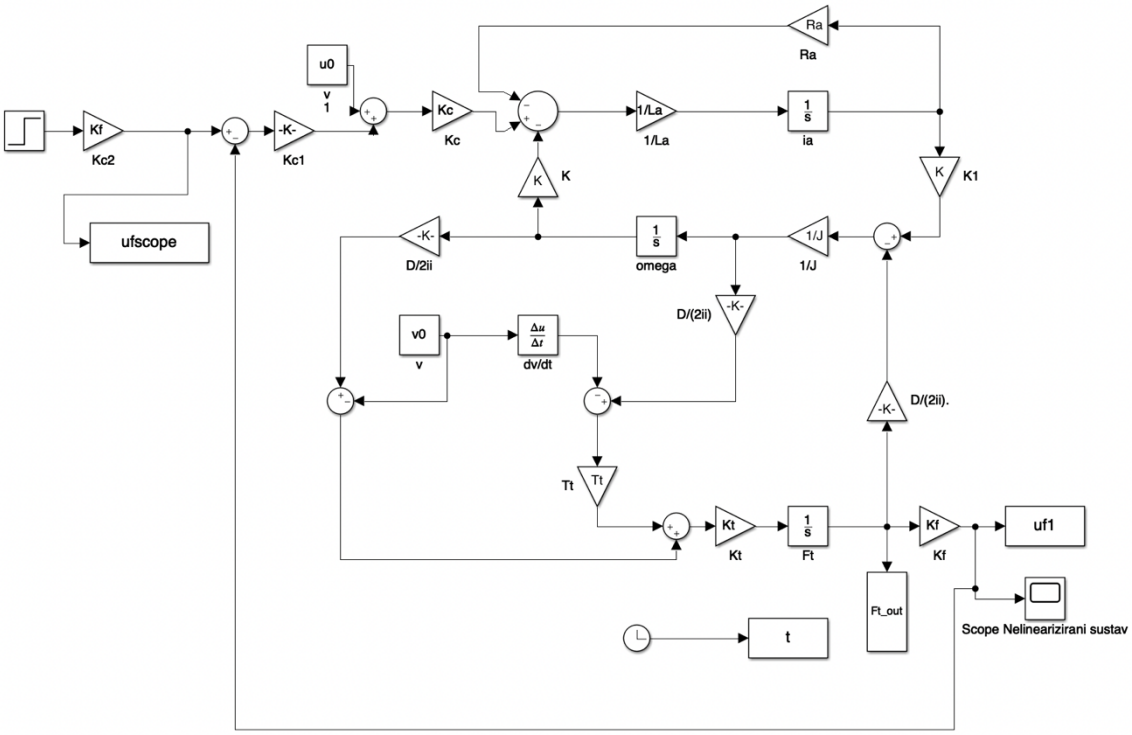
II. Priprema za vježbu:

a) Nacrtati blokovsku shemu dinamičkog matematičkog modela razmatranog procesa upravljanog P-regulatorom te izraditi simulacijski model razmatranog procesa u Simulinku. Model donijeti na vježbu.



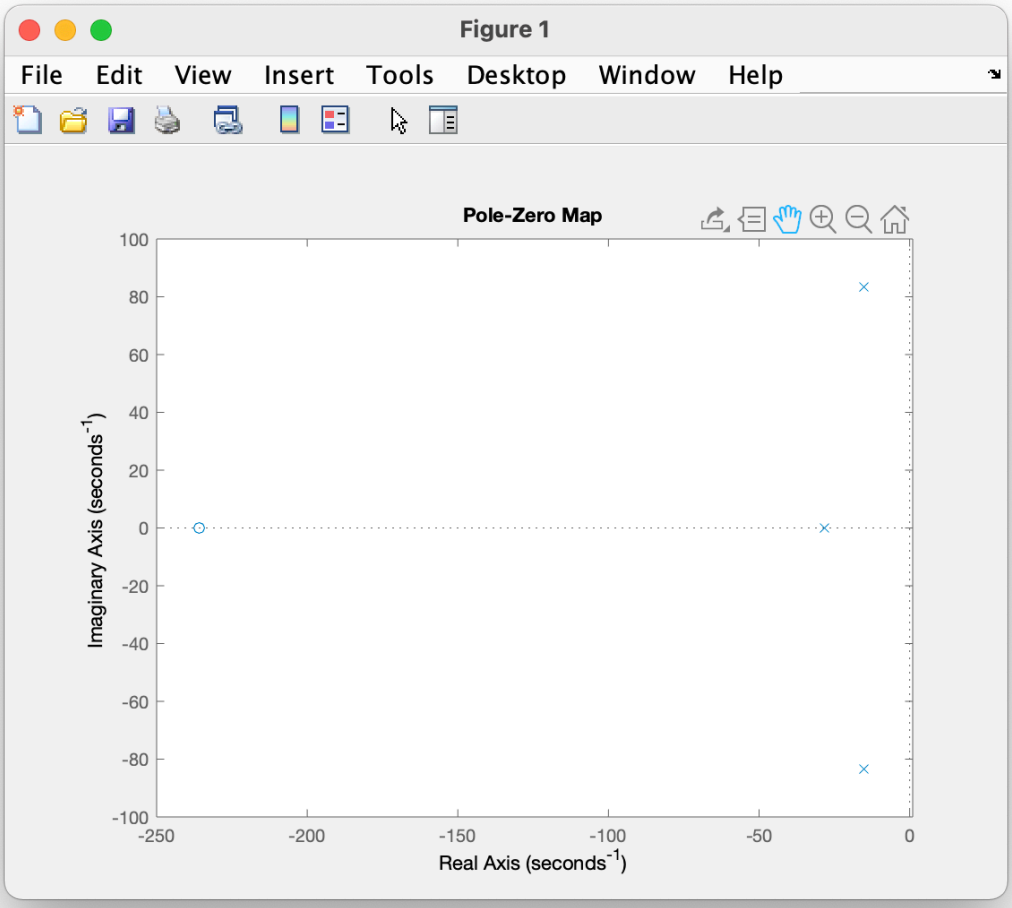
b) Nacrtati polove i nule prijenosne funkcije procesa u *s*-ravnini.

Polovi i nule:

```
44 -    P = pole(G)
45 -    Z= zero(G)
```

```
Command Window
  P =

   -15.2452 +83.4635i
   -15.2452 -83.4635i
   -28.2184 + 0.0000i


  Z =

   -235.8491
```

Naredba pzplot(G) ih crta:



c) Pomoću Hurwitzovog kriterija stabilnosti odrediti područje vrijednosti pojačanja P-regulatora za koje je regulacijski krug stabilan. Prikažite izračun.

STANDARDNI OBLIK

a) $G_0 = \frac{(0{,}28907 s + 63{,}17857) K}{4{,}9242 \cdot 10^{-6} s^3 + 2{,}3907 \cdot 10^{-4} s^2 + 0{,}039685 s + 1}$

$G_{zk} = \frac{G_0}{1+G_0} \Rightarrow$

$$\frac{(0{,}28907 s + 63{,}17857) K}{4{,}9242 \cdot 10^{-6} s^3 + 2{,}3907 \cdot 10^{-4} s^2 + 0{,}039685 s + 1}$$

$$1 + \frac{(0{,}28907 s + 63{,}17857) K}{4{,}9242 \cdot 10^{-6} s^3 + 2{,}3907 \cdot 10^{-4} s^2 + 0{,}039685 s + 1}$$

$$= \frac{(0{,}28907 s + 63{,}17857) K}{4{,}9242 \cdot 10^{-6} s^3 + 2{,}3907 \cdot 10^{-4} s^2 + 0{,}039685 s + 1}$$

$$\frac{(0{,}28907 s + 63{,}17857) K}{4{,}9242 \cdot 10^{-6} s^3 + 2{,}3907 \cdot 10^{-4} s^2 + 0{,}039685 s + 1 + (0{,}28907 s + 63{,}17857) K}$$

$$= \frac{(0{,}28907 s + 63{,}17857) K}{4{,}9242 \cdot 10^{-6} s^3 + 2{,}3907 \cdot 10^{-4} s^2 + 0{,}039685 s + 1 + (0{,}28907 s + 63{,}17857) K}$$

$a_3 \Rightarrow 4,2447 \cdot 10^{-4}$

$a_2 \Rightarrow 2,8507 \cdot 10^{-4}$

$a_1 \Rightarrow 0,039685 + k\,0,28207 > 0$

$a_0 \Rightarrow 1 + 68,1785k > 0$

$k\,0,28207 > -0,039685$

$k > -0,1373$

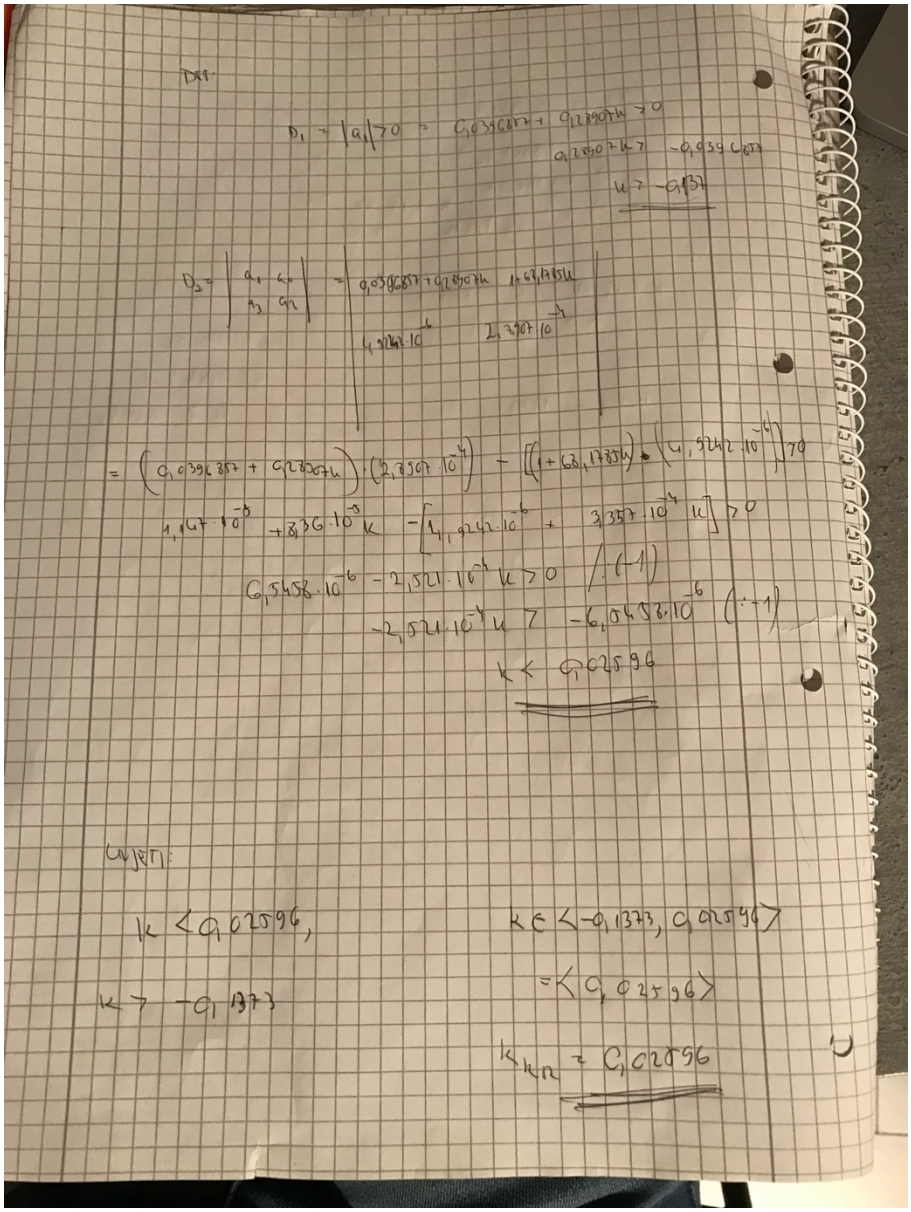
$1 + 68,1785k > 0$

$68,1785k > -1$

$k > -0,0146$

$k > -0,1373$

$k \in]-0,1373, \infty[$



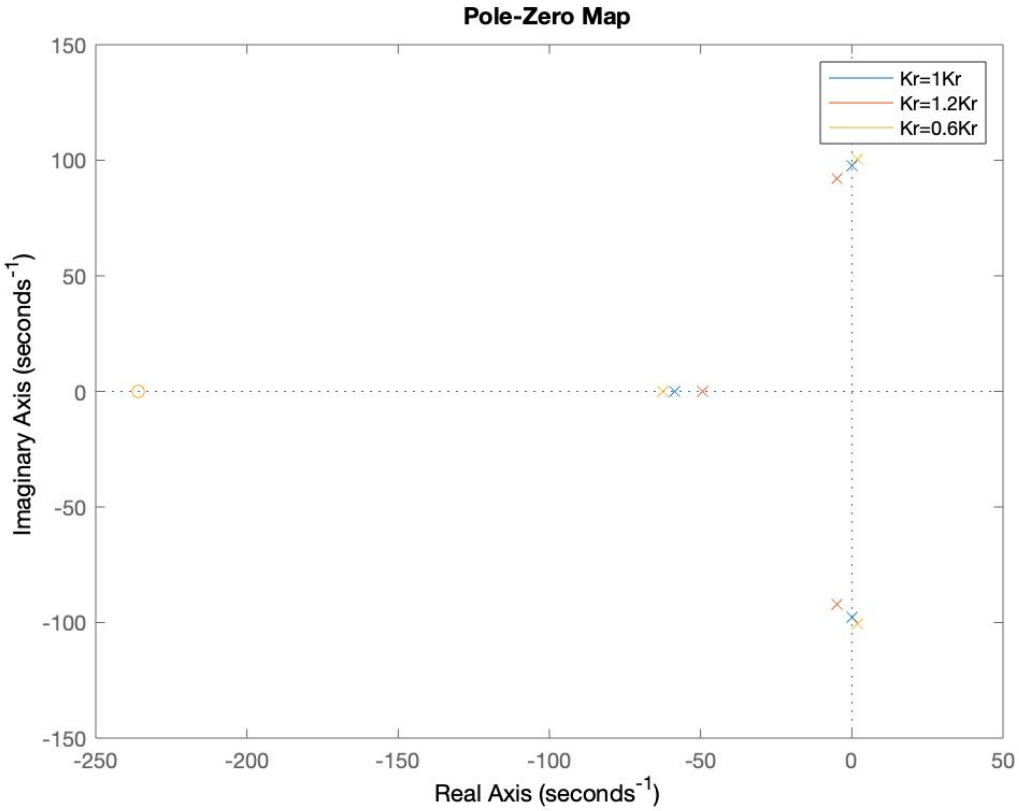
III. Rad na vježbi:

Za tri različite vrijednosti pojačanja regulatora $K_R = 0.6\ K_{R,kr}$, $K_R = K_{R,kr}$ i $K_R = 1.2\ K_{R,kr}$ uradite sljedeće:

1. a) Simulacijom odredite odziv regulacijskog kruga na skokovitu promjenu referentne veličine sile napetosti F_r s F_{T0} na $1.1 \cdot F_{T0}$.

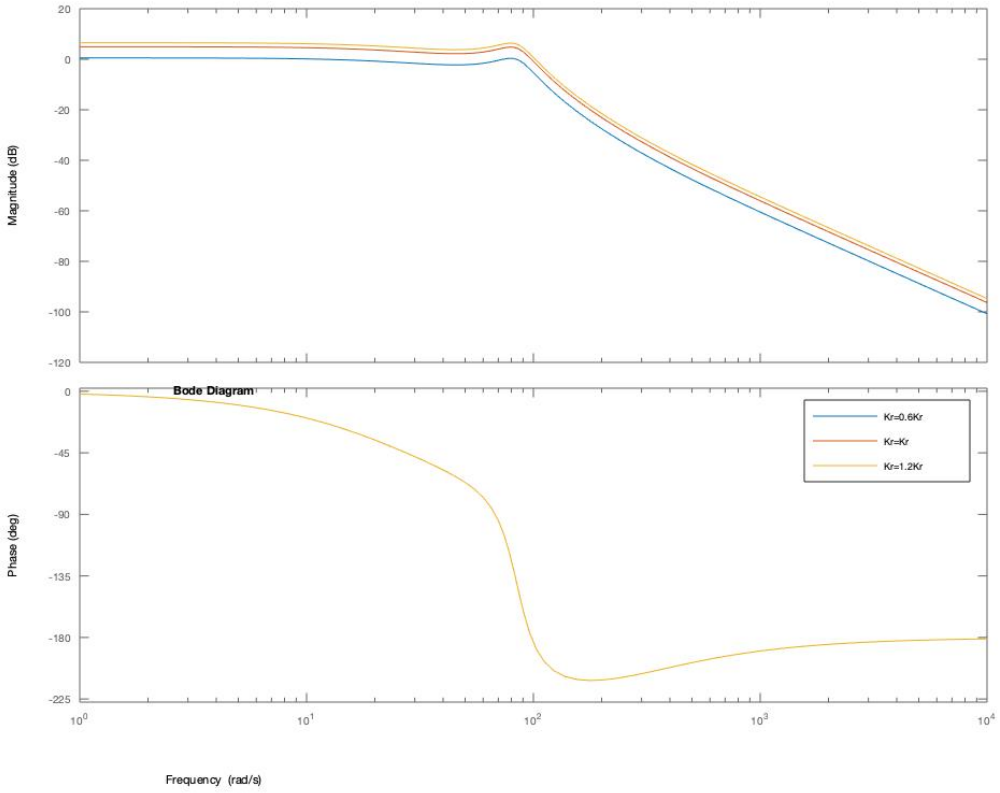
2. b) Naredbama Matlaba nacrtati polove i nule regulacijskog kruga u s-ravnini.

```
%pokusavam nesto
%obicniKr
num1 = [0.28907*0.02596 68.17857*0.02596]
den1 = [4.9242*10^-6 2.8907*10^-4 0.0396857+0.02596*0.28907 1+68.1785*0.02596]
fja1 = tf(num, den)


%kr je 0.6Kr
numv = [0.28907*0.015576 68.17857*0.015576]
denv = [4.9242*10^-6 2.8907*10^-4 0.0396857+0.015576*0.28907 1+68.1785*0.015576]
fjav = tf(numv, denv)


%kr je 1.2Kr
numm = [0.28907*0.031152 68.17857*0.031152]
denm = [4.9242*10^-6 2.8907*10^-4 0.0396857+0.031152*0.28907 1+68.1785*0.031152]
fjam = tf(numm, denm)


pzmap(fja1, fjav, fjam)
legend('Kr=1Kr', 'Kr=1.6Kr', 'Kr=0.2Kr')
```



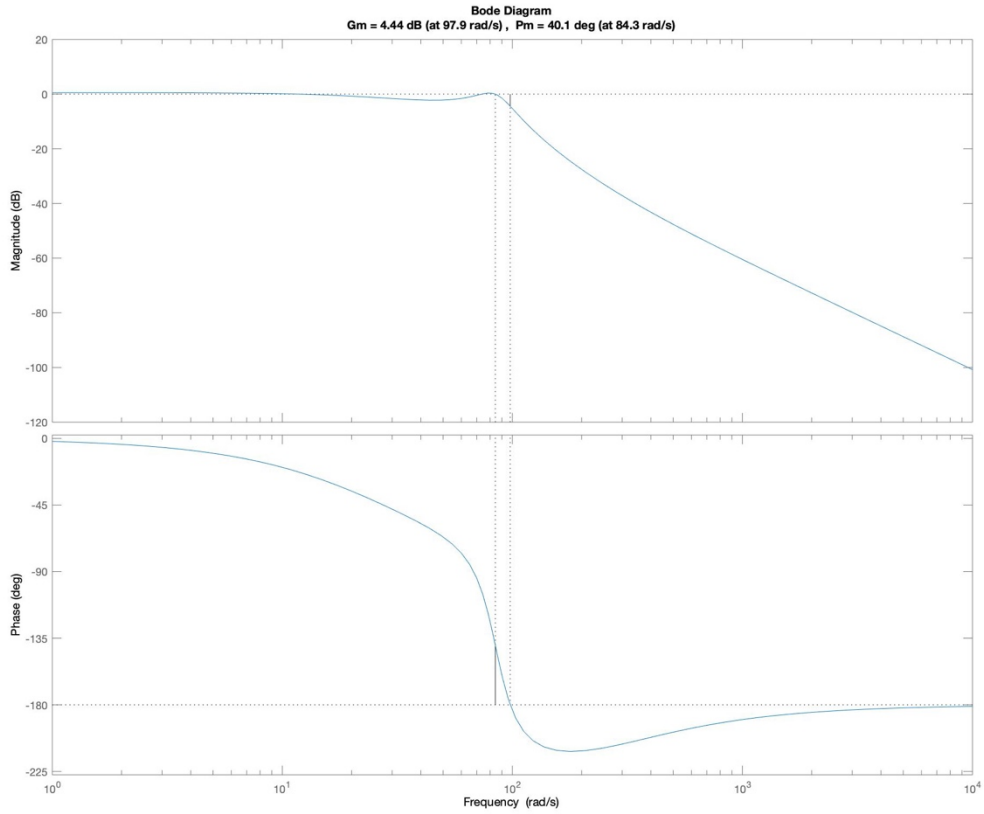
3. c) Naredbama Matlaba nacrtati Bodeov dijagram i odrediti fazno osiguranje, amplitudno osiguranje i presječnu frekvenciju.

```
87
88      %pokusaj bodea
89
90 -    numb = [0.28907*0.02596 68.17857*0.02596]
91 -    denb = [4.9242*10^-6 2.8907*10^-4 0.039685 1]
92
93 -    numb12 = [0.28907*0.031152 68.17857*0.031152]
94 -    denb12 = [4.9242*10^-6 2.8907*10^-4 0.039685 1]
95
96
97 -    numb06 = [0.28907*0.015576 68.17857*0.015576]
98 -    denb06 = [4.9242*10^-6 2.8907*10^-4 0.039685 1]
99
100
101
102
103 -    funkcijabode = tf(numb, denb)
104 -    funkcijabode12 = tf(numb12, denb12)
105 -    funkcijabode06 = tf(numb06, denb06)
106
107 -    bode(funkcijabode06, funkcijabode, funkcijabode12)
108 -    title('funkcijabode bode');
109 -    legend('Kr=0.6Kr', 'Kr=Kr', 'Kr=1.2Kr')
110
```



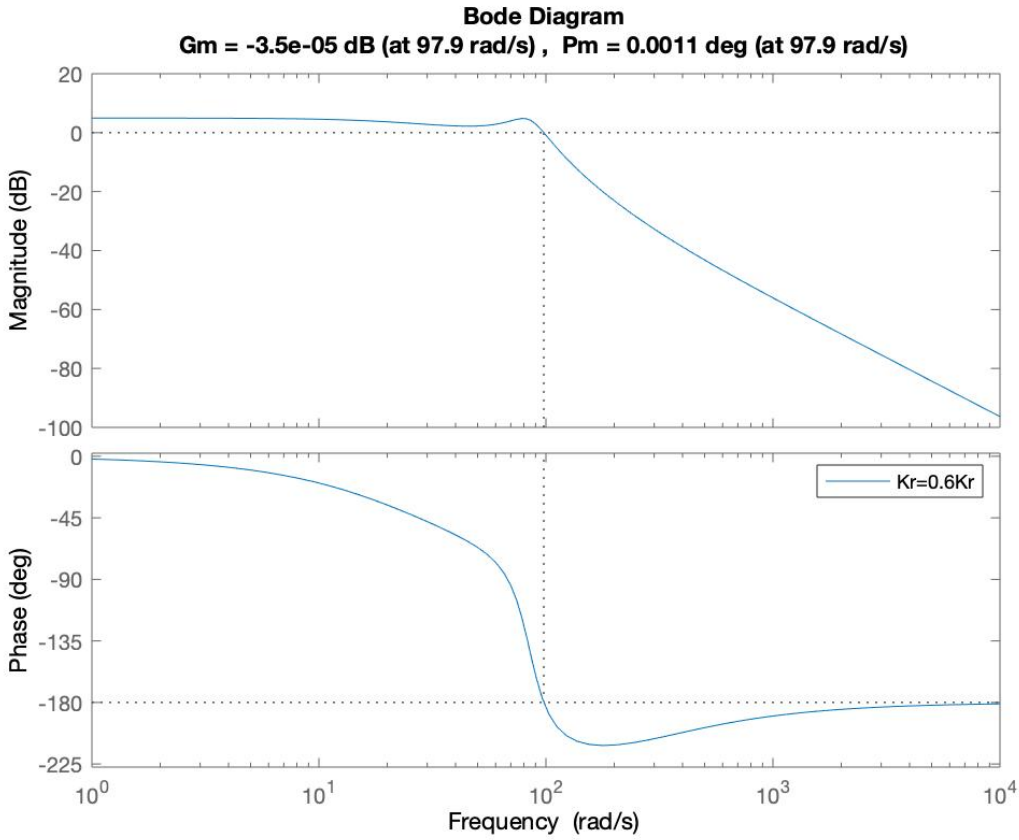
Za Kr = 0.6Kr

A_r=4.44(ispod osi)dB ω_π=97.9rad/s ω_c=84.3rad/s γ=40.1deg



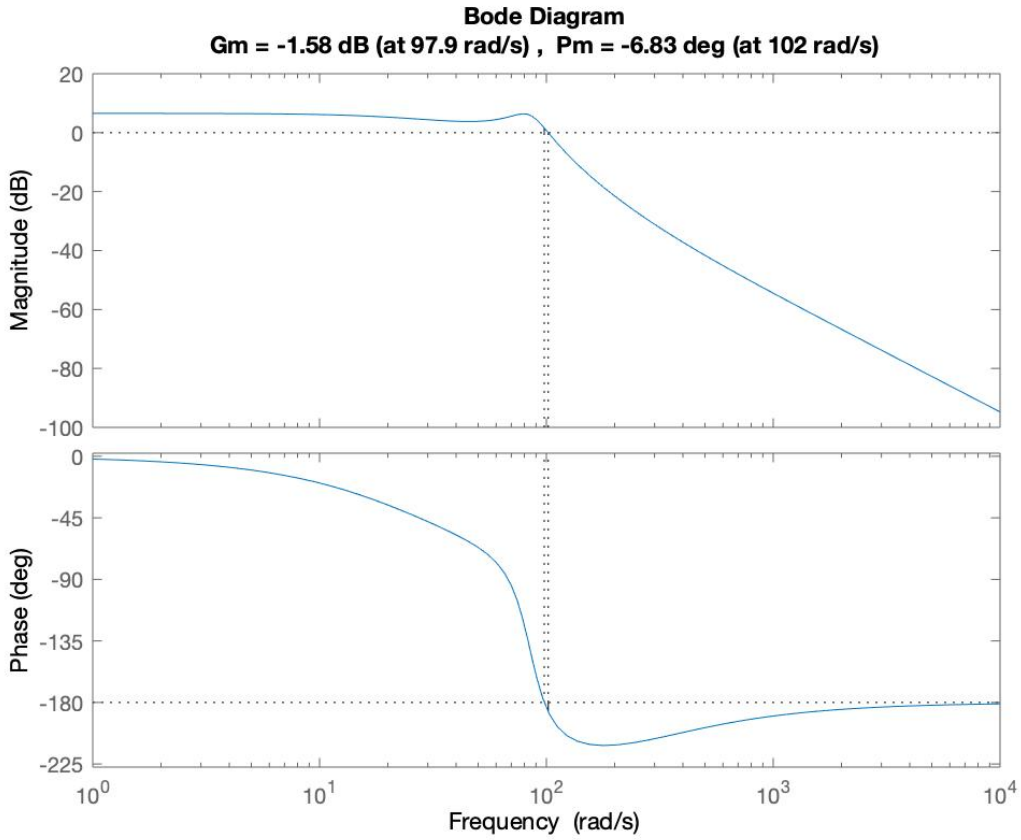
Za Kr=Kr

A_r=-0.000035dB ω_π=97.9 rad/s ω_c=97.9rad/s γ=0.0011deg



Za Kr=1.2 Kr

A_r=-1.58dB (iznad x osi) ω_π=97.9rad/s ω_c=102rad/s γ=-6.83deg



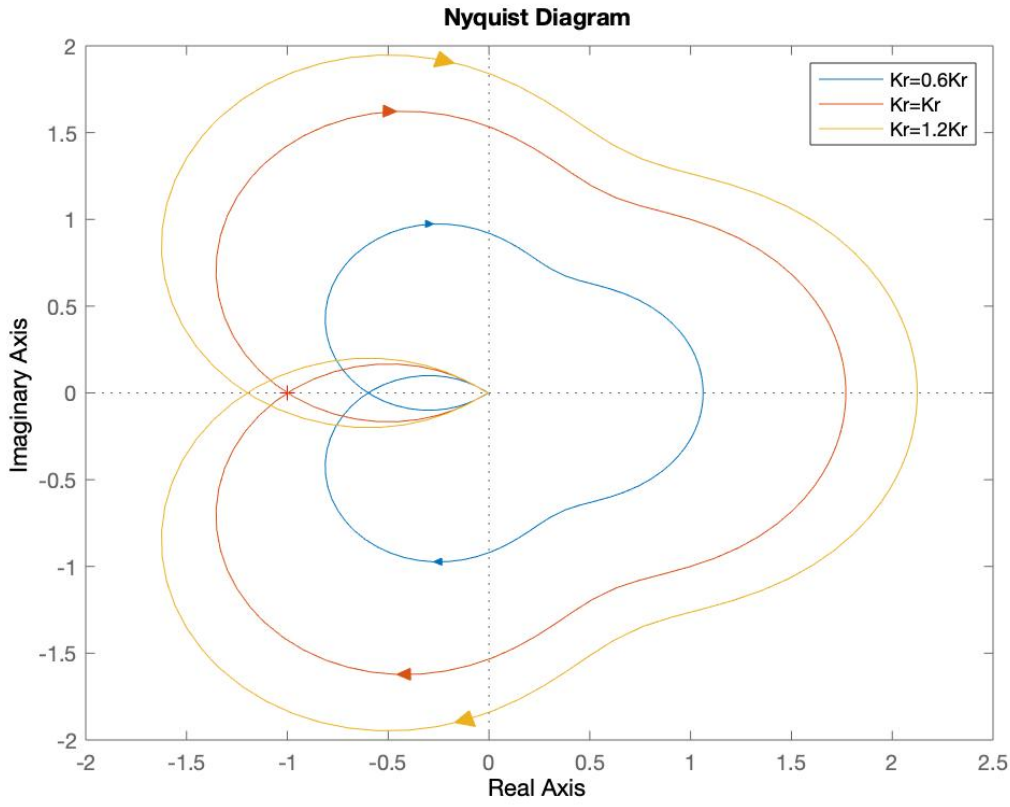
4. d) Naredbama Matlaba nacrtati Nyquistov dijagram. Usporediti dijagrame za zadana pojačanja.

```
denb06 = [4.9242*10^-6 2.8907*10^-4 0.039685 1]
```

```
%
funkcijabode = tf(numb, denb)
funkcijabode12 = tf(numb12, denb12)
funkcijabode06 = tf(numb06, denb06)

% bode(funkcijabode06, funkcijabode, funkcijabode12);
% title('funkcijabode bode');
% legend('Kr=0.6Kr', 'Kr=Kr', 'Kr=1.2Kr');

nyquist(funkcijabode06, funkcijabode, funkcijabode12)
legend('Kr=0.6Kr','Kr=Kr','Kr=1.2Kr')
```

5.

```
%Rabimo = pole((Kr)*fja)
```



6.

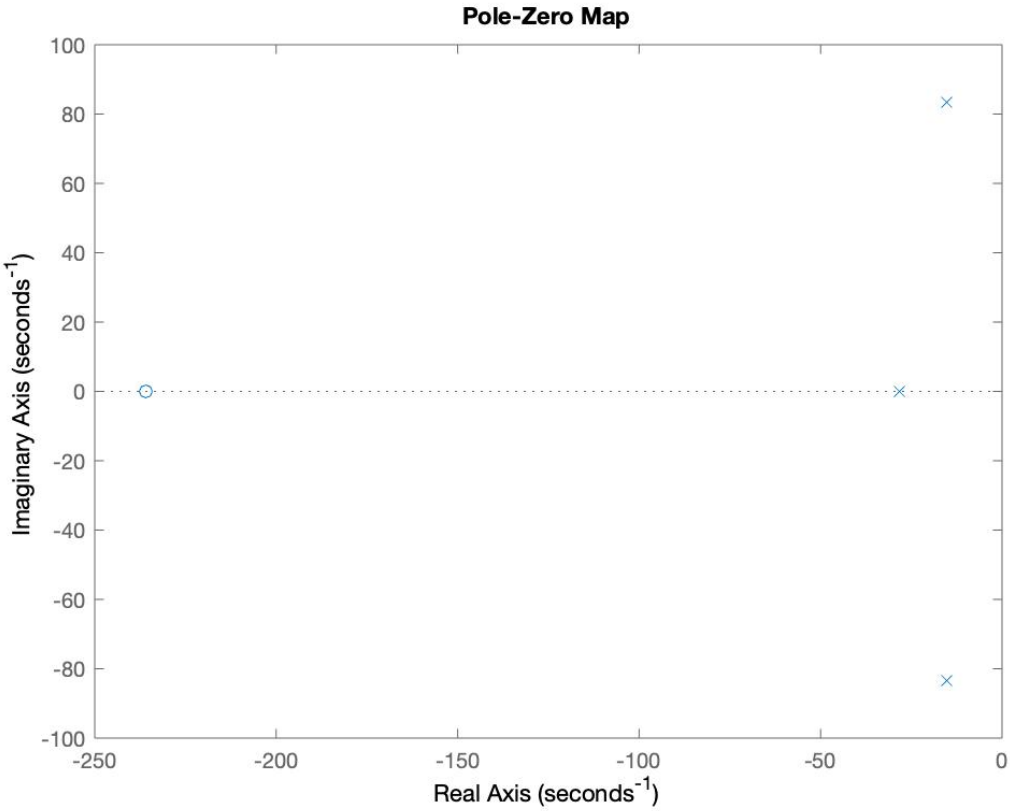
Neke od naredbi Matlaba korisne za rad na vježbi:

margin, bode, nyquist, zoom, pzmap, feedback

IZVJEŠTAJ

Odgovorite na sljedeća pitanja.

1. a) Prikažite polove i nule prijenosne funkcije procesa u *s*-ravnini.



b) Koliko iznosi najveće pojačanje regulatora za koje je regulacijski krug stabilan, tj. vrijednost **[1]** $K_{R,kr}$ dobivena u točki c) pripreme za vježbu? **[1]**

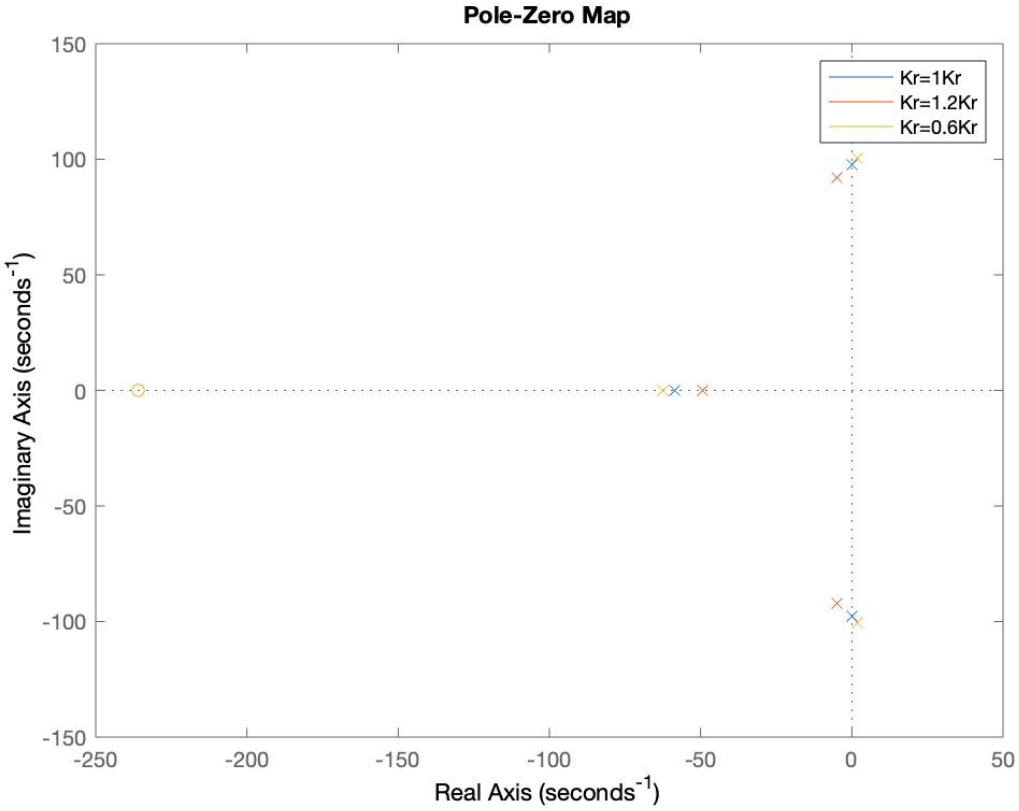
Odgovor: Kr= 0.02596

c) Napišite karakteristični polinom prijenosne funkcije zatvorenog kruga u standardnom obliku.

[1]

4.9242*10^-6 s^3 + 2.8908*10^-4 s^2 + 0.0396857s + 1 + Kr*0.28907s+ Kr*68.1785 = 0

4. d) Na istom grafu prikažite polove i nule zatvorenog regulacijskog kruga za $K_R = 0.6\ K_{R,kr}$, $K_R = K_{R,kr}$ te $K_R = 1.2\ K_{R,kr}$. Dodajte legendu **[2]**



5. e) Odrediti amplitudno osiguranje A_r, frekvenciju ω_π, fazno osiguranje γ i presječnu frekvenciju ω_c regulacijskog kruga ako se koristi *P* regulator:
   i. $K_R = 0.6\ K_{R,kr}$; **[2]** ii. $K_R = K_{R,kr}$; **[2]** iii. $K_R = 1.2\ K_{R,kr}$; **[2]**

Za Kr = 0.6Kr

A_r=4.44(ispod osi)dB ω_π=97.9rad/s ω_c=84.3rad/s γ=40.1deg

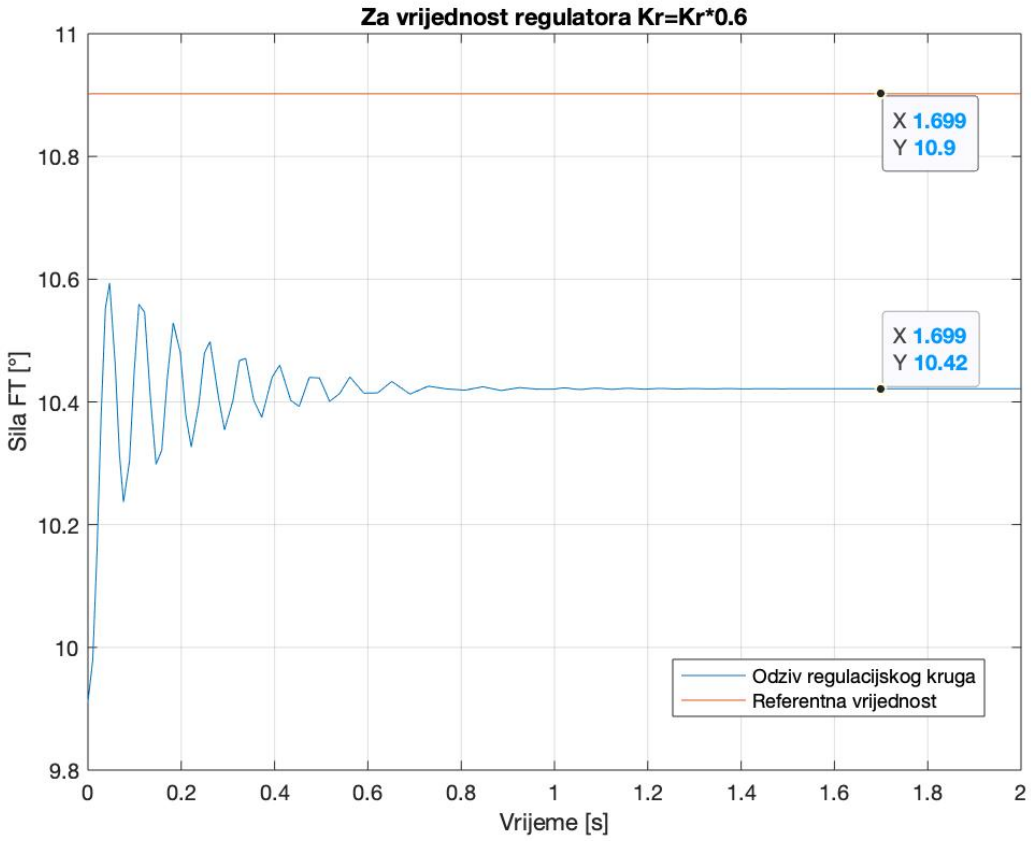
Za Kr=Kr

A_r=-0.000035dB ω_π=97.9 rad/s ω_c=97.9rad/s γ=0.0011deg

Za Kr=1.2 Kr

A_r=-1.58dB (iznad x osi) ω_π=97.9rad/s ω_c=102rad/s γ=-6.83deg

6. f) Za vrijednosti pojačanja regulatora $K_R = 0.6\ K_{R,kr}$ i skokovitu promjenu referentne veličine sile napetosti F_r s F_{T0} na $1.1 \cdot F_{T0}$,
   i. prikažite odziv regulacijskog kruga. **[1]**



ii. koliko iznosi pogreška u stacionarnom stanju ε_∞ ? **[1]**

7. ε_∞= 0.48V referenca – izlaz sustava sve kroz referencu puta 100%

i. koliko iznosi maksimalno nadvišenje σ_m ? **[1]**

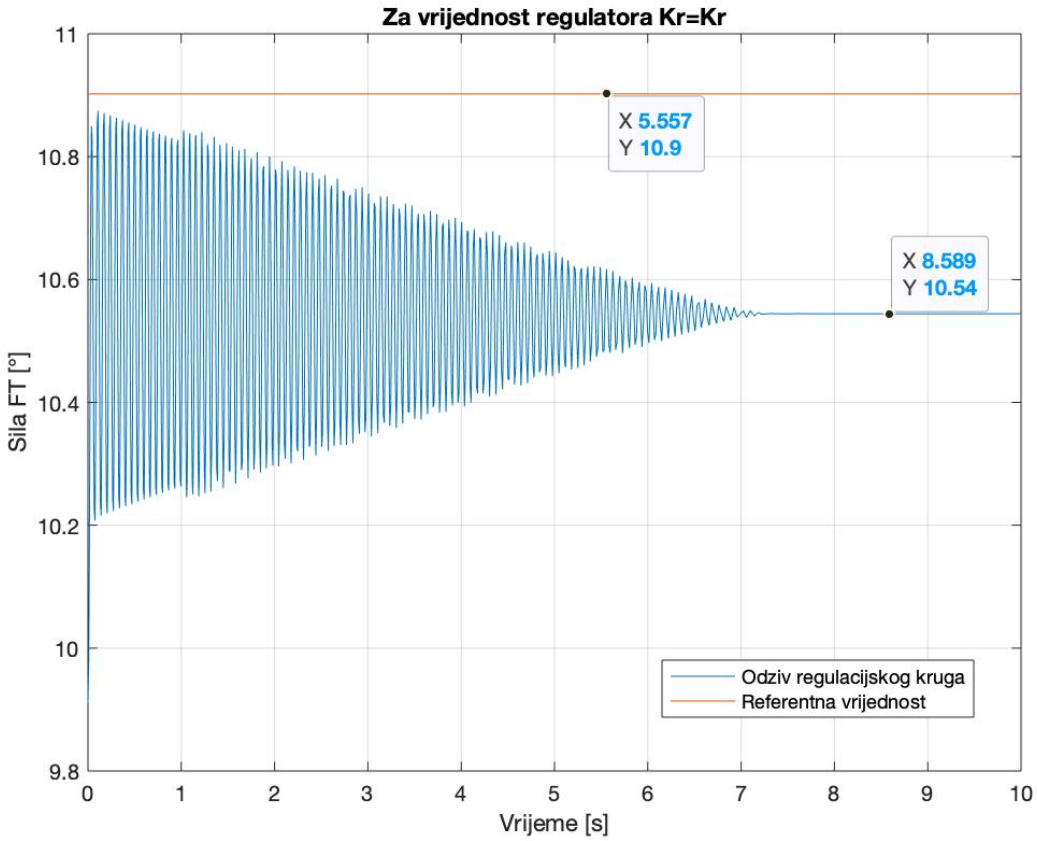
(ymax - ys) / (ys - ymin) sve puta 100%

Ymax = 10.59, ys=10.42… ymin=10.23

10.42 do 10.59

8. g) Za vrijednosti pojačanja regulatora $K_R = K_{R,kr}$ i skokovitu promjenu referentne veličine sile napetosti F_r s F_{T0} na $1.1 \cdot F_{T0}$,

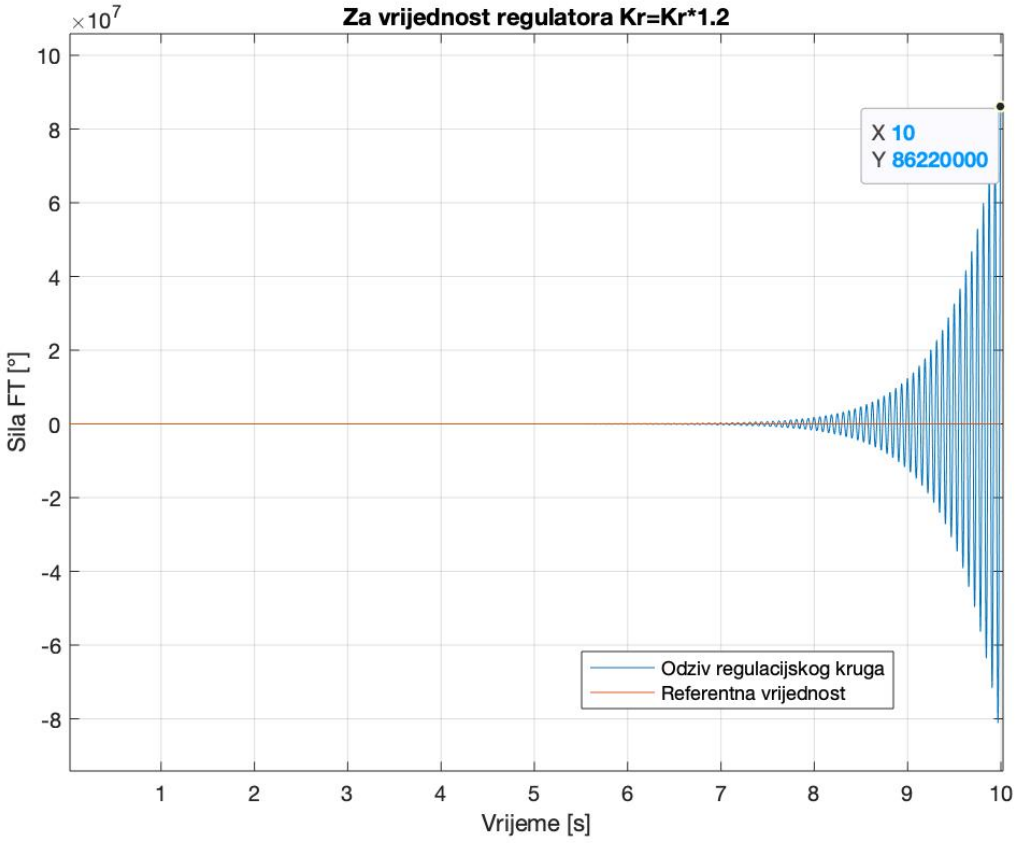
i. prikažite odziv regulacijskog kruga. **[1]**



ii. koliko iznosi pogreška u stacionarnom stanju ε_∞? **[1]**

$\varepsilon_\infty = 0.36V$

9. h) Za vrijednosti pojačanja regulatora $K_R = 1.2\ K_{R,kr}$ i skokovitu promjenu referentne veličine sile napetosti F_r s F_{T0} na $1.1 \cdot F_{T0}$,
   i. prikažite odziv regulacijskog kruga. **[1]**



   ii. koliko iznosi pogreška u stacionarnom stanju ε_∞?

ε_∞ = 8.622e+07