is correct.

(B) Let $x(t)$ and $x_p(t)$ be a nominal and a perturbed solution of the system, respectively. Both the solutions correspond to bounded initial conditions $x(0)$ and $x_p(0)$ respectively. The time evolution of the error $\delta x(t) = x(t) - x_p(t)$ is described by the equation $\delta \dot{x}(t) = A\delta x(t)$. Being one eigenvalue of A with a positive real part, it follows that one mode of $\delta x(t)$ is divergent and thus $x_p(t)$ diverges from $x(t)$ as $t \to \infty$. Then, for any neighbourhood of $x(0)$ a divergent perturbed solution exists, implying that the nominal solution is unstable. This reasoning can be repeated for any nominal solution, showing that instability is a property of the whole system and not of a particular solution.

(C) Let $x(t)$ be a solution of the system, corresponding to bounded initial conditions and a ramp input $u(t)$. Being $u(t)$ unbounded, it follows that $x(t)$ is divergent as $t \to \infty$. Such a result implies that the solution is unstable. This reasoning can be repeated for any nominal solution, showing that instability is a property of the whole system and not of a particular solution.

(D) Let $x(t)$ and $x_p(t)$ be a nominal and a perturbed solution of the system, respectively. Both the solutions correspond to bounded initial conditions $x(0)$ and $x_p(0)$ respectively. The time evolution of the error $\delta x(t) = x(t) - x_p(t)$ is described by the equation $\delta \dot{x}(t) = A\delta x(t)$. Being one eigenvalue of A with a positive real part, it follows that one mode of $\delta x(t)$ is divergent and thus $x_p(t)$ diverges from $x(t)$ as $t \to \infty$. This holds just for one perturbed solution but it is enough to conclude that the nominal solution is unstable.

Answers:

%quiz6

%I think we did it differently, I would say B

c is nonsense. and for LTI , the stability is global and not just for one solution like for nonlinear. so B

Domanda **1**

Risposta non ancora data

Punteggio max.: 3,00

Contrassegna domanda

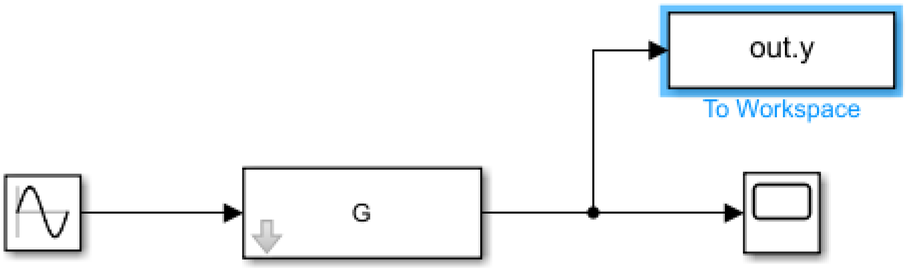
Consider the LTI system defined by the transfer function $H(s) = \frac{1}{s^2 - 4s + 13}$.

Let $u(t) = (4\sin(2t))\epsilon(t)$. Recall that $\mathcal{L}(\sin(\omega t)) = \frac{\omega}{s^2+\omega^2}$. The output response is

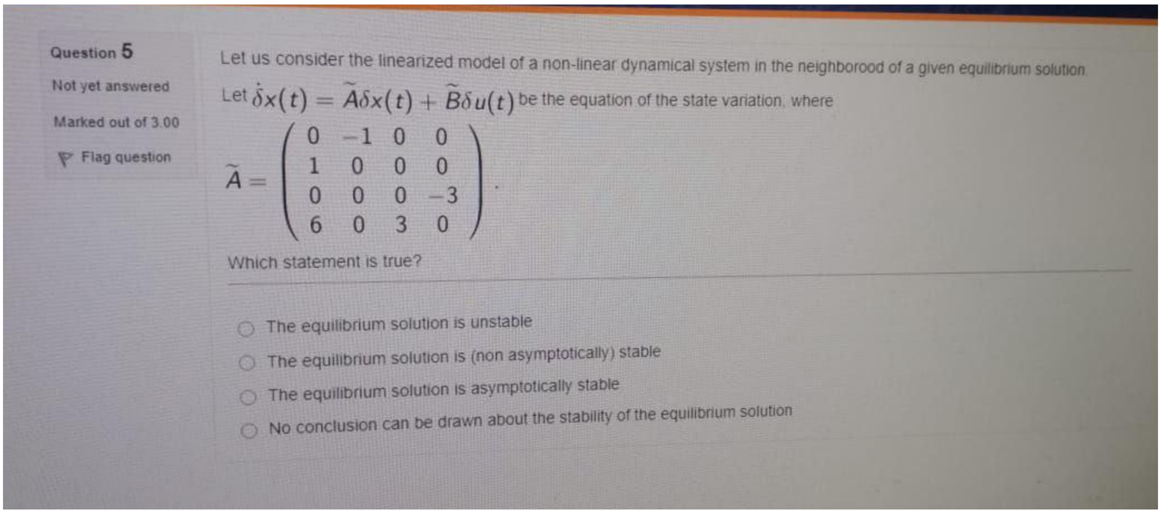
- ○ $y(t) = (0.2215e^{-2t}\cos(3t + 3.0585) + 0.3322e^{2t}\cos(-0.8442))\epsilon(t)$
- ○ It is impossible to compute the output response as the system is internally unstable
- ○ $y(t) = (0.2215e^{2t}\cos(3t + 3.0585) + 0.3322\cos(2t - 0.8442))\epsilon(t)$
- ○ $y(t) = (0.3322e^{3t}\cos(2t + 3.0585) + 0.2215\cos(2t - 0.8442))\epsilon(t)$

Answer:

```
    H=1/(s^2-4*s+13);
    pole(H);
    U=4*2/(s^2+2*2);
    Y=zpk(minreal(H*U,1e-3));
    [numY,denY]=tfdata(Y,'v');
    [rY,pY]=residue(numY,denY);
    mod1=2*abs(rY(1));
    phase1=angle(rY(1));
    mod2=2*abs(rY(3));
    phase2=angle(rY(3));
%it is not BIBO stable, but B is wrong. C is unbounded but correct => C
%alternative solution :
s=tf("s");
G=1/(s^2-4*s+13);
out=sim("untitled")
t=1;
y1=0.2215*exp(-2*t)*cos(3*t+3.0585)+0.3322*exp(2*t)*cos(-0.8442)
y3=0.2215*exp(2*t)*cos(3*t+3.0585)+0.3322*cos(2*t-0.8442)

%by putting an arbitrary t inside functions and get the result, and then
check the value in out.y values for that t and choose the system which has
the closest value
it is tricky since a mistake in any step will make you to choose a wrong
choice
simulink input should have proper gain and frequency which w=2 and gain=4
in this question
```



INF only



Question 5

Not yet answered

Marked out of 3.00

Flag question

Let us consider the linearized model of a non-linear dynamical system in the neighborood of a given equilibrium solution.

Let $\dot{\delta x}(t) = \widetilde{A}\delta x(t) + \widetilde{B}\delta u(t)$ be the equation of the state variation, where

$$\widetilde{A} = \begin{pmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & -3 \\ 6 & 0 & 3 & 0 \end{pmatrix}.$$

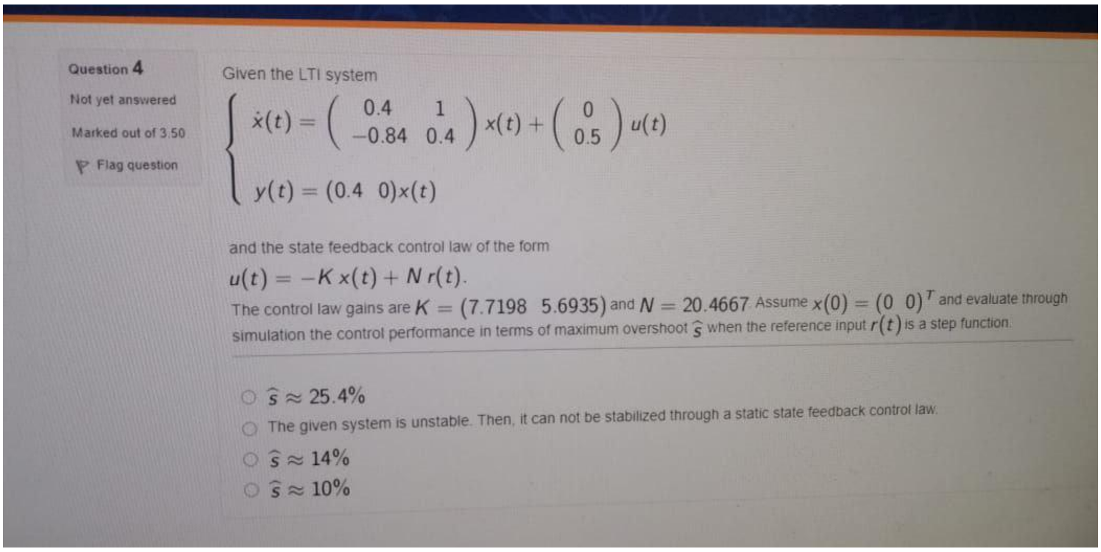
Which statement is true?

- The equilibrium solution is unstable
- The equilibrium solution is (non asymptotically) stable
- The equilibrium solution is asymptotically stable
- No conclusion can be drawn about the stability of the equilibrium solution

Answer:

```
A=[0 -1 0 0; 1 0 0 0; 0 0 0 -3; 6 0 3 0];
   eig(A); %In linearized model, if Re(lambda)=0 No conclusions can be
drawn
%No conclusions => D
```

INF only



Question 4

Not yet answered

Marked out of 3.50

Flag question

Given the LTI system

$$\begin{cases} \dot{x}(t) = \begin{pmatrix} 0.4 & 1 \\ -0.84 & 0.4 \end{pmatrix} x(t) + \begin{pmatrix} 0 \\ 0.5 \end{pmatrix} u(t) \\ y(t) = (0.4 \quad 0)x(t) \end{cases}$$

and the state feedback control law of the form

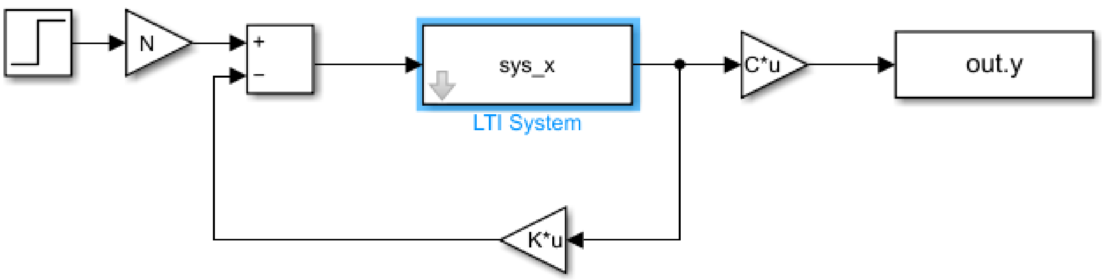
$u(t) = -K\,x(t) + N\,r(t)$.

The control law gains are $K = (7.7198 \quad 5.6935)$ and $N = 20.4667$. Assume $x(0) = (0 \quad 0)^T$ and evaluate through simulation the control performance in terms of maximum overshoot $\widehat{s}$ when the reference input $r(t)$ is a step function.

- $\widehat{s} \approx 25.4\%$
- The given system is unstable. Then, it can not be stabilized through a static state feedback control law.
- $\widehat{s} \approx 14\%$
- $\widehat{s} \approx 10\%$

Answer:

```
A=[0.4 1;-0.84 0.4];
   B=[0;0.5];
   C=[0.4 0];
   K=[7.7198 5.6935];
   N=[20.4667];
   x0)=[0;0];
   sys_x=ss(A,B,eye(2),0);
   sim1=sim('quiz9.slx');
   plot(sim1.y);
   s_hat=(1.254-1.1)/1.1; % ss is not 1
% s_hat = 14% => C
```



Automatic control

Question 3

Not yet answered

Marked out of 3.50

Flag question

A minimal continuous time LTI dynamical system

$$\dot{x}(t) = Ax(t) + Bu(t)$$
$$y(t) = Cx(t) + Du(t)$$

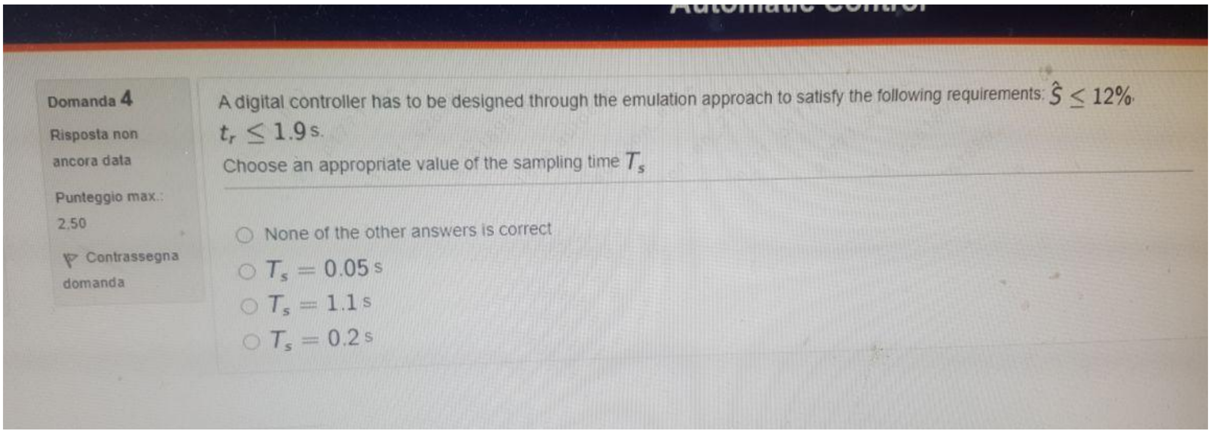
is BIBO stable if and only if

- ○ The step response of the system in the presence of zero initial condition is bounded for all the possible step amplitudes
- ○ The system is internally (non asymptotically) stable
- ○ All the system natural modes are convergent
- ○ More than one among the other answers is correct

Answer:

```
%A->WRONG: any bounded input, not only steps
   %B->WRONG: nonsense
   %C->Since we always assume minimality (unless reported), it is true
   %D->WRONG: since only C is true => C
```

INF ONLY
guys, write “why” in matlab ;)


Domanda 4
Risposta non ancora data
Punteggio max.: 2,50
Contrassegna domanda

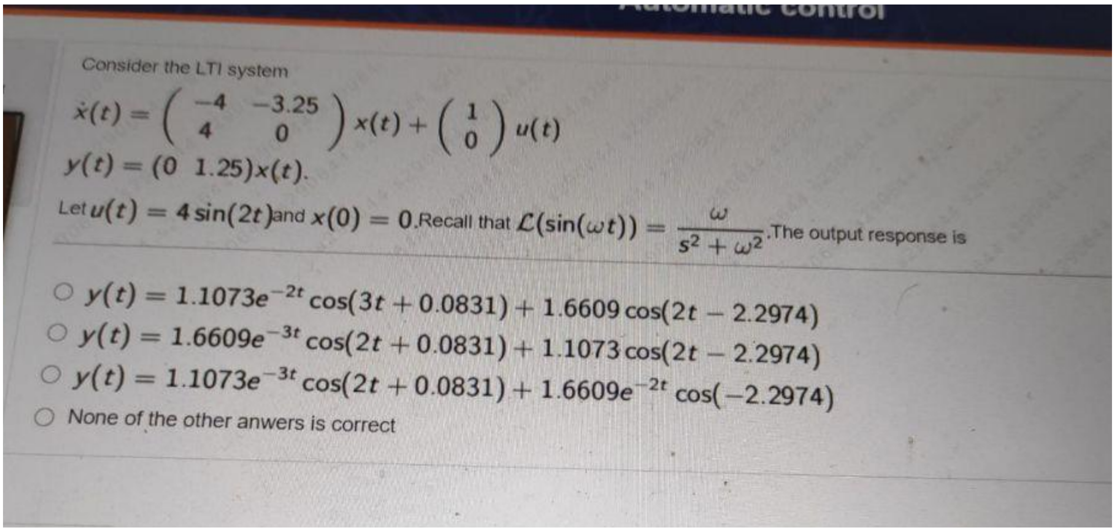
A digital controller has to be designed through the emulation approach to satisfy the following requirements: $\hat{S} \leq 12\%$, $t_r \leq 1.9$ s.
Choose an appropriate value of the sampling time T_s

- None of the other answers is correct
- $T_s = 0.05$ s
- $T_s = 1.1$ s
- $T_s = 0.2$ s

Answer:

```
zeta=0.56;
   wc_des=1.90/1.9; %see diagrams to find tr*wc (from zeta)!
   T_min=2*pi/(50*wc_des);
   T_max=2*pi/(20*wc_des); %we want the freq to be around 20*wc<w<50wc
%T=0.2 => D
```

why we want the freq to be around 20*wc<w<50*wc ? Ans: it is a rule of thumb (see ACs_INF_L06)



Automatic control

Consider the LTI system

$$\dot{x}(t) = \begin{pmatrix} -4 & -3.25 \\ 4 & 0 \end{pmatrix} x(t) + \begin{pmatrix} 1 \\ 0 \end{pmatrix} u(t)$$

$$y(t) = (0 \;\; 1.25)x(t).$$

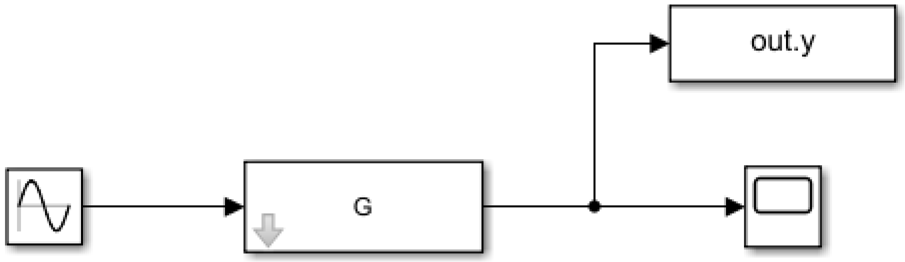
Let $u(t) = 4\sin(2t)$ and $x(0) = 0$. Recall that $\mathcal{L}(\sin(\omega t)) = \frac{\omega}{s^2+\omega^2}$. The output response is

- $y(t) = 1.1073e^{-2t}\cos(3t + 0.0831) + 1.6609\cos(2t - 2.2974)$
- $y(t) = 1.6609e^{-3t}\cos(2t + 0.0831) + 1.1073\cos(2t - 2.2974)$
- $y(t) = 1.1073e^{-3t}\cos(2t + 0.0831) + 1.6609e^{-2t}\cos(-2.2974)$
- None of the other anwers is correct

Answer:

```
A=[-4 -3.25;4 0];
   B=[1;0];
   C=[0 1.25];
   H=minreal(C*inv(s*eye(2)-A)*B,1e-3);
   pole(H);
   U=4*2/(s^2+4);
   Y=minreal(H*U,1e-3);
   [numY,denY]=tfdata(Y,'v');
   [rY,pY]=residue(numY,denY);
   modY1=2*abs(rY(1));
   phasY1=angle(rY(1));
   modY2=2*abs(rY(3));
   phasY2=angle(rY(3));
%A

%from residue we obtain:
      ans =

      r =

         0.5517 + 0.0460i
         0.5517 - 0.0460i
        -0.5517 - 0.6207i
        -0.5517 + 0.6207i

      p =

        -2.0000 + 3.0000i
        -2.0000 - 3.0000i
        -0.0000 + 2.0000i
        -0.0000 - 2.0000i
```

```
%alternative approach
A=[-4 -3.25;4 0];
B=[1;0];
C=[0 1.25];
D=[0];
G=ss(A, B, C, D);
out=sim("untitled.slx")
t=10
y1=1.1073*exp(-2*t)*cos(3*t+0.0831)+1.6609*cos(2*t-2.2974)
y2=1.6609*exp(-3*t)*cos(2*t+0.0831)+1.1073*cos(2*t-2.2974)
y3=1.1073*exp(-3*t)*cos(2*t+0.0831)+1.6609*exp(-2*t)*cos(-2.2974)
```



INF only

Given the LTI system

$$\begin{cases} \dot{x}(t) = \begin{pmatrix} -0.2 & 1 \\ -0.96 & -0.2 \end{pmatrix} x(t) + \begin{pmatrix} 0 \\ 0.5 \end{pmatrix} u(t) \\ y(t) = (0.4 \quad 0)x(t) \end{cases}$$

and the state feedback control law of the form

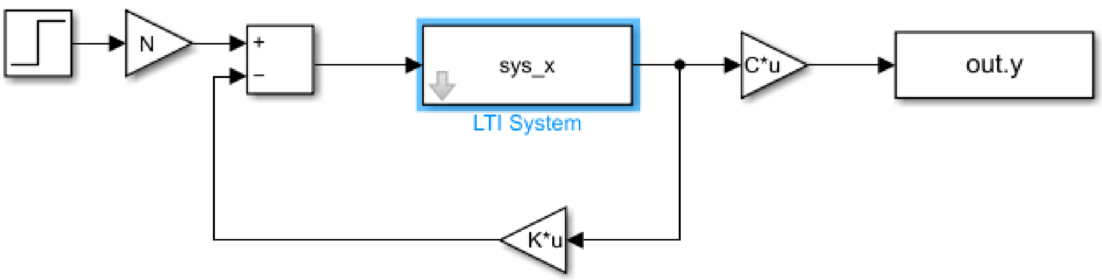
$u(t) = -K\,x(t) + N\,r(t)$.

The control law gains are $K = (5.1798 \quad 3.2935)$ and $N = 21.5558$. Assume $x(0) = (0 \quad 0)^T$ and evaluate through simulation the control performance in terms of maximum overshoot $\hat{s}$ when the reference input $r(t)$ is a step function.

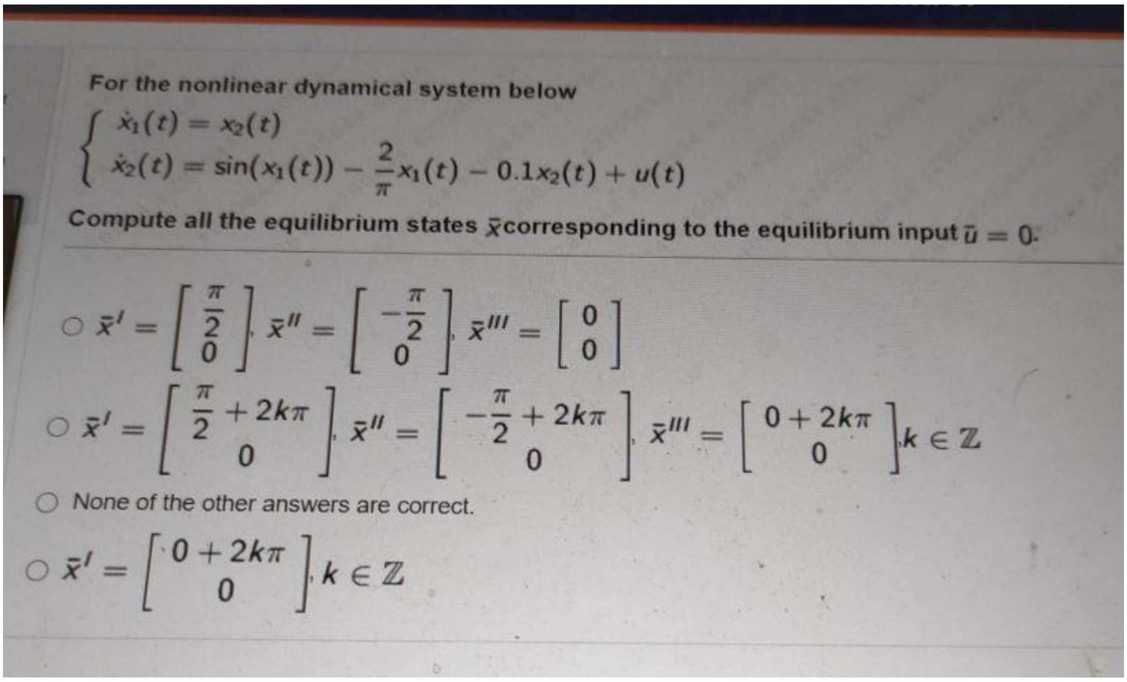
- $\hat{s} \approx 15\%$
- $\hat{s} \approx 26.5\%$
- $\hat{s} \approx 20\%$
- It is not possible to evaluate the control performance since the controlled system is not stable.

Answer:

```
A=[-0.2 1;-0.96 -0.2];
   B=[0;0.5];
   C=[0.4 0];
   N=21.5558;
   K=[5.1798 3.2935];
   x0=[0;0
   sys_x=ss(A,B,eye(2),0);
sim2=sim('quiz9.slx');];


   s_hat=(1.265-1.1)/1.1; %ss is not 1
%s_hat = 15% => A
```



INF only



For the nonlinear dynamical system below

$$\begin{cases} \dot{x}_1(t) = x_2(t) \\ \dot{x}_2(t) = \sin(x_1(t)) - \frac{2}{\pi}x_1(t) - 0.1x_2(t) + u(t) \end{cases}$$

Compute all the equilibrium states $\bar{x}$corresponding to the equilibrium input $\bar{u} = 0$.

- $\bar{x}' = \begin{bmatrix} \frac{\pi}{2} \\ 0 \end{bmatrix}, \bar{x}'' = \begin{bmatrix} -\frac{\pi}{2} \\ 0 \end{bmatrix}, \bar{x}''' = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$
- $\bar{x}' = \begin{bmatrix} \frac{\pi}{2} + 2k\pi \\ 0 \end{bmatrix}, \bar{x}'' = \begin{bmatrix} -\frac{\pi}{2} + 2k\pi \\ 0 \end{bmatrix}, \bar{x}''' = \begin{bmatrix} 0 + 2k\pi \\ 0 \end{bmatrix}, k \in \mathbb{Z}$
- None of the other answers are correct.
- $\bar{x}' = \begin{bmatrix} 0 + 2k\pi \\ 0 \end{bmatrix}, k \in \mathbb{Z}$

Answer:

```
%solutions of sin(x)-2/pi*x=0, solve graphically
   x=[-5:0.01:5];
   y=sin(x)-2/pi*x;
   plot(x,y);
   %easy to see that they're only [-pi/2 0],[pi/2 0], [0 0]
%A
```

A continuous time LTI dynamical system described by the state equation $\dot{x}(t) = Ax(t) + Bu(t)$ is internally asymptotically stable if and only if

- (A) All the eigenvalues have real part smaller or equal to 0.
- (B) All the eigenvalues have real part strictly smaller than 0.
- (C) There is at least one eigenvalue with real part larger than 0.
- (D) More than one among the other answers is correct.

Answer:

```
%internally asimpt. iff all Re(lambda)<0

%B
```

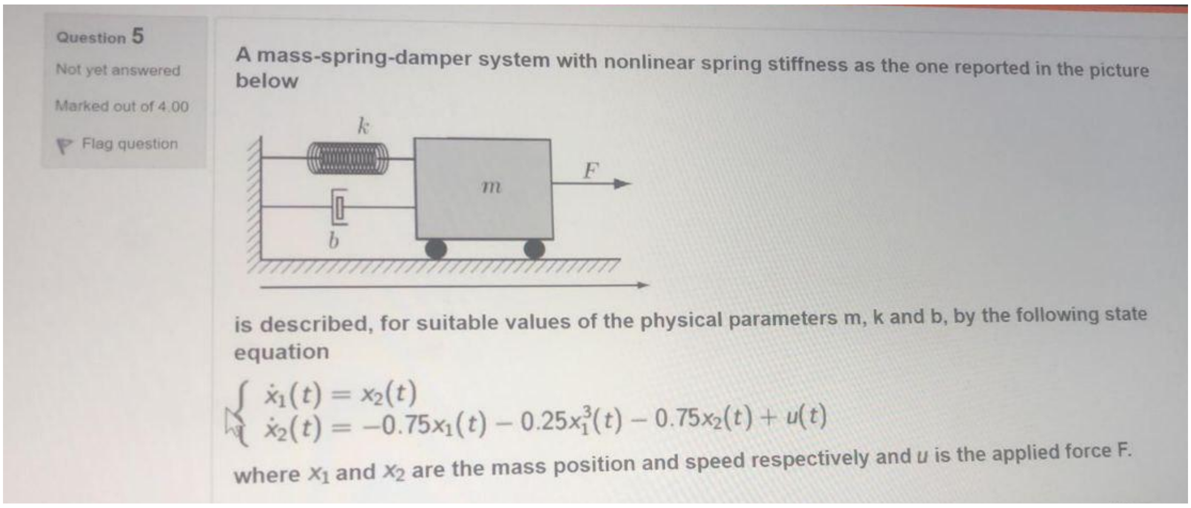
Given an LTI system with transfer function $H(s) = \dfrac{0.1(s+2)}{2s^3+6s^2+5s-1}$, compute, if possible, the steady state response $y_{ss}(t)$ of the output when the input is $u(t) = 0.4\varepsilon(t), t \geq 0$

- (A) $y_{ss}(t) = -0.08\varepsilon(t)$
- (B) $y_{ss}(t) = -0.2\varepsilon(t)$
- (C) $y_{ss}(t) = 0.3029\varepsilon(t)$
- (D) None among the other answers is correct

Answer:

```
H=0.1*(s+2)/(2*s^3+6*s^2+5*s-1);
   pole(H); %has Re(p)>0
   %not BIBO stable, we don't have to compute. Otherwise it would be
   %0.4*dcgain(H)=-0.08;
%D
```

g
INF only



Question 5

Not yet answered

Marked out of 4.00

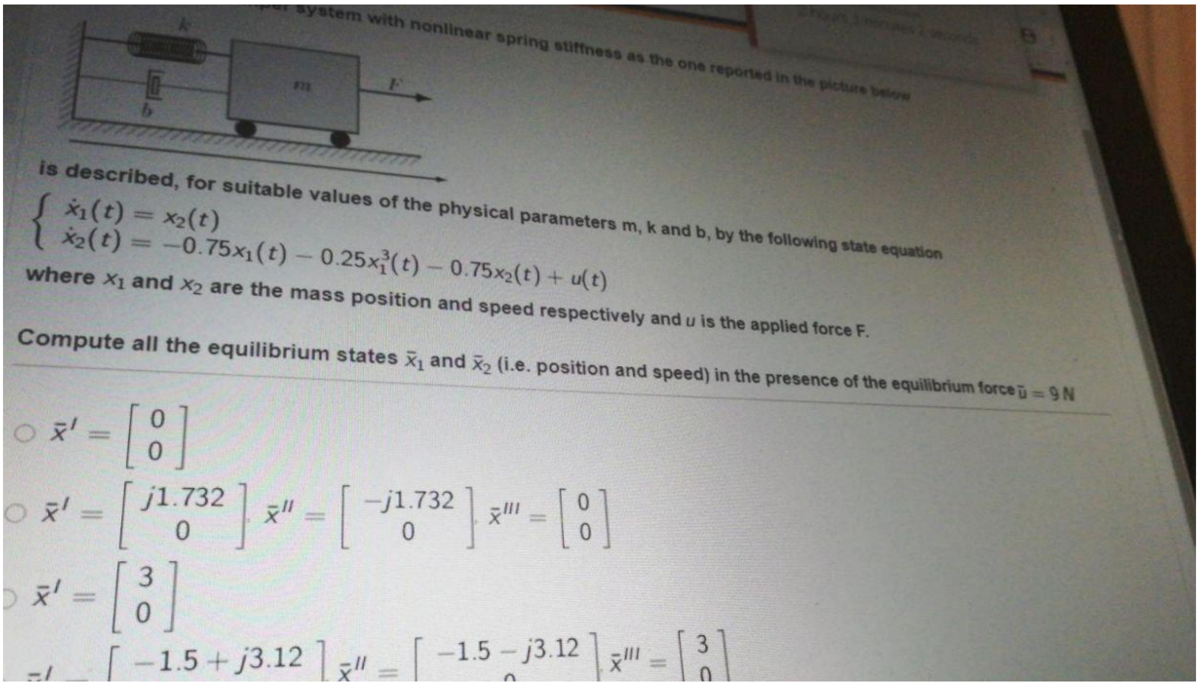
Flag question

A mass-spring-damper system with nonlinear spring stiffness as the one reported in the picture below

is described, for suitable values of the physical parameters m, k and b, by the following state equation

$$\begin{cases} \dot{x}_1(t) = x_2(t) \\ \dot{x}_2(t) = -0.75x_1(t) - 0.25x_1^3(t) - 0.75x_2(t) + u(t) \end{cases}$$

where x_1 and x_2 are the mass position and speed respectively and u is the applied force F.



... system with nonlinear spring stiffness as the one reported in the picture below

is described, for suitable values of the physical parameters m, k and b, by the following state equation

$$\begin{cases} \dot{x}_1(t) = x_2(t) \\ \dot{x}_2(t) = -0.75x_1(t) - 0.25x_1^3(t) - 0.75x_2(t) + u(t) \end{cases}$$

where x_1 and x_2 are the mass position and speed respectively and u is the applied force F.

Compute all the equilibrium states $\bar{x}_1$ and $\bar{x}_2$ (i.e. position and speed) in the presence of the equilibrium force $\bar{u} = 9$ N

- $\bar{x}' = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$
- $\bar{x}' = \begin{bmatrix} j1.732 \\ 0 \end{bmatrix}, \bar{x}'' = \begin{bmatrix} -j1.732 \\ 0 \end{bmatrix}, \bar{x}''' = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$
- $\bar{x}' = \begin{bmatrix} 3 \\ 0 \end{bmatrix}$
- $\bar{x}' = \begin{bmatrix} -1.5 + j3.12 \\ \end{bmatrix}, \bar{x}'' = \begin{bmatrix} -1.5 - j3.12 \\ 0 \end{bmatrix}, \bar{x}''' = \begin{bmatrix} 3 \\ 0 \end{bmatrix}$

f

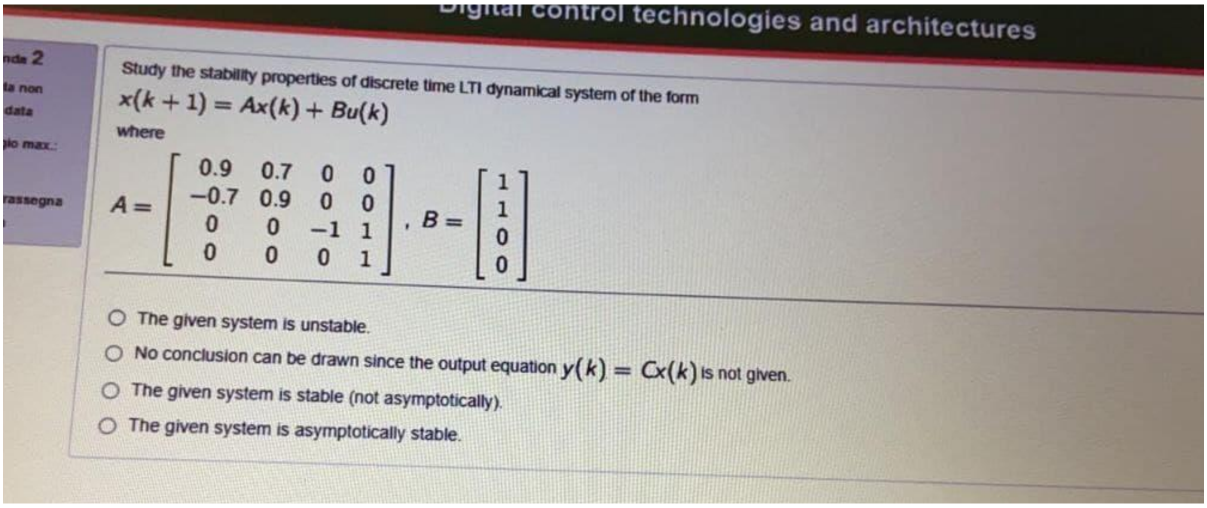
Answers:

From results, x2=0 then x1_dot=0 and x2_dot too.

0=-0.75*x1-0.25*x1^3+9

```
%x2=0, x1 are the solution of
   %-0.75x-0.25x^3+9
   x=[-20:0.01:20];
   y=-0.75*x-0.25*x.^3+9;
   figure(1),plot(x,y),hold ond
   y=0*x;
   figure(1),plot(x,y);
   %intersection only in x=3 if we exclude complex solutions (physical sys)
% x=[3;0] => C

% we can also compute
```

```
close all
clear all
clc
syms 'x'
eqn=-0.75*x-0.25*x^3 + 9 ==0
S=solve(eqn)
ANS. C
```



Digital control technologies and architectures

Study the stability properties of discrete time LTI dynamical system of the form

$x(k+1) = Ax(k) + Bu(k)$

where

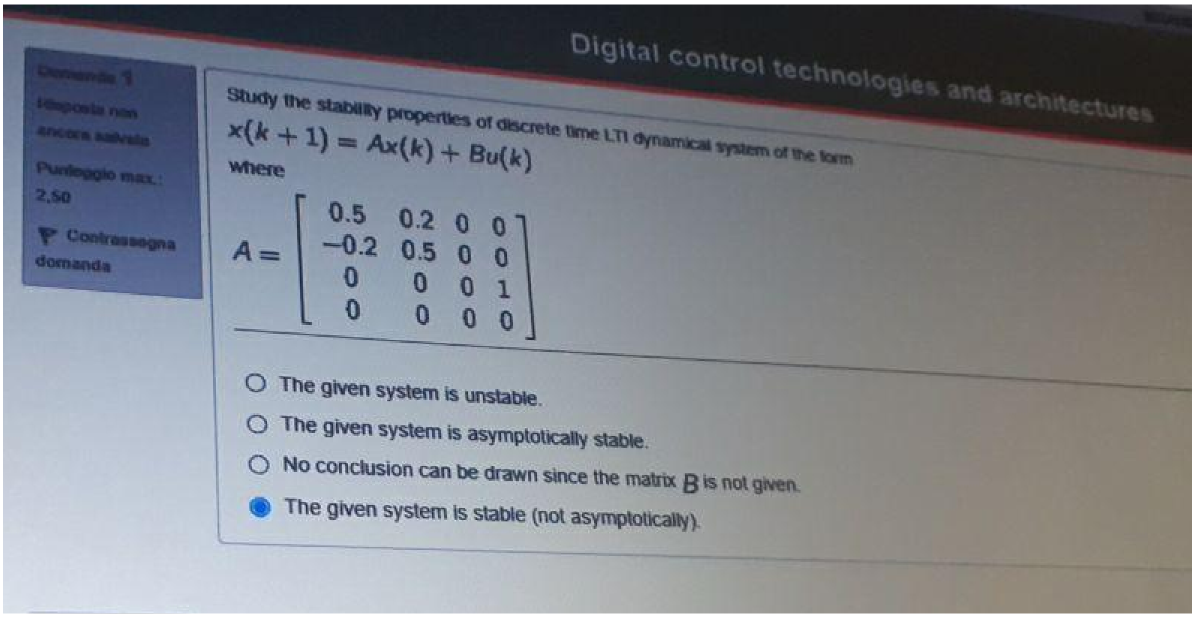
$$A = \begin{bmatrix} 0.9 & 0.7 & 0 & 0 \\ -0.7 & 0.9 & 0 & 0 \\ 0 & 0 & -1 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad B = \begin{bmatrix} 1 \\ 1 \\ 0 \\ 0 \end{bmatrix}$$

- ○ The given system is unstable.
- ○ No conclusion can be drawn since the output equation $y(k) = Cx(k)$ is not given.
- ○ The given system is stable (not asymptotically).
- ○ The given system is asymptotically stable.

Answer:

```
A=[0.9 0.7 0 0;-0.7 0.9 0 0;0 0 -1 1;0 0 0 1];
   e=eig(A);
   abs(e(1)); %we have a pole which |lambda|>1, unstable
%unstable => A
```

INF ONLY



Digital control technologies and architectures

Domanda 1
Risposta non ancora salvata
Punteggio max.: 2,50
Contrassegna domanda

Study the stability properties of discrete time LTI dynamical system of the form
$x(k+1) = Ax(k) + Bu(k)$
where

$$A = \begin{bmatrix} 0.5 & 0.2 & 0 & 0 \\ -0.2 & 0.5 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

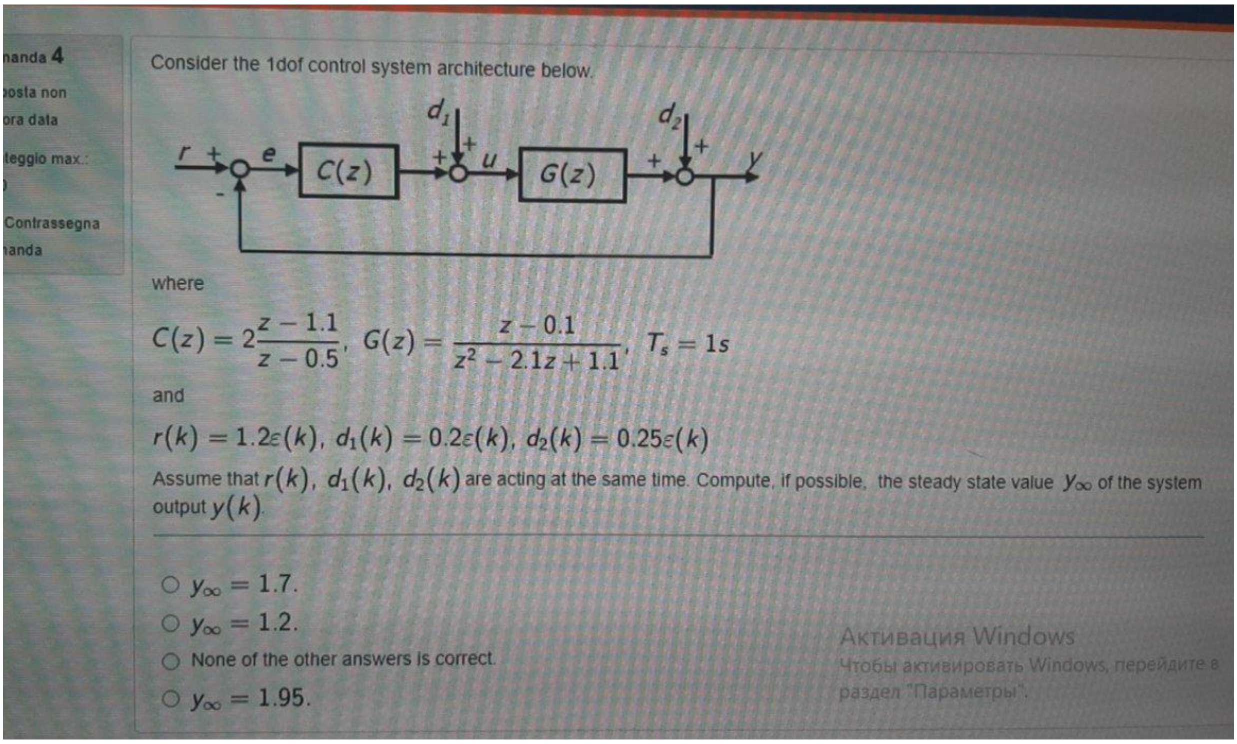
- ○ The given system is unstable.
- ○ The given system is asymptotically stable.
- ○ No conclusion can be drawn since the matrix B is not given.
- ● The given system is stable (not asymptotically).

Answer:

```
A = [0.5 0.2 0 0; -0.2 0.5 0 0; 0 0 0 1; 0 0 0 0];
e = eig(A)
abs(e(1)) % = 0,5385
abs(e(3)) % = 0
```

all the eigenvalues have |lambda| < 1 => asymptotically stable => B

INF only



nanda 4
posta non
ora data
teggio max.:
Contrassegna
nanda

Consider the 1dof control system architecture below.

where

$$C(z) = 2\frac{z-1.1}{z-0.5},\quad G(z) = \frac{z-0.1}{z^2-2.1z+1.1},\quad T_s = 1s$$

and

$$r(k) = 1.2\varepsilon(k),\ d_1(k) = 0.2\varepsilon(k),\ d_2(k) = 0.25\varepsilon(k)$$

Assume that $r(k)$, $d_1(k)$, $d_2(k)$ are acting at the same time. Compute, if possible, the steady state value y_∞ of the system output $y(k)$.

- $y_\infty = 1.7$.
- $y_\infty = 1.2$.
- None of the other answers is correct.
- $y_\infty = 1.95$.

Answer:

```
C = 2 *(z-1.1)/(z-0.5)
G = (z-0.1)/((z-1.1)*(z-1))
%cancellation of the positive pole z=1.1 => system is not stable, Yinf
cannot be computed => C


%otherwise:
%do the design in simulink and plot(y.time,y.data) and check yinf
```

out of the scope of the course

Domanda 3

Risposta non ancora data

Punteggio max.: 4.00

Contrassegna domanda

Given the continuous time LTI system

$$\dot{x}(t) = \begin{bmatrix} -4.5 & 9 \\ -1 & 2 \end{bmatrix} x(t) + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u(t), \quad x(0) = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

$$y(t) = \begin{bmatrix} 0 & -1 \end{bmatrix} x(t)$$

Assume $T_s = 0.03\,s$. Consider the MPC controller defined through the optimization problem below

$$\min_{\Delta U} \sum_{i=0}^{H_p-1} (y(k+i+1 \mid k) - r(i))^T Q (y(k+i+1 \mid k) - r(i)) + \Delta u^T(k+i \mid k) R \Delta u(k+i \mid k)$$

$$\Delta U = [\Delta u(k \mid k) \quad \Delta u(k+1 \mid k) \quad \cdots \quad \Delta u(k+H_p \mid k)], \quad r(i) = 1, i = 0, \dots, H_p - 1$$

together with the following settings

$|u(k|k+i)| \le 1.8,\ i = 0, \dots, H_p - 1$

$|\Delta u(k|k+i)| \le 0.2,\ i = 0, \dots, H_p - 1$

$0 \le y(k|k+i) \le 1.1,\ i = 1, \dots, H_p$

$H_p = H_c = 25$

Choose suitable values of the weight matrices Q and R so that the settling time 1% is such that $t_{s,1\%} \le 3s$

- (A) $Q = 1$ $R = 0.5$
- (B) $Q = 1$ $R = 1$
- (C) $Q = 10$ $R = 1$
- (D) More than one answer is correct.

Answers:

%I think we've never seen something like this in our course

INF only

Given the LTI system

$$\begin{cases} \dot{x}(t) = \begin{pmatrix} -0.6 & -1 \\ 1 & 0 \end{pmatrix} x(t) + \begin{pmatrix} 0.5 \\ 0 \end{pmatrix} u(t) \\ y(t) = (0 \;\; 3) x(t) \end{cases}$$

and the estimated state feedback controller $u(t) = -K\widehat{x}(t) + Nr(t)$.

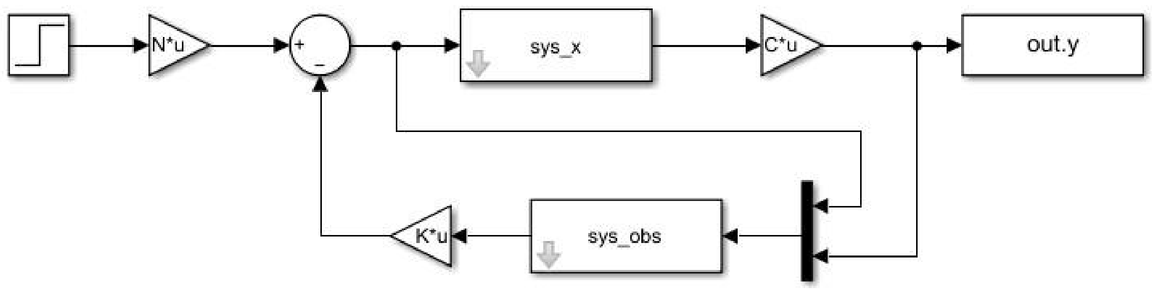
The control law gains are $K = (6.6 \;\; 14.1)$, $N = 5.35$ while the observer gain is $L = (119.5 \;\; 12.8)^T$. Suppose that $x(0) = (-0.1 \;\; 0.1)^T$, $\widehat{x}(0) = (0 \;\; 0)^T$. Evaluate through simulation the control performance in terms of maximum overshoot $\widehat{s}$.

- ○ $\widehat{s} \approx 3.7\%$
- ○ $\widehat{s} \approx 11.4\%$
- ○ $\widehat{s} \approx 7.6\%$
- ○ It is not possible to evaluate the control performance since the controlled system is not stable

Answers:

```
A = [-0.6 -1; 1 0];
B = [0.5;0];
C = [0 3];
D = 0;
K = [6.6 14.1];
N = 5.35;
L = [119.5; 12.8];
x0 = [-0.1; 0.1];
x0_hat = [0; 0];
sys_obs = ss((A-L*C),[B L],eye(2),0);
sys_x = ss(A,B,eye(2),0);
out = sim('quiz.slx');
plot(out.y.time,out.y.data)
grid on
hold on
```

```
%We obtain Ymax = 1.034 and Yinf = 0.977 => s_hat = 3.7% => A
```




```
%Remember to put (in Simulink) x0 inside sys_x and x0_hat inside sys_obs
(initial conditions)!
```

Given an LTI system with transfer function

$$H(s) = \frac{s+5}{s^3+6s^2+50s+90},$$

compute, if possible, the maximum magnitude of the steady state output response When the input is $u(t) = 2 + \sin(4t), t \geq 0$.

- (TO) $\max_t |y_{ss}(t)| = 0.0470$
- (B) $\max_t |y_{ss}(t)| = 0.1111$
- (C) $\max_t |y_{ss}(t)| = 0.1581$
- (D) $\max_t |y_{ss}(t)| = 0.1026$

Answers:

```
H = (s+5)/(s^3+6*s^2+50*s+90)
pole(H) %it's stable so we can compute the ss value
Y_ss_step = dcgain(H)*2
H_at_4i = evalfr(H, 4i)
max_Y_ss_sin = abs(H_at_4i)
max_Y_ss = Y_ss_step + max_Y_ss_sin

%solution 0.1581 => C

%instead of using evalfr, can also use instead [m,f]=bode(H,w) where
in this case w=4 (the coef of t in sine)
m is directly max_Y_ss_sin

%another solution is to compute Yss,1 and Yss,2 by hand, using the
following formulas:
```

Step input $u(t) = A_u \varepsilon(t)$

$$y_{ss}(t) = A_y \varepsilon(t)$$

$$A_y = \lim_{s \to 0} sY(s) = \lim_{s \to 0} sH(s)U(s)$$

Sinusoidal input $u(t) = A_u \sin \omega t$

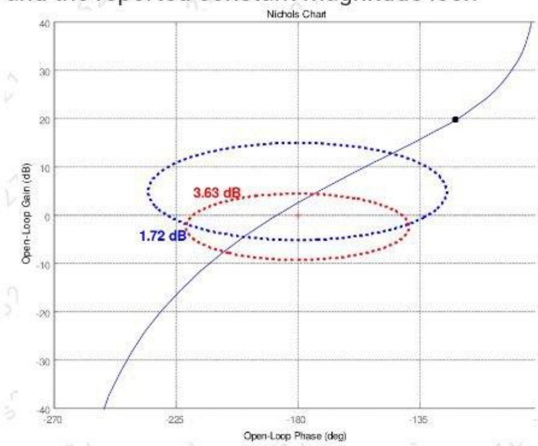
$$y_{ss}(t) = A_y \sin(\omega t + \phi)$$

$$A_y = A_y(j\omega) = A_u |H(j\omega)| \quad \phi = \phi(j\omega) = \angle H(j\omega)$$

Summing them, we obtain the function = (0.111+0.0470*sin(4t-0.9401))*ε(t). Here it is asked to compute the max, so the sin = 1 and at the end we have 0.111+0.0470 = 0.1581 => C

After the steady state design step, the Nichols plot of the loop function $L(s)$ of a unitary feedback system shows the course reported in the figure (the black dot denotes the point corresponding to the desired crossover frequency $\omega_{c,des}$).

Supposing that the controller gain K_c can not be modified, which of the following controller functions can be reasonably employed in order to satisfy the frequency domain requirements described by the desired crossover frequency and the reported constant magnitude loci?



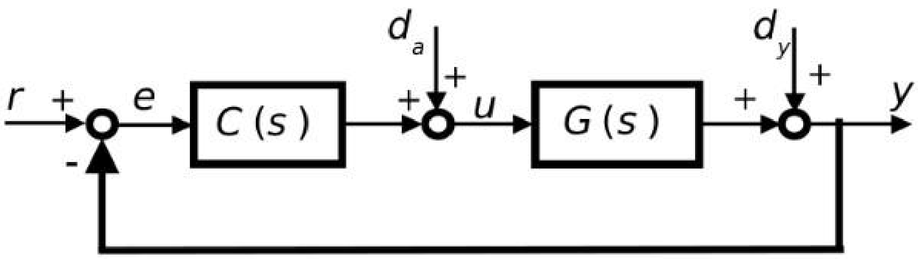
- (A) More than one controller indicated in the other answers
- (B) A lag network
- (C) A lead network
- (D) A proportional controller

Answers:

%we need a magnitude decrease for the gain => lag network => B

In the control system depicted in the figure, we have $G(s) = \dfrac{2}{s^2 + s - 2}$.

Which of the following controllers makes the control system stable?



- [x] $C(s) = \dfrac{5(s+0.5)}{s}$
- [ ] More than one controller among those indicated in the other answers stabilizes the given control system
- [ ] $C(s) = \dfrac{10(s-1)}{s}$
- [ ] $C(s) = \dfrac{4}{s}$

Answers:

```
%Nyquist stability criterion faster than the next solution. Compute L =
G*C, plot or draw Nyquist diagram, calculate N and P numbers and see if N =
-P. This happens only with the first controller transfer function (moreover
we have no cancellations) => A

clc
clear all
s = tf('s')
TOL = 1e-3;
G = 2 / (s^2 + s-2);
C = (5*(s+0.5))/s;
%C = 4 / s; //no
%C = 10*(s-1)/s; // no
P2 = s*(s^2 + s-2) + 8;
P2 = [1 1 -2 8];
roots(P2)
P = s^3 + s^2 + 8*s + 5;
P = [1 1 8 5]
roots(P)
L = G*C
L = zpk(minreal(L, TOL))
%[n, d] = tfdata(L, 'v');
%[r,p] = residue(n, d)
T = zpk(minreal(L /(1+L), TOL))
S = zpk(minreal(1 / (1+L), TOL))
R = zpk(minreal(C / (1 + L), TOL))
Q = zpk(minreal(G / (1+L), TOL))
[n, d] = tfdata(S, 'v');
[rs,ps] = residue(n, d)
```

```
[n, d] = tfdata(T, 'v');
[rt,pt] = residue(n, d)
[n, d] = tfdata(R, 'v');
[rr,pr] = residue(n, d)
[n, d] = tfdata(Q, 'v');
[rq,pq] = residue(n, d)
if ps == pt
   disp('yes')
   if pt == pr
       disp('yes')
   end
       if pr == pq
           disp('yes')
       end
end
s =

  s

Continuous-time transfer function.


ans =

  -2.7673 + 0.0000i
   0.8837 + 1.4526i
   0.8837 - 1.4526i


P =

     1     1     8     5


ans =

  -0.1783 + 2.7819i
  -0.1783 - 2.7819i
  -0.6435 + 0.0000i


L =

     10 s + 5
  ---------------
  s^3 + s^2 - 2 s

Continuous-time transfer function.


L =

   10 (s+0.5)
  -------------
  s (s+2) (s-1)
```

```
Continuous-time zero/pole/gain model.


T =

              10 (s+0.5)
  ----------------------------------
  (s+0.6435) (s^2 + 0.3565s + 7.771)

Continuous-time zero/pole/gain model.


S =

            s (s+2) (s-1)
  ----------------------------------
  (s+0.6435) (s^2 + 0.3565s + 7.771)

Continuous-time zero/pole/gain model.


R =

        5 (s+0.5) (s+2) (s-1)
  ----------------------------------
  (s+0.6435) (s^2 + 0.3565s + 7.771)

Continuous-time zero/pole/gain model.


Q =

                 2 s
  ----------------------------------
  (s+0.6435) (s^2 + 0.3565s + 7.771)

Continuous-time zero/pole/gain model.


rs =

  -0.0902 + 1.7823i
  -0.0902 - 1.7823i
   0.1803 + 0.0000i


ps =

  -0.1783 + 2.7819i
  -0.1783 - 2.7819i
  -0.6435 + 0.0000i


rt =

   0.0902 - 1.7823i
```

```
   0.0902 + 1.7823i
  -0.1803 + 0.0000i


pt =

  -0.1783 + 2.7819i
  -0.1783 - 2.7819i
  -0.6435 + 0.0000i


rr =

   1.1495 + 8.8899i
   1.1495 - 8.8899i
   0.2010 + 0.0000i


pr =

  -0.1783 + 2.7819i
  -0.1783 - 2.7819i
  -0.6435 + 0.0000i


rq =

   0.0809 - 0.3459i
   0.0809 + 0.3459i
  -0.1618 + 0.0000i


pq =

  -0.1783 + 2.7819i
  -0.1783 - 2.7819i
  -0.6435 + 0.0000i

yes
yes
yes
```

There is another better and quicker solution in MatLab by exploiting the Nyquist stability criterion that says that a system is stable if Z is 0.

Nyquist stability criterion

Denote with

- N the number of encirclements of the Nyquist diagram of $L(s)$ around the point (-1 , j0) → **critical point** .
  ($N > 0$ → clockwise, $N < 0$ → counterclockwise).
- Z the number of poles of $T(s)$ with strictly positive real part.
- P the number of poles of $L(s)$ with strictly positive real part.

Then

$$N = Z - P$$

Z can be computed as the number of poles of T(s) with Re[.] > 0, so we can compute L(s), then T(s) and then pole(T) and look at them.
An example with the first C(s) would be:

```
s = tf('s');
G = zpk(minreal(2 / (s^2 + s - 2), 1e-3));
C = zpk(minreal(5 * (s+0.5) / s, 1e-3));
L = zpk(minreal(C * G, 1e-3));
T = zpk(minreal(L / (1 + L), 1e-3));
pole(T)
```

Result:

```
 -0.6435 + 0.0000i
 -0.1783 + 2.7819i
 -0.1783 - 2.7819i
```

Both A and C stabilize the controller, but C introduces a zero-pole cancellation, which we have to avoid! So the solution is A.

7

Answers:

```
H = (s+5)/((s+2)*(s^2+1))
pole(H)
%not all the poles have real part < 0 => you can't compute yss => D
```

A discrete time LTI dynamical system described by the state equation

$$x(k+1) = Ax(k) + Bu(k)$$

is internally asymptotically stable if and only if

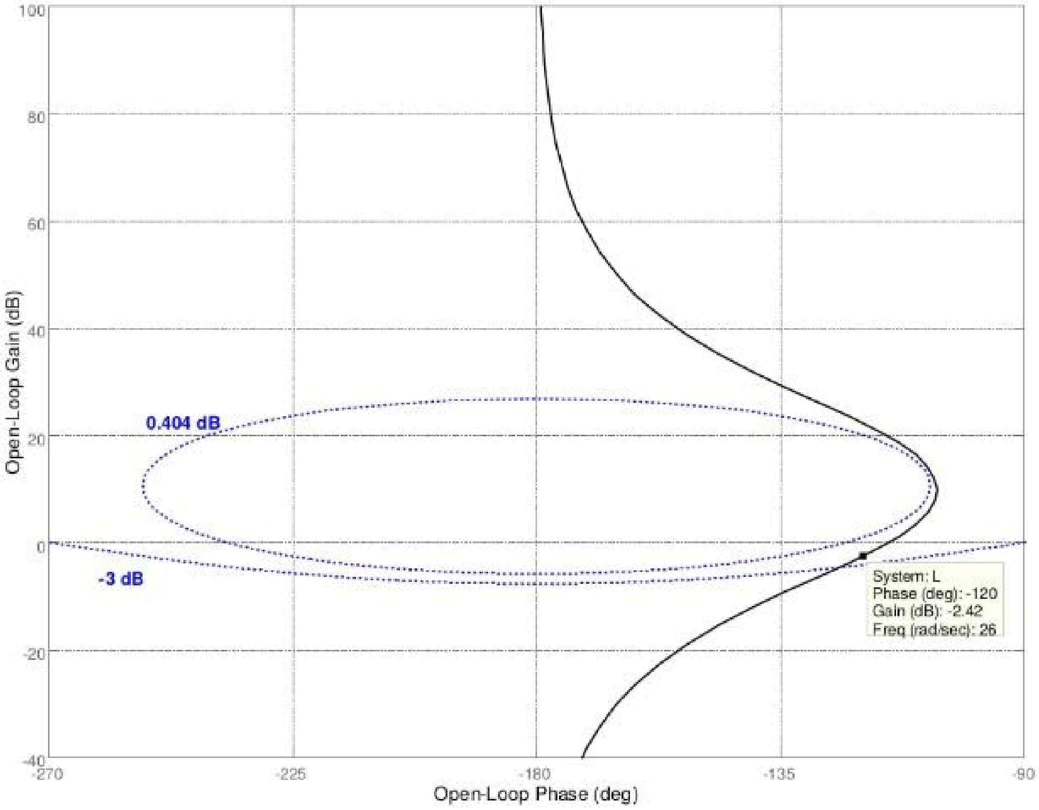
- ◯ All the eigenvalues of A have magnitude smaller or equal to 1
- ◉ All the eigenvalues of A have magnitude strictly smaller than 1
- ◯ There is at least one eigenvalue of A with magnitude greater than 1
- ◯ More than one among the other answers is correct

Answers:

```
%definition from theory => B
```

Consider the Nichols plot of the loop function $L(s)$ of a stable unitary feedback control system depicted in the figure. The constant magnitude loci are referred to the complementary sensitivity function $T(s)$. The point corresponding to the angular frequency $26\ rad/s$ is reported as well.

On the basis of the given Nichols plot, which of the following requirements are surely satisfied?



- ○ $T_p \leq 0.404$ dB, $\omega_b \leq 26\ rad/s$ and $|e_r^\infty| = 0$ for a ramp reference
- ○ $T_p \leq 0.404$ dB, $\omega_b \geq 26\ rad/s$ and $|e_r^\infty| = 0$ for a step reference
- ○ $\hat{S} \leq 10\%$, $\omega_c \leq 26\ rad/s$ and $|e_r^\infty| = 0$ for a ramp reference
- ○ More than one among the other reported answers is correct

Answers:

```
%wb is the frequency at -3 dB. At 26 rad/s the gain is close to -3 dB, and
to reach this value the frequency has to increase a little bit => B
```

in the exercise platform for this question when you select B, it will give you the point. so I guess the following reasoning is wrong.

C is wrong because you cannot say for sure that the overshoot will be smaller than 10%, you need to simulate for that. So you don’t have enough information to say that for sure the overshoot will stay within the threshold even when there is no locus intersection.

INF only

Given the continuous time, nonlinear, time invariant dynamical system

$$\dot{x}_1(t) = x_1(t)\left[1 + x_1(t)x_2(t)\right] - 4x_2(t) - u(t)\sin(x_1(t))$$
$$\dot{x}_2(t) = -3x_1(t) + x_1(t)x_2(t) + x_2(t) + u(t)\cos(x_2(t))$$
$$y(t) = e^{x_1(t)}$$

Compute the matrices of the linearized model

$$\delta\dot{x}(t) = \tilde{A}\delta x(t) + \tilde{B}\delta u(t)$$
$$\delta y(t) = \tilde{C}\delta x(t) + \tilde{D}\delta u(t)$$

obtained by linearizing the given nonlinear system in the equilibrium point

$$(\bar{x}, \bar{u}) : \bar{x} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \ \bar{u} = 0$$

- ○ $\tilde{A} = \begin{bmatrix} 1 & -4 \\ -3 & 1 \end{bmatrix}, \tilde{B} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}, \tilde{C} = \begin{bmatrix} 0 & 0 \end{bmatrix}, \tilde{D} = 0$
- ○ $\tilde{A} = \begin{bmatrix} 1 & -4 \\ -3 & 1 \end{bmatrix}, \tilde{B} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}, \tilde{C} = \begin{bmatrix} 1 & 0 \end{bmatrix}, \tilde{D} = 0$
- ○ $\tilde{A} = \begin{bmatrix} 0 & -4 \\ -3 & 1 \end{bmatrix}, \tilde{B} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \tilde{C} = \begin{bmatrix} 1 & 0 \end{bmatrix}, \tilde{D} = 0$
- ○ $\tilde{A} = \begin{bmatrix} 0 & -4 \\ -3 & 1 \end{bmatrix}, \tilde{B} = \begin{bmatrix} 0 \\ 1 \end{bmatrix}, \tilde{C} = \begin{bmatrix} 1 & 0 \end{bmatrix}, \tilde{D} = 0$

Answers:

```
%Put x1_dot = 0 and x2_dot = 0. After this, use the following formulas to
compute the matrices:
```

$$A = \left.\frac{\partial f(x,u)}{\partial x}\right|_{\substack{x=\bar{x}\\ u=\bar{u}}} \quad B = \left.\frac{\partial f(x,u)}{\partial u}\right|_{\substack{x=\bar{x}\\ u=\bar{u}}}$$

$$C = \left.\frac{\partial g(x,u)}{\partial x}\right|_{\substack{x=\bar{x}\\ u=\bar{u}}} \quad D = \left.\frac{\partial g(x,u)}{\partial u}\right|_{\substack{x=\bar{x}\\ u=\bar{u}}}$$

%we obtain the second answer => B

two questions of stability showed up, verified by emails

1-the system is internally stable if

- [ ] 1-if all the eigenvalues of A have a negative real part.
- [ ] 2-all poles of the transfer function have a negative real part
- [ ] 3-More than one answer is correct.
- [ ] 4-all poles of the transfer function have a strictly negative real part

2-system is bibo stable if

- [ ] 1-if all the eigenvalues of A have a negative real part.
- [ ] 2-all poles of the transfer function have a negative real part
- [ ] 3-More than one answer is correct.
- [ ] 4-all poles of the transfer function have a strictly negative real part