Tecnológico de Monterrey

Control engineering

PhD. Enrique Aguayo

Second
Simulation Project

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Birthday September 17^{th}

- A = 17
- B = 9
- C = 26

I used the following formulas to obtain the values of Kc, Ti and Td of PID

Sustained oscillations

Ziegler-Nichols (1942)

2. Obtain the values for Kc, Ti and Td

	Kc	Ti	Td
P	$\frac{K_u}{2}$		
PI	$\frac{K_u}{2.2}$	$\frac{t_u}{1.2}$	
PID	$\frac{K_u}{1.7}$	$\frac{t_u}{2}$	$\frac{t_u}{8}$

Damped oscillations

Harriot (1957)

2. Obtain the values for Kc, Ti and Td

	Kc	Ti	Td
P	K_o		
PI	K_o	t_o	
PID	K_o	$\frac{t_o}{1.5}$	$\frac{t_o}{6}$

System 1

Proportional controller

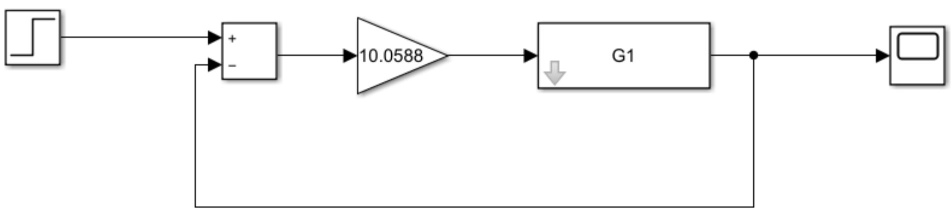
System 1

$G(s) = \frac{17K}{26s + 9 + 17K}$ $= \frac{17K}{9+17K} = .95$ K= 10.0588

K > 0 $\frac{17K}{9+17K} = 1.05$ K=-11.1176

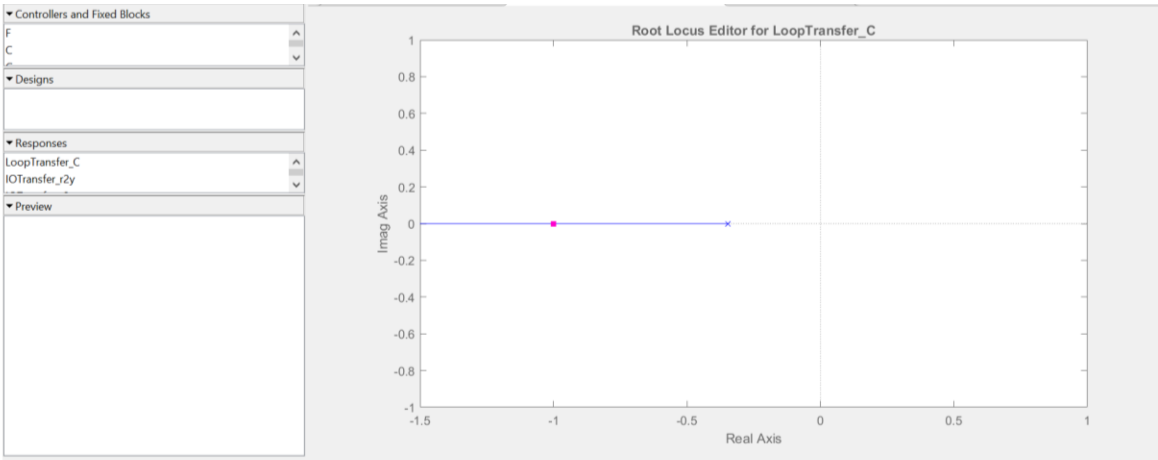
K= 10.0588

K = 10.0588



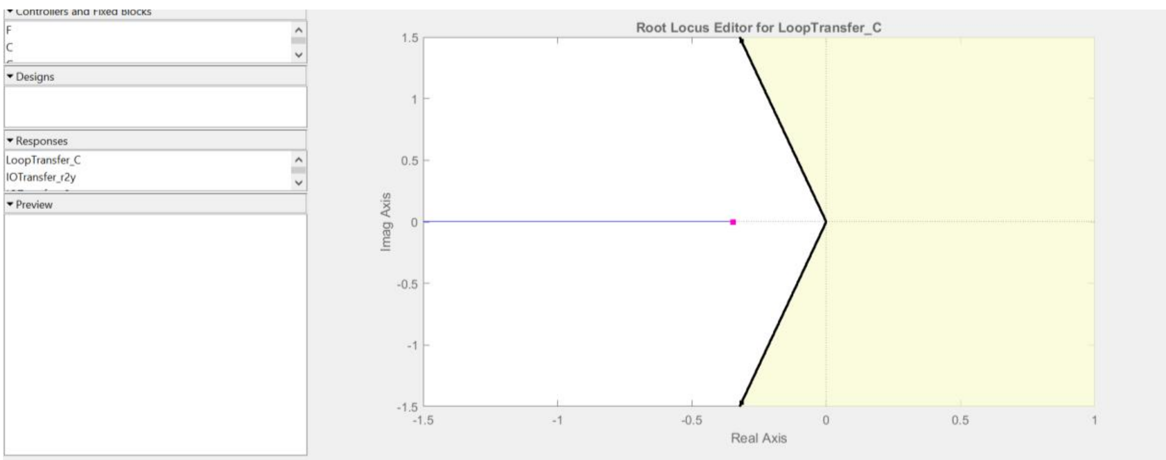
PID - Sustained Oscillations

Point C can not be in the imaginary axis



PID - Damped Oscillations

Point C can not be in the intersection of damping ratio = 0.21



PID - Algebraic method

K = .00011803

a = .6792

b = .194

kd = .00011803

kc=1.0306e-04

ki=1.5552e-05

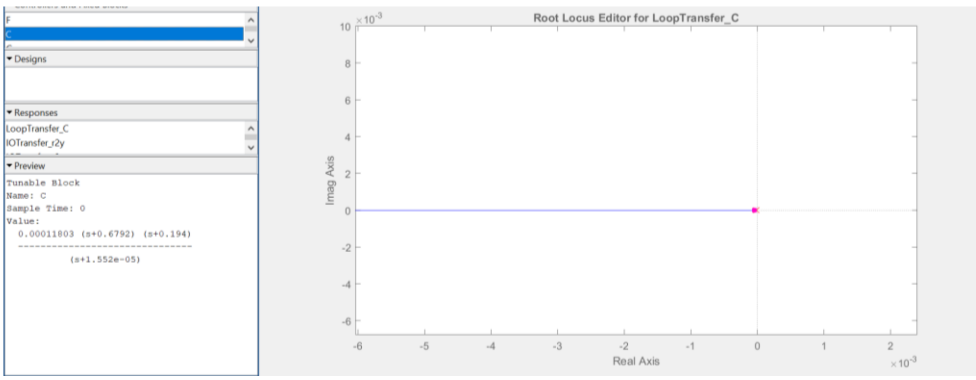
Algebraic method

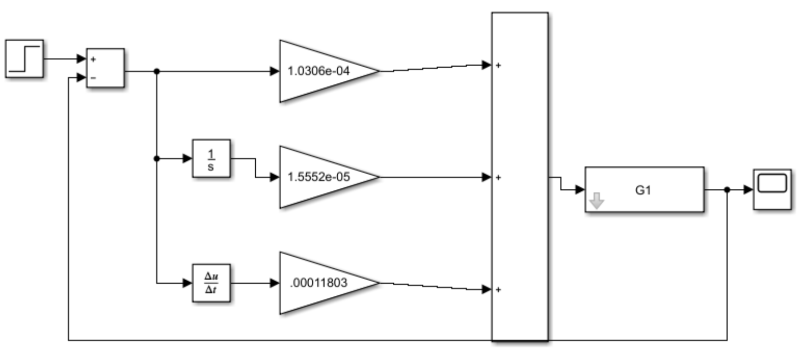
$$\frac{.00011803\,(s+.6792)(s+.194)}{s} = \frac{K(s+a)(s+b)}{s}$$

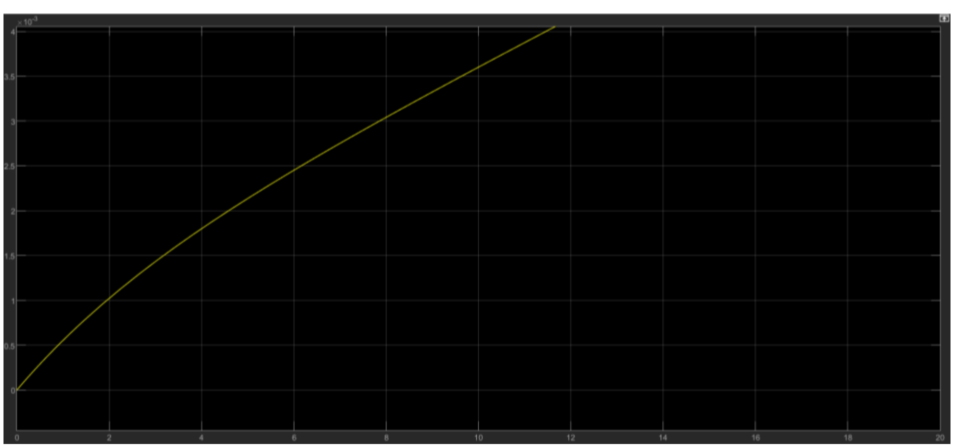
K= .00011803
a= .6792
b= .194

$$\underbrace{Ks^2}_{Kd} + \underbrace{K(a+b)}_{Kc} + \underbrace{Kab}_{K_i}$$

Kd= .00011803
Kc= 1.0306e-04
Ki= 1.5552e-05







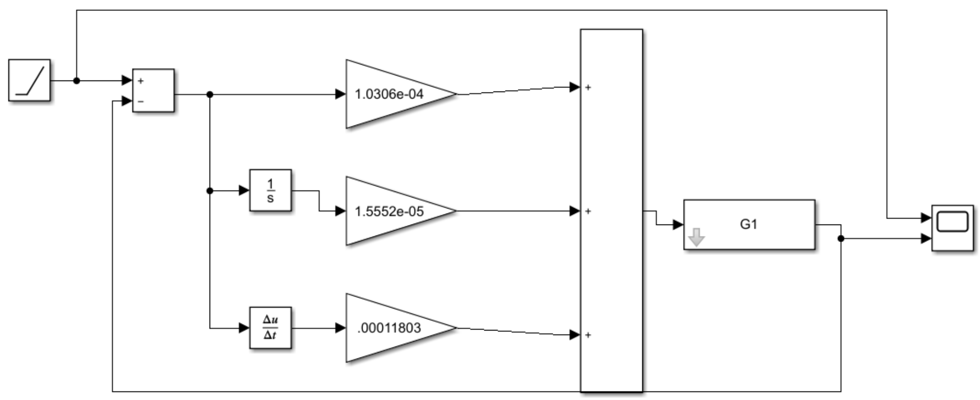
PID controller r(t)=at

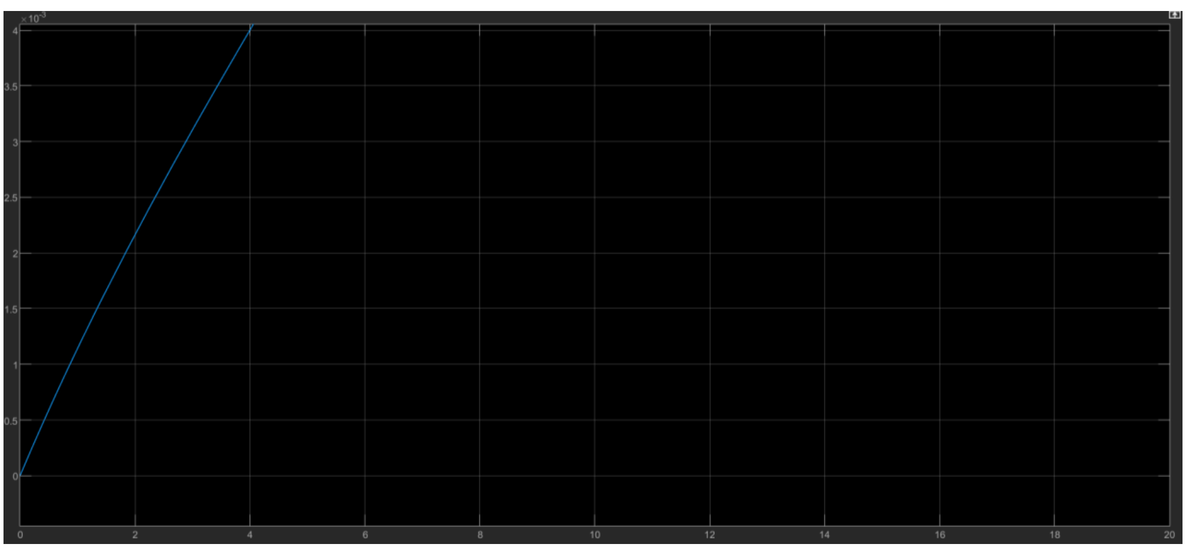
kv = 2.93e-05
ess = 34.041e03

PID for ramp

$$\lim_{s \to 0} \frac{s(k_c s + k_i + k_d s^2)}{s} \frac{17}{9} = \frac{K_i\, 17}{9} = 2.9376 \times 10^{-5}$$

$$ess = \frac{1}{K_v} = \underline{34041.3943}$$

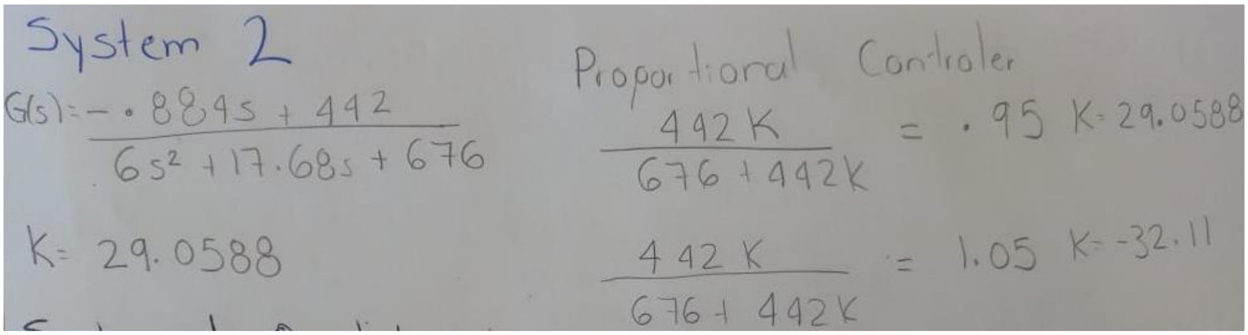




System 2

Proportional controller

K=29.0588 and it is unstable, so we have to design PID controller



System 2

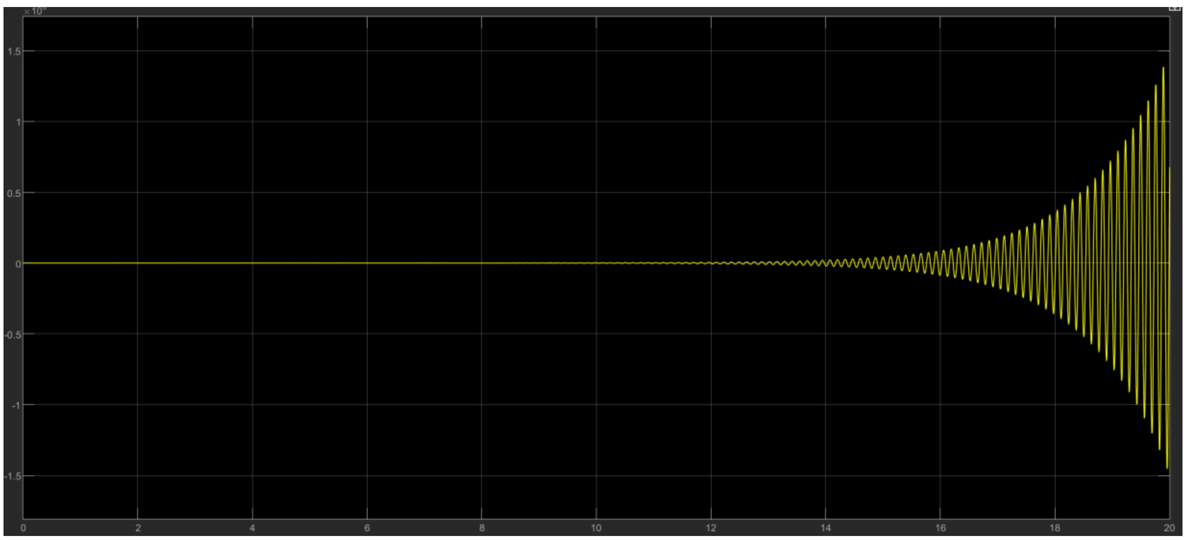
$G(s) = \dfrac{-.884s + 442}{6s^2 + 17.68s + 676}$

$K = 29.0588$

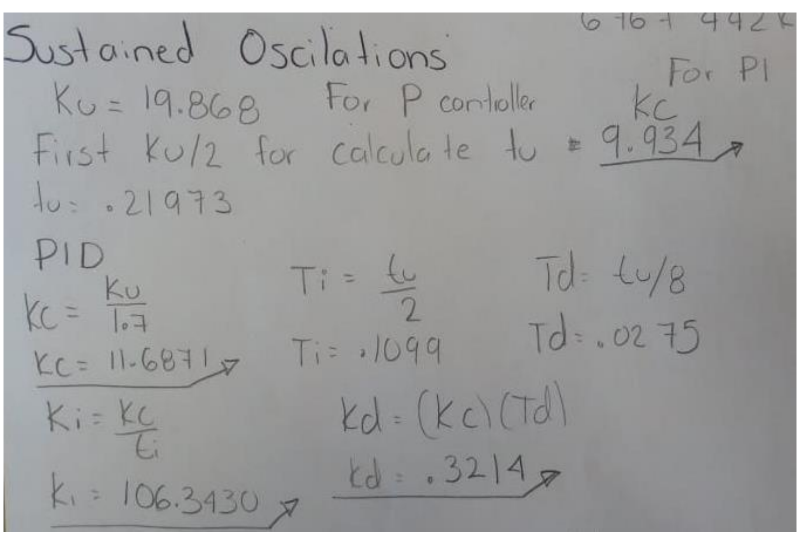
Proportional Controler

$\dfrac{442K}{676 + 442K} = .95 \quad K = 29.0588$

$\dfrac{442K}{676 + 442K} = 1.05 \quad K = -32.11$



PID - Sustained Oscillations



Sustained Oscilations

$K_u = 19.868$ For P controller

First $K_u/2$ for calculate t_u = $\underline{9.934}$

For PI

Kc

$t_u = .21973$

PID

$K_c = \dfrac{K_u}{1.7}$

$\underline{K_c = 11.6871}$

$T_i = \dfrac{t_u}{2}$

$T_i = .1099$

$T_d = t_u/8$

$T_d = .0275$

$K_i = \dfrac{K_c}{t_i}$

$\underline{K_i = 106.3430}$

$K_d = (K_c)(T_d)$

$\underline{K_d = .3214}$

P

Ku = 19.868

kc = 9.934

tu= .21973

PID

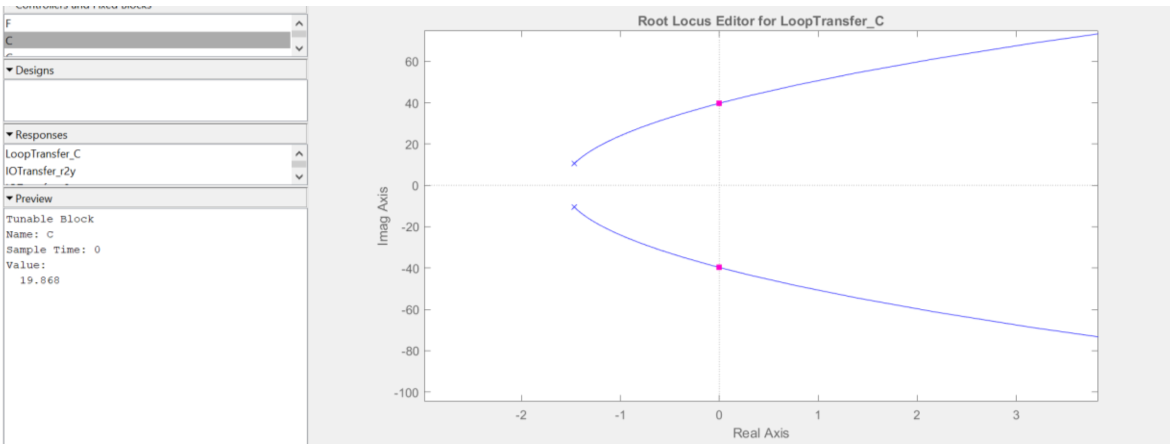
kc = 11.6871

ti = .1099

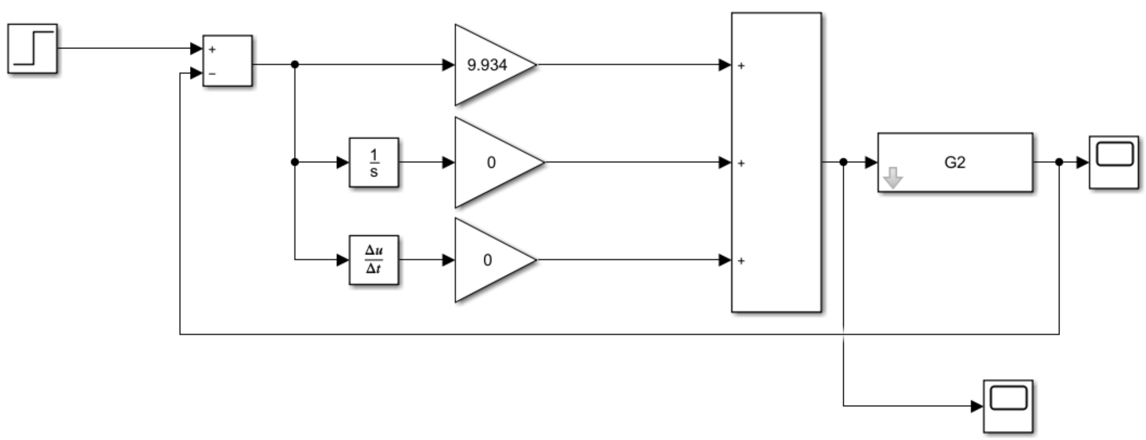
td = .0275

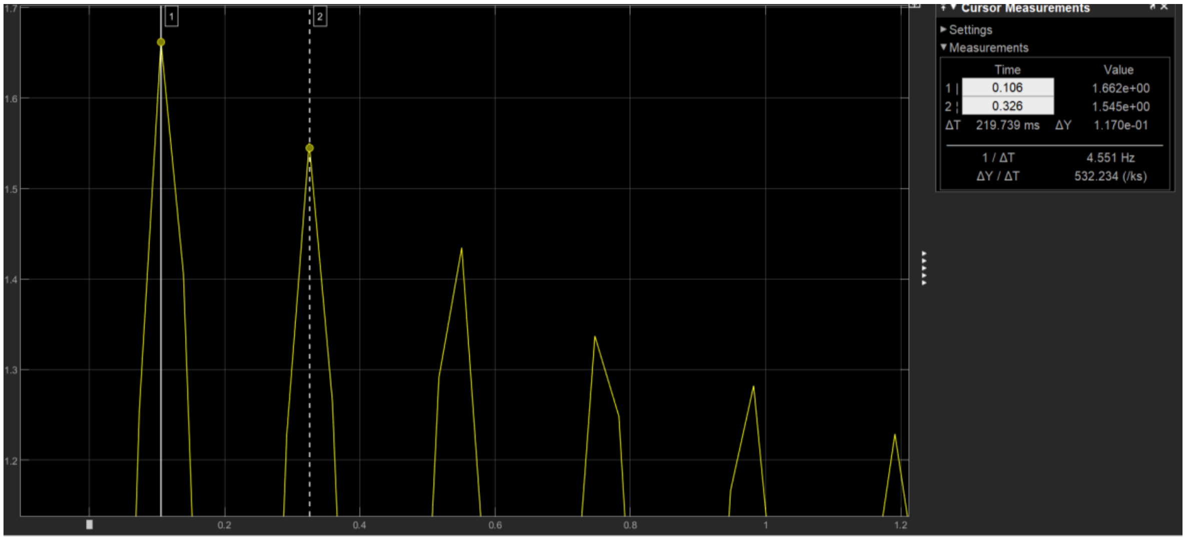
ki = 106.343

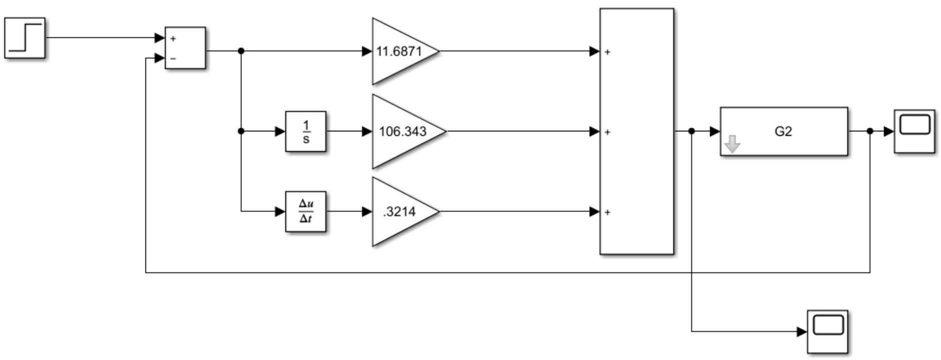
kd = .3214

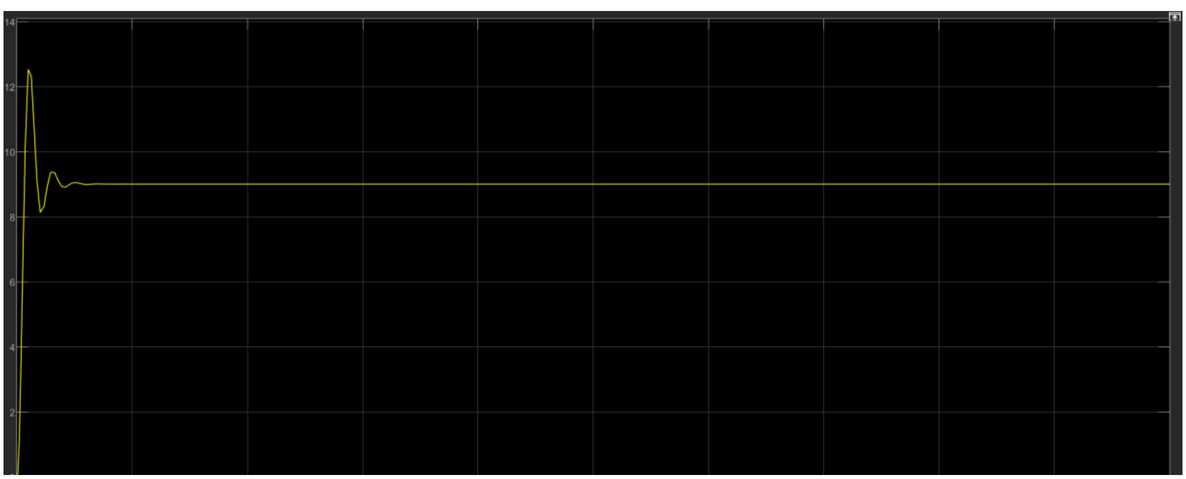


First design a P controller



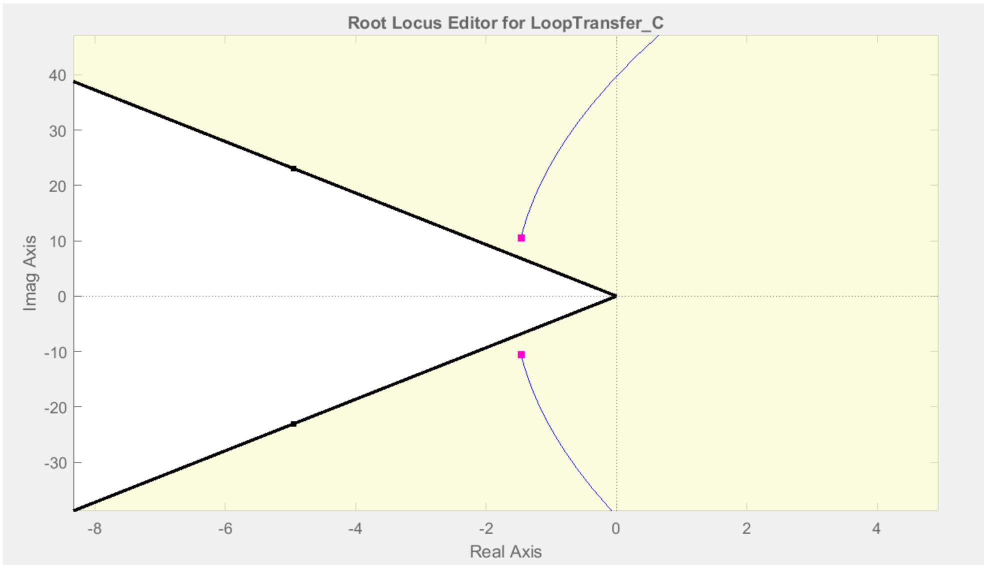

Cursor Measurements
Settings
Measurements
Time
Value
1
0.106
1.662e+00
2
0.326
1.545e+00
ΔT
219.739 ms
ΔY
1.170e-01
1 / ΔT
4.551 Hz
ΔY / ΔT
532.234 (/ks)
1.7
1.6
1.5
1.4
1.3
1.2
0.2
0.4
0.6
0.8
1
1.2


11.6871
106.343
.3214
1/s
Δu/Δt
G2

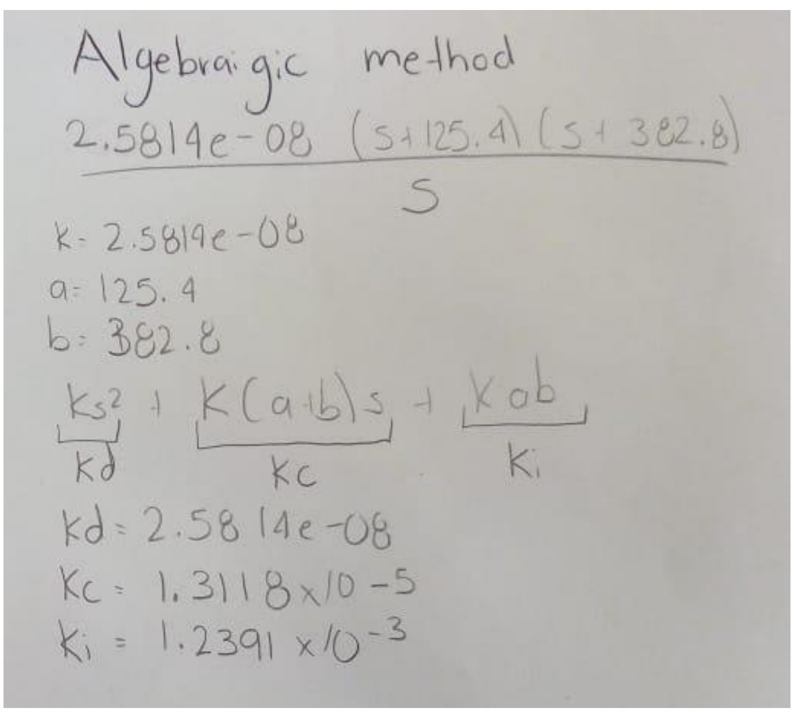

14
12
10
8
6
4
2

PID - Damped Oscillations

It is not possible to do a damped oscillations PID controller

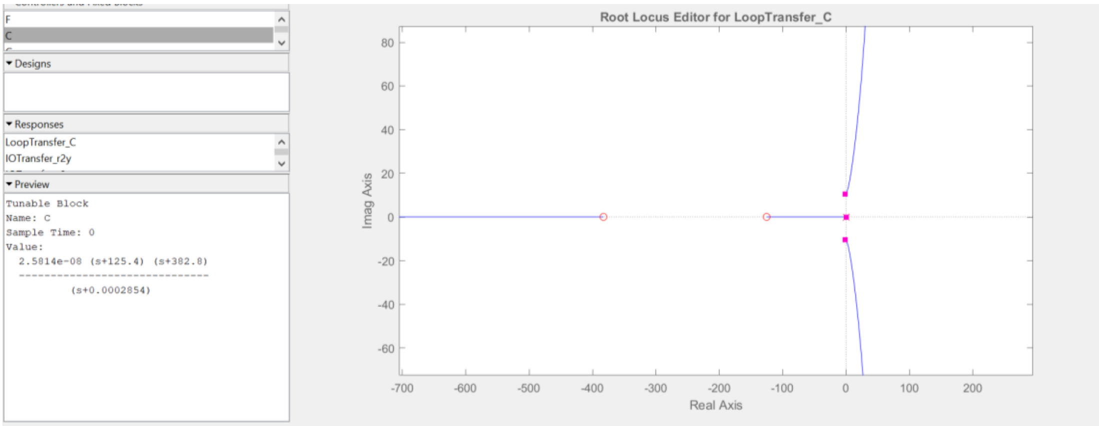


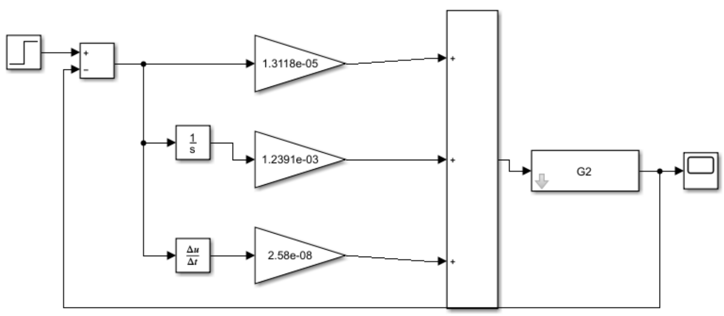
PID - Algebraic method



K = 2.5814e-08
a = 125.4
b = 382.8

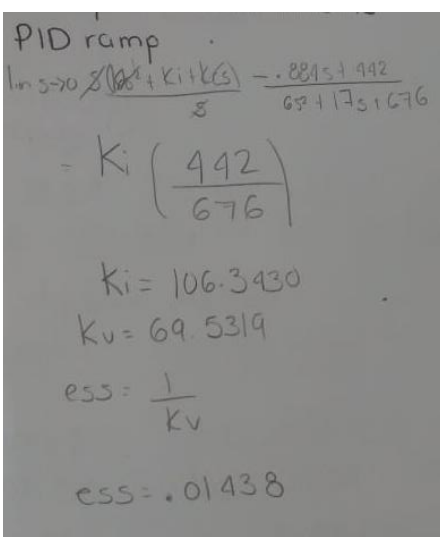
kd = 2.5814e-08
kc=1.3118e-05
ki=1.239e-03





PID controller r(t)=at

Kv = 69.5319
ess = .01438


PID ramp

$\lim_{s\to 0} s\frac{(K_d s^2+K_i+K_c s)}{s} \cdot \frac{.881s+442}{6s^2+17s+676}$

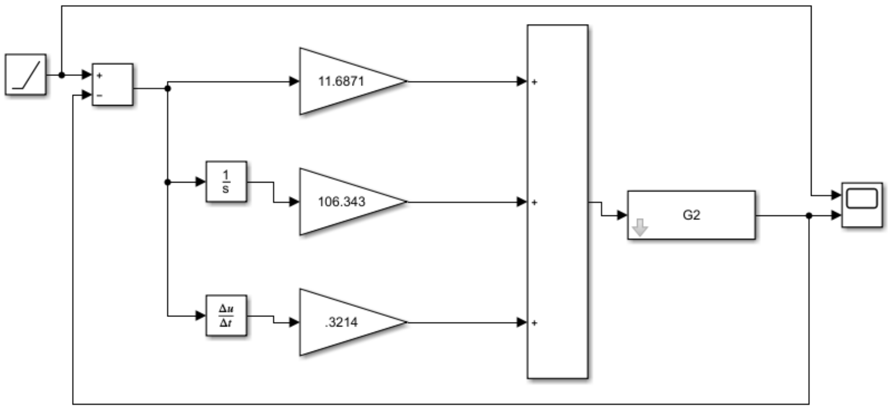
$= K_i\left(\frac{442}{676}\right)$

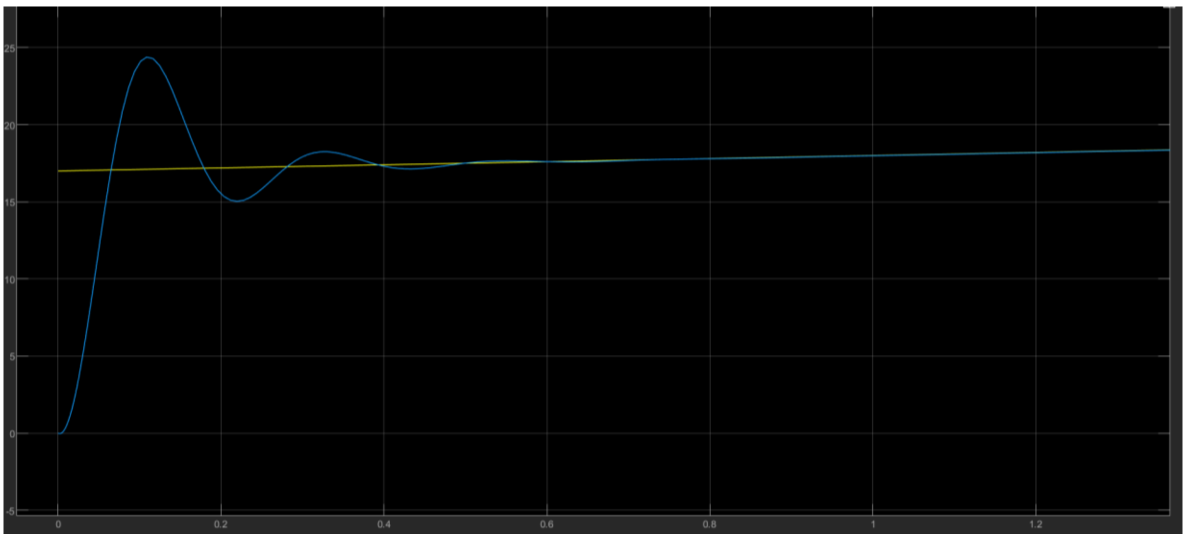
$K_i = 106.3430$

$K_v = 69.5319$

$e_{ss} = \frac{1}{K_v}$

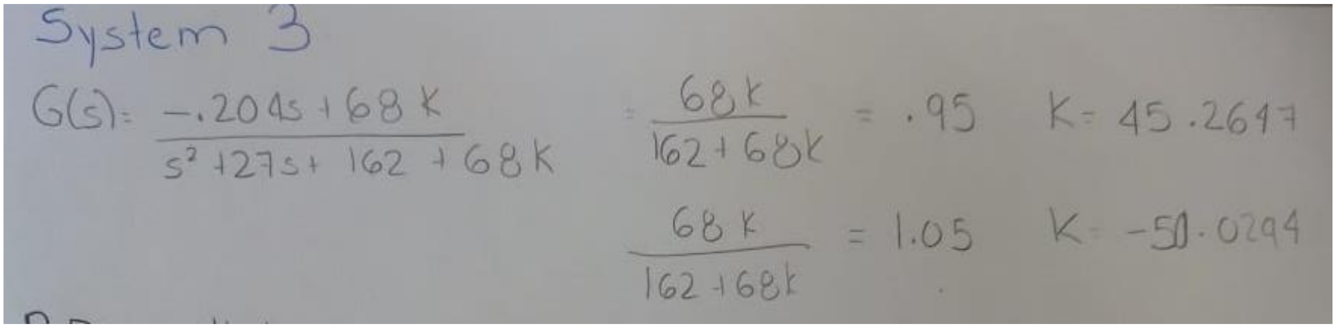
$e_{ss} = .01438$


+
-
11.6871
1
s
106.343
Δu
Δt
.3214
+
+
+
G2

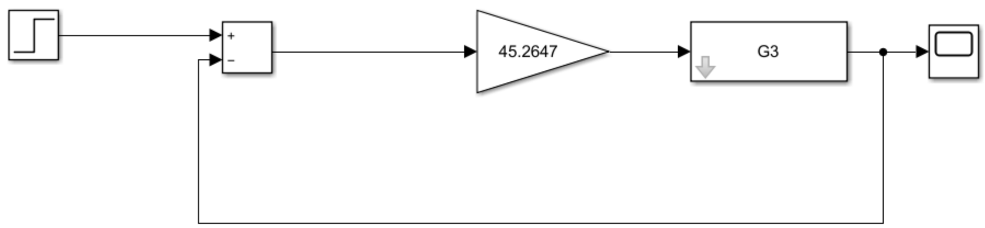

25
20
15
10
5
0
-5
0
0.2
0.4
0.6
0.8
1
1.2

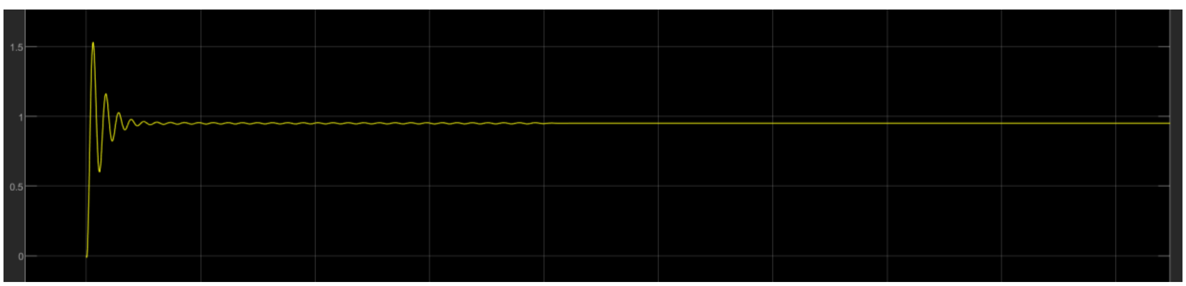
System 3

Proportional controller



K= 45.2647





PID - Sustained Oscillations

P

Ku = 135.09

kc = 67.545

tu= .096875

PID

kc = 79.4647

ti = .04843

td = .012109

ki = 1640-8156

kd= 1.6759

PID oscillations method

K_u = C in imaginary axis   C = 135.09

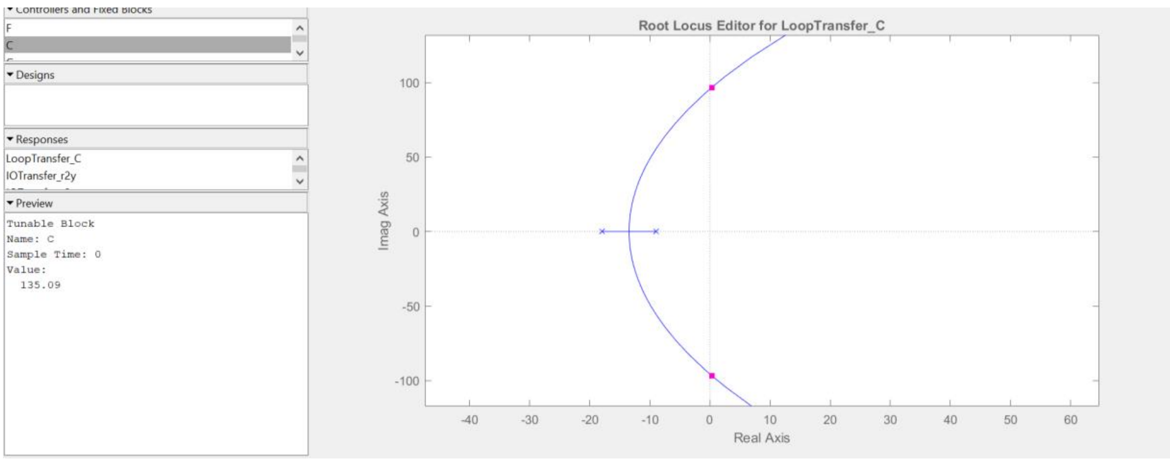
For P $K_c = K_u/2 = 67.545$

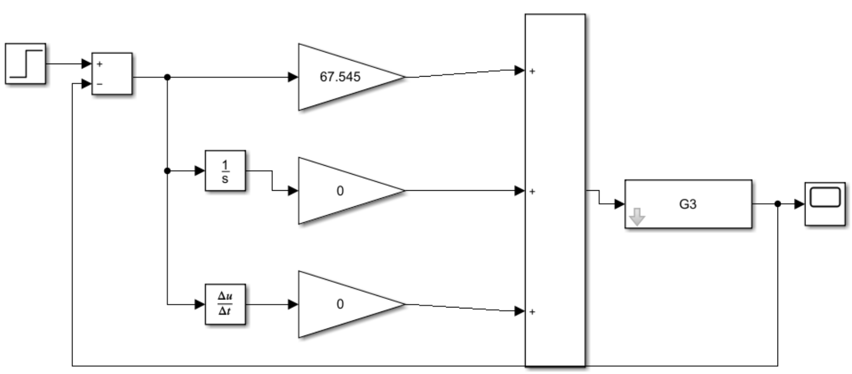
$t_u = .096875$

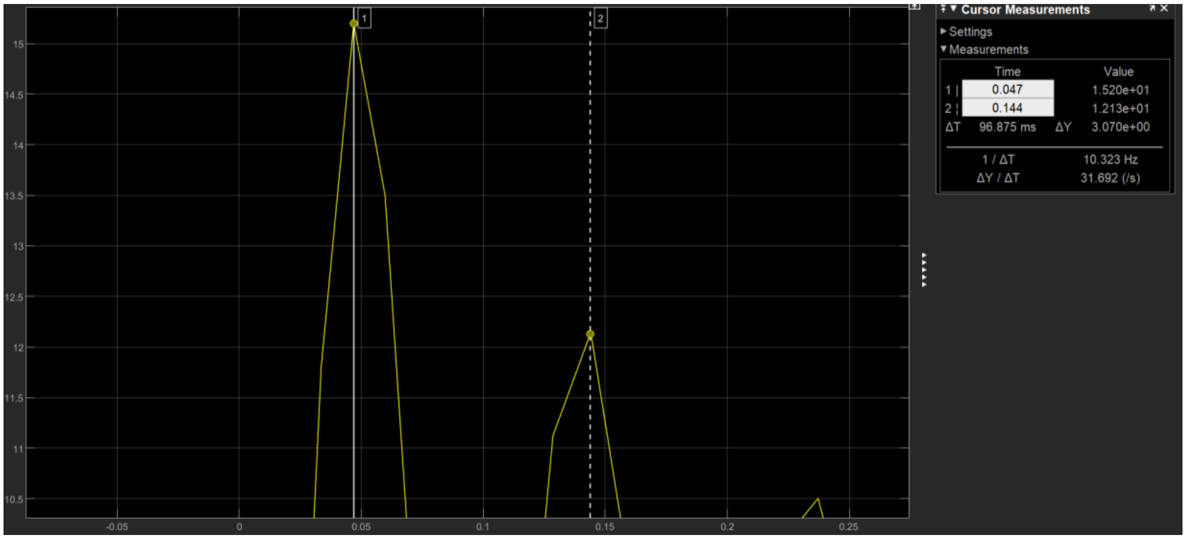
For PID

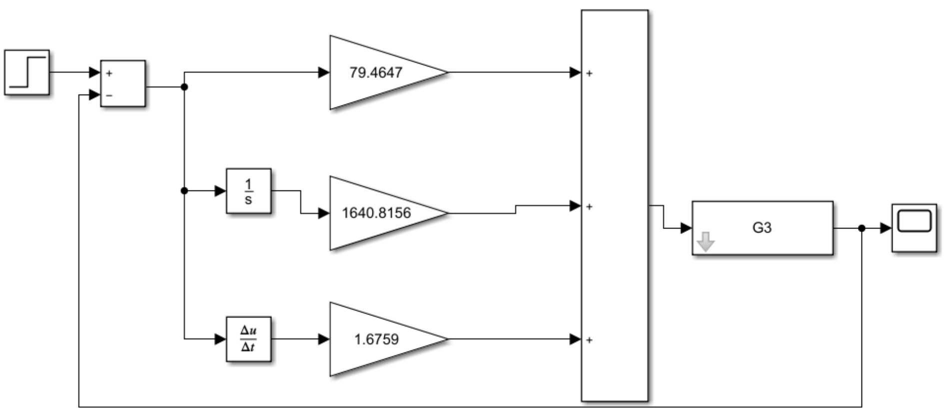
$K_c = \frac{K_u}{1.7} = \underline{79.4647}$ $T_i = \frac{t_u}{2} = .04843$ $T_d = \frac{t_u}{8} = .012109$

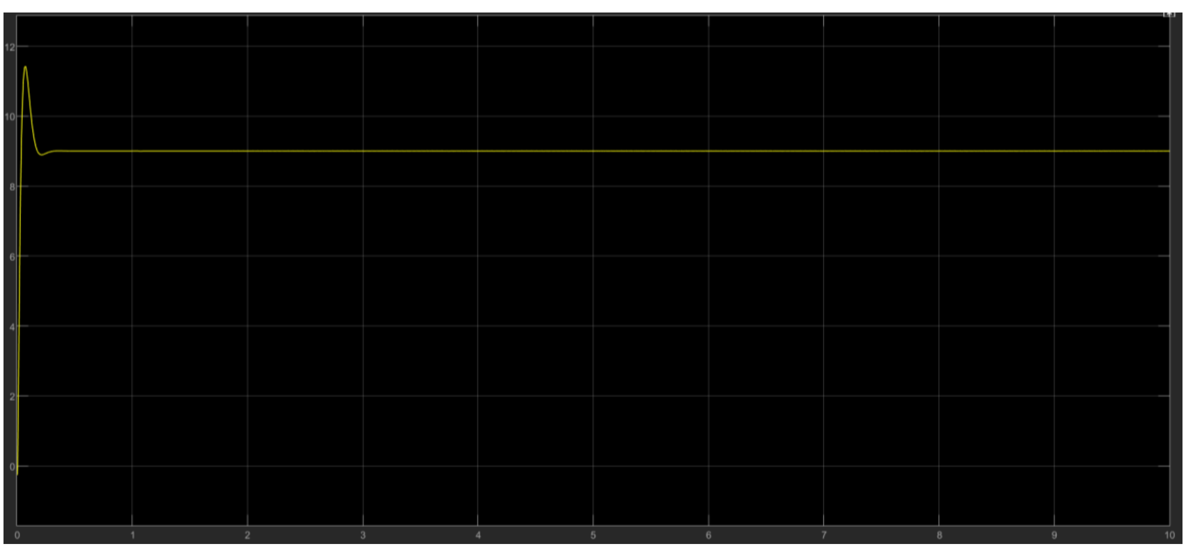
$K_i = \frac{K_c}{T_i} = \underline{1640.8156}$ $K_d = K_c T_d = \underline{1.6759}$






Cursor Measurements
Settings
Measurements
Time
Value
1
0.047
1.520e+01
2
0.144
1.213e+01
ΔT
96.875 ms
ΔY
3.070e+00
1 / ΔT
10.323 Hz
ΔY / ΔT
31.692 (/s)


79.4647
1640.8156
1.6759
G3

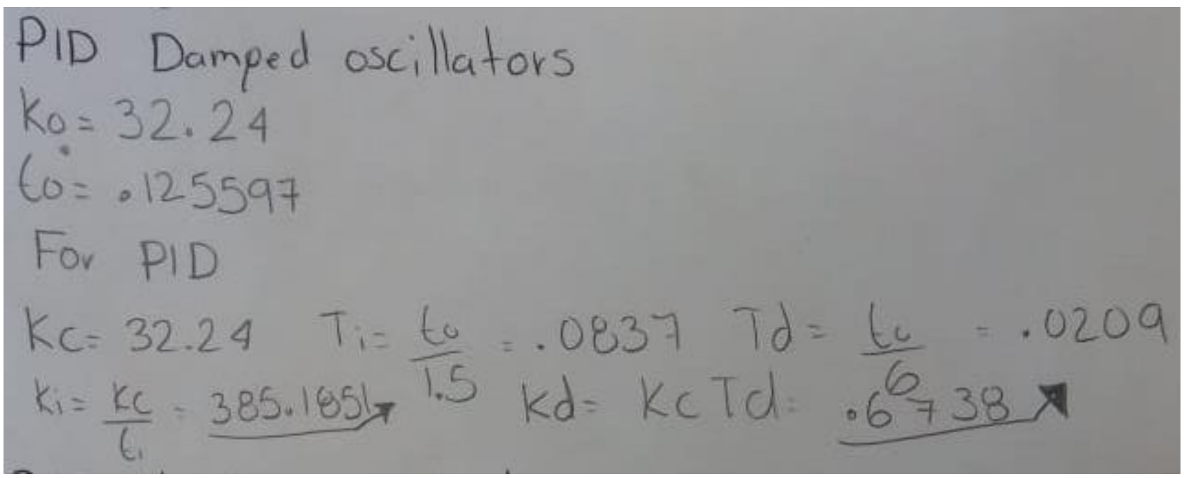


PID - Damped Oscillations

P

Ko= 32.24
kc = 32.24
to = 0.125597

PID
kc = 32.24
ti =.0837
td = .0209
ki = 385.1851
kd= .6738



PID Damped oscillators

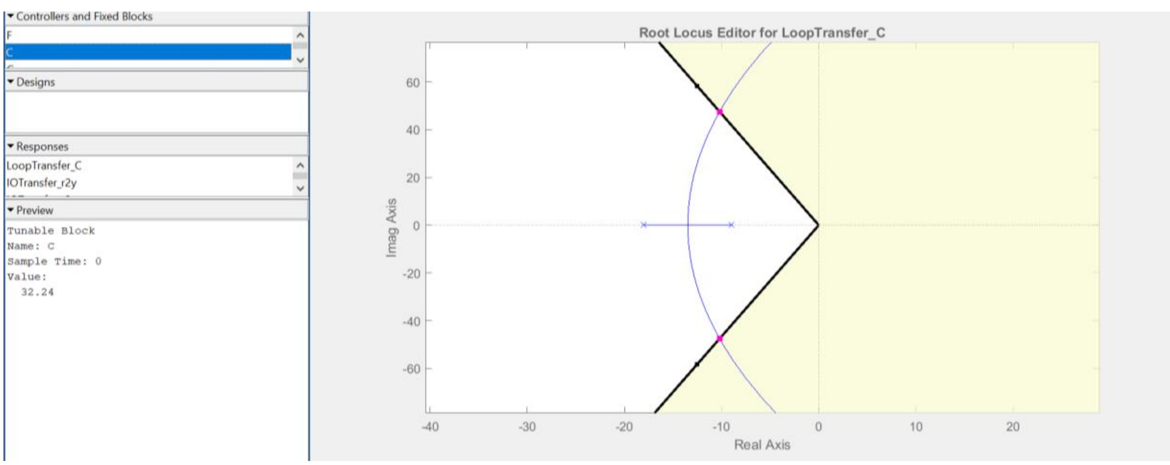
$K_o = 32.24$

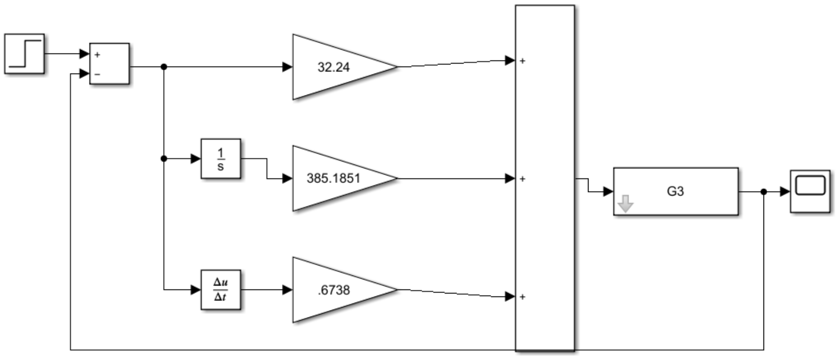
$t_o = .125597$

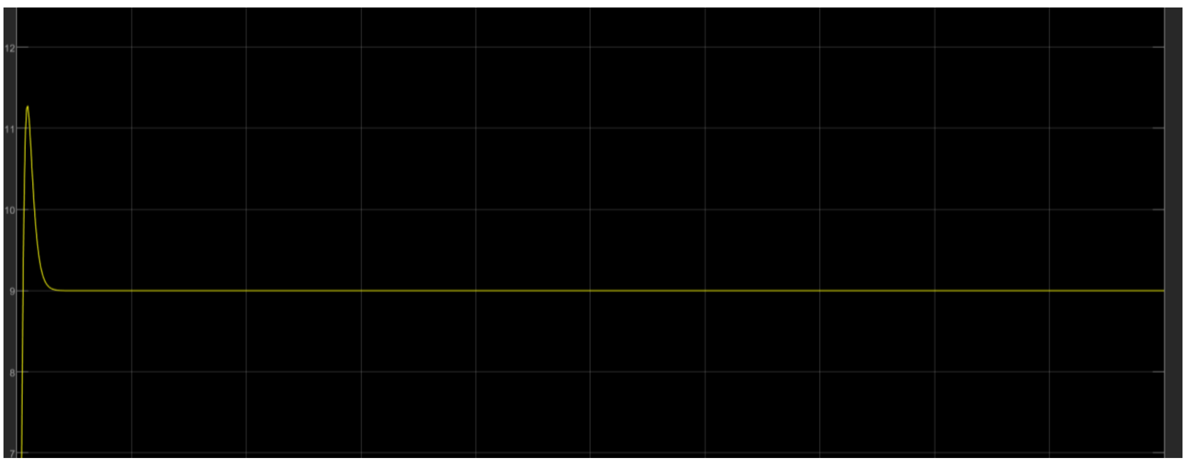
For PID

$K_c = 32.24 \quad T_i = \frac{t_o}{1.5} = .0837 \quad T_d = \frac{t_o}{6} = .0209$

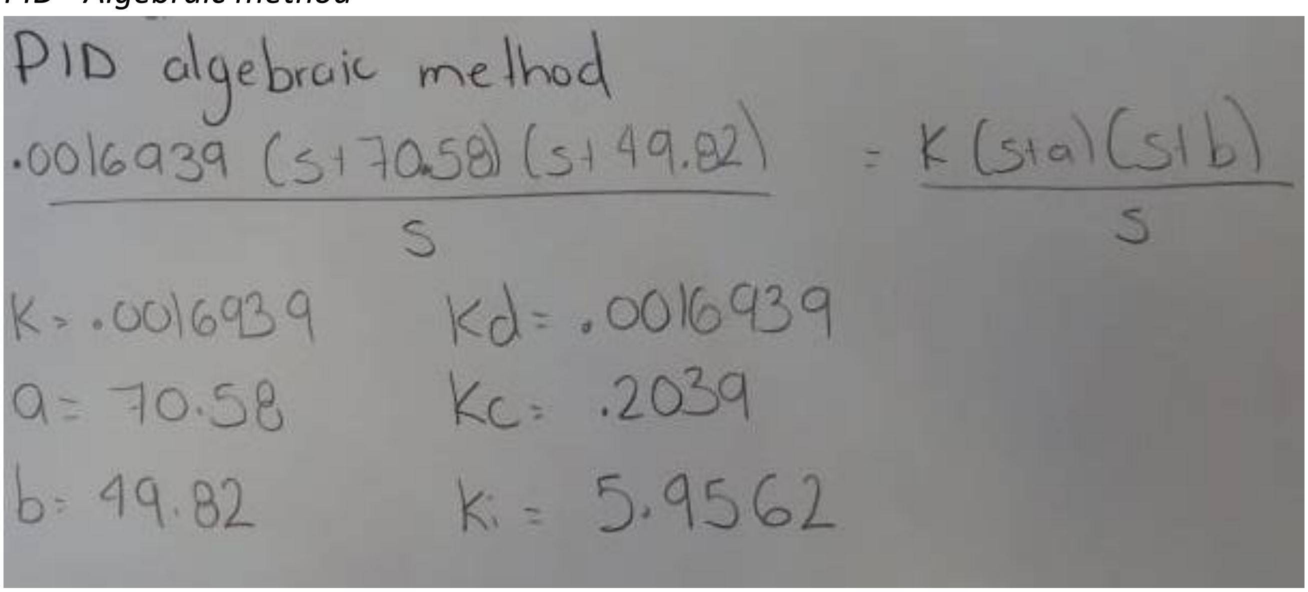
$k_i = \frac{K_c}{t_i} = 385.1851 \quad k_d = K_c T_d = .6738$







PID - Algebraic method



PID algebraic method

$$\frac{.0016939\,(s+70.58)(s+49.82)}{s} = \frac{K(s+a)(s+b)}{s}$$

$K = .0016939$ $\quad$ $K_d = .0016939$

$a = 70.58$ $\quad$ $K_c = .2039$

$b = 49.82$ $\quad$ $K_i = 5.9562$

K = .0016939

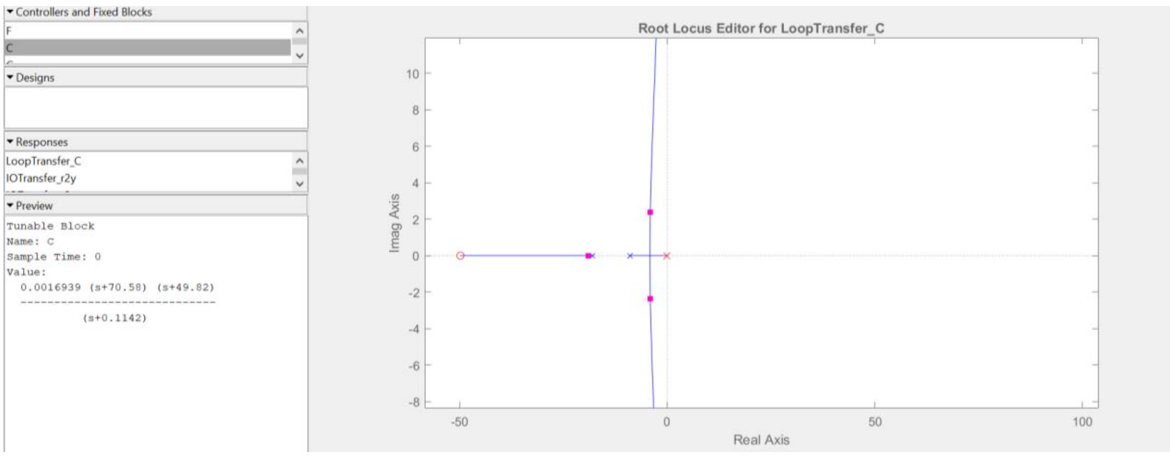
a = 70.58

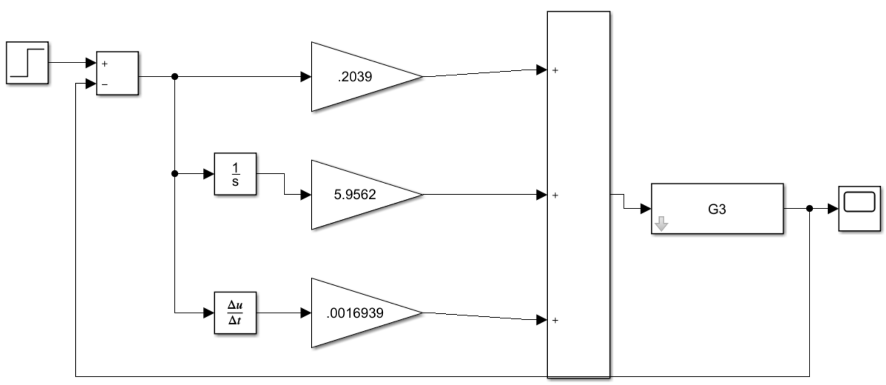
b = 49.82

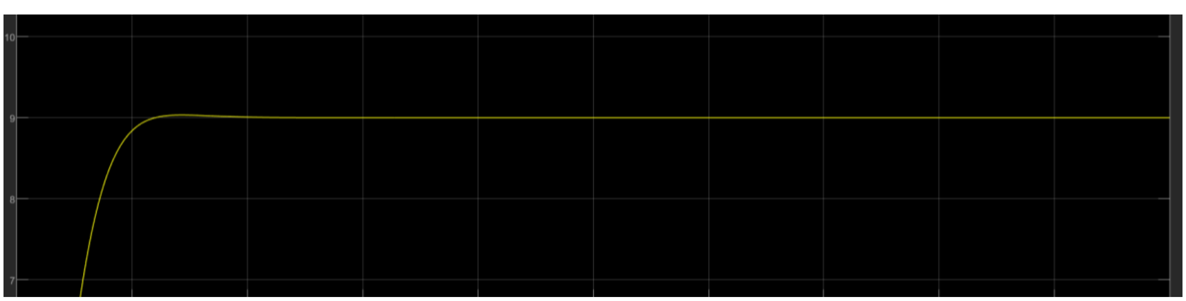
kd = .0016939

kc= .2039

ki= 5.9562

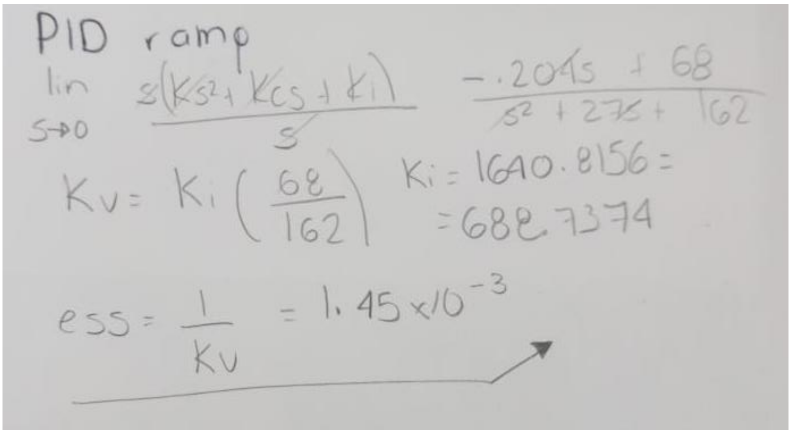


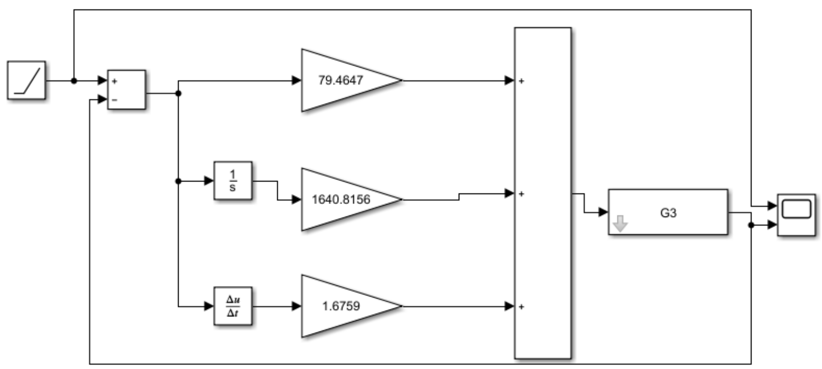


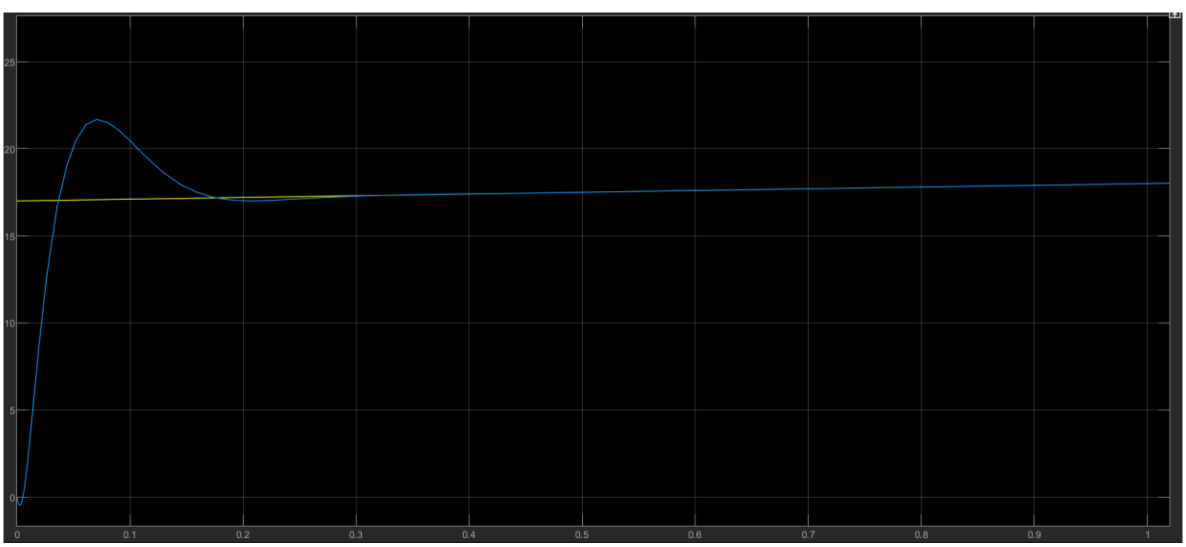


PID controller r(t)=at

kv = 688.7374
ess=1.43e-03







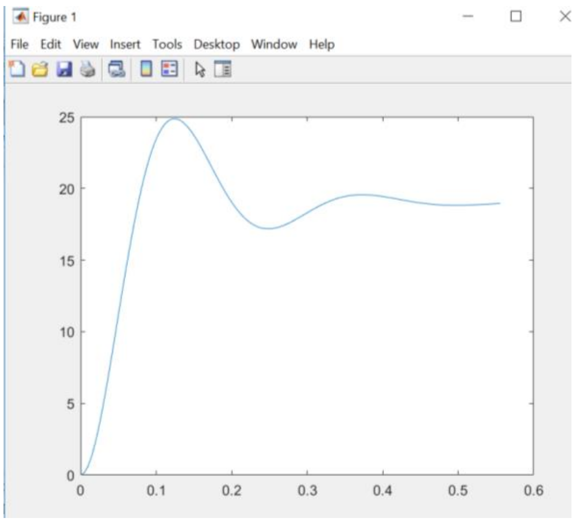
System 4

With the following script I obtain the transfer function

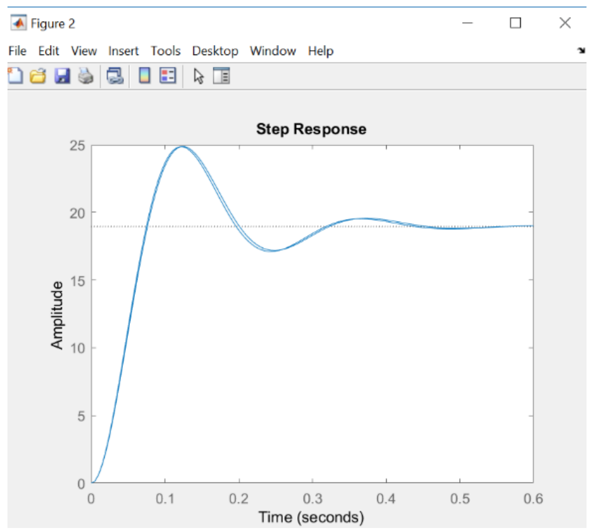
```
close all
t=zeros(); %arreglo de tiempo
k=zeros(); % arreglo de la ganancia
[fil,col]=size(Out); % declaro el arreglo para leer la posicion de los valores de la funcion
t=Out(:,1);%Datos del tiempo obtenidos de la tf G mediante simulink
k=Out(:,2);%Datos de la ganancia obtenidos de la tf G mediante simulik
figure;
plot(t,k); %grafica de la tf

%identificar el #orden del sistema
pico=max(k);
final=k(end);
if   pico == final
    z = 1;

else
    z = 2;

end
%implementacion una vez conocido el orden del sistema
if z==1
        Orden=1
        for y=1:fil
            if Out(y,2) > final*0.9933  %Encontrar el valor de 5Tao
                pos=y             %Posicion del arreglo donde esta 5tao
                break

            else
            end

        end
       Tss=Out(pos,1);
       Tao=Tss/5;
      ktf=final;
      G1=tf(ktf,[Tao 1])
      figure;
      plot(t,k);
      hold on
      step(G1)
else
   Orden=2
   for y=1:fil
            if Out(y,2) == pico
                tpa=y;
                break

            else
            end

        end
    tp=Out(tpa,1);
    wd=pi/tp;
    mp=((pico-final)/final);
    delta=-(log(mp))/(sqrt(log(mp)^2 + pi^2));
    wn=wd/sqrt(1-delta^2);
    ks2=final;
    G2=tf((ks2*wn^2),[1 (2*delta*wn) (wn^2)])
    figure;
    plot(t,k);
    hold on
    step(G2)
end
```

```
>> G4

G4 =

         14340
  ---------------------
  s^2 + 19.14 s + 756.5

Continuous-time transfer function.
```

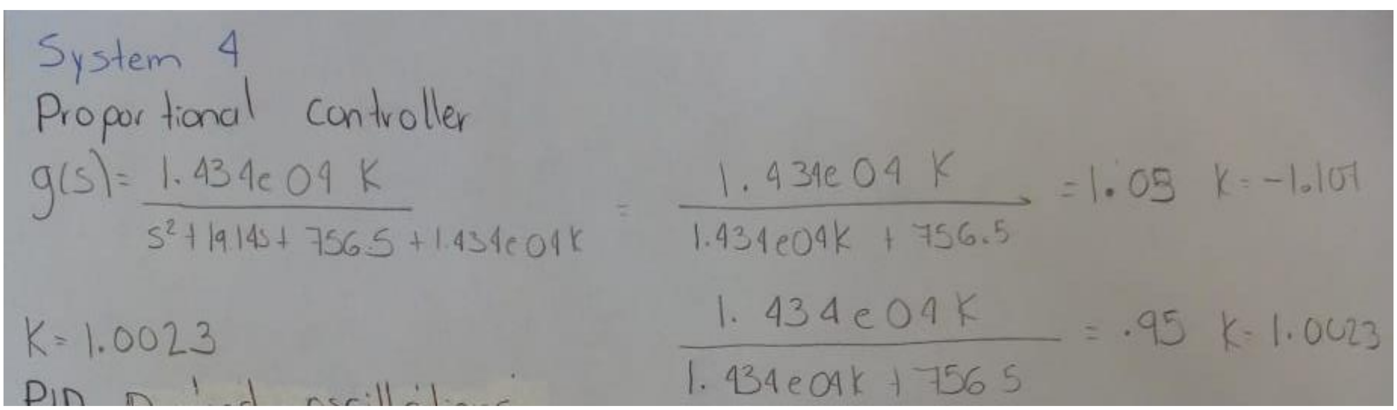
Original function



Approximate function



Proportional controller



System 4

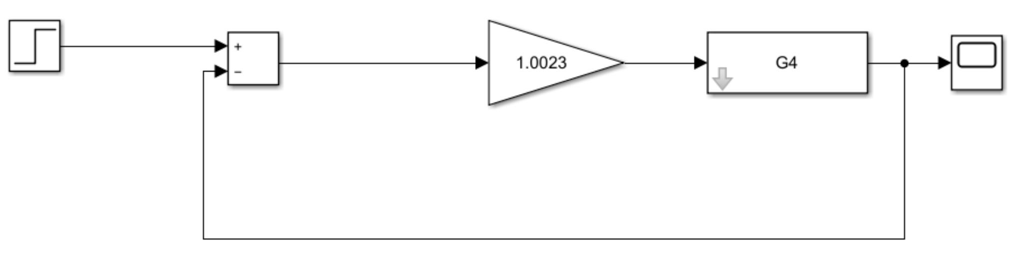
Proportional controller

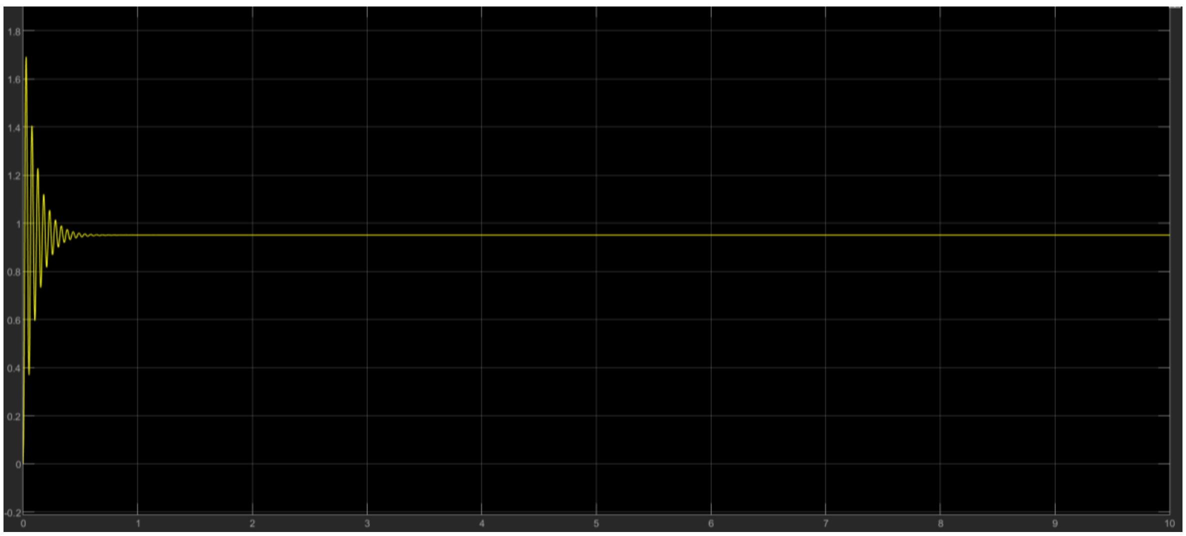
$$g(s) = \frac{1.434e04\ K}{s^2 + 19.14s + 756.5 + 1.434e04K} = \frac{1.434e04\ K}{1.434e04K + 756.5} = 1.05 \quad K = -1.101$$

$K = 1.0023$

$$\frac{1.434e04\ K}{1.434e04K + 756.5} = .95 \quad K = 1.0023$$

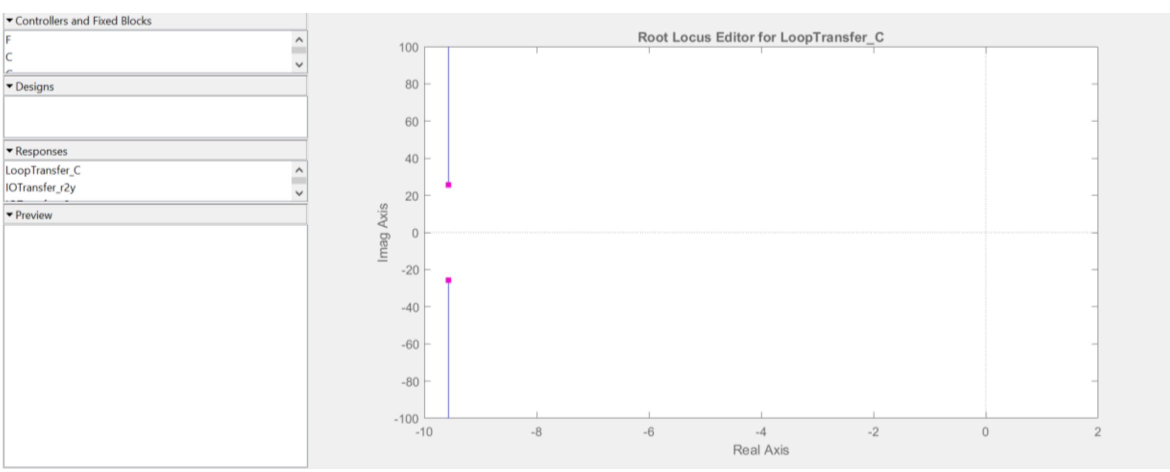
K = 1.0023





PID - Sustained Oscillations

It can not in imaginary axis



PID - Damped Oscillations

P

Ko= 0.092106

kc = 0.092106

to = 0.13848

PID

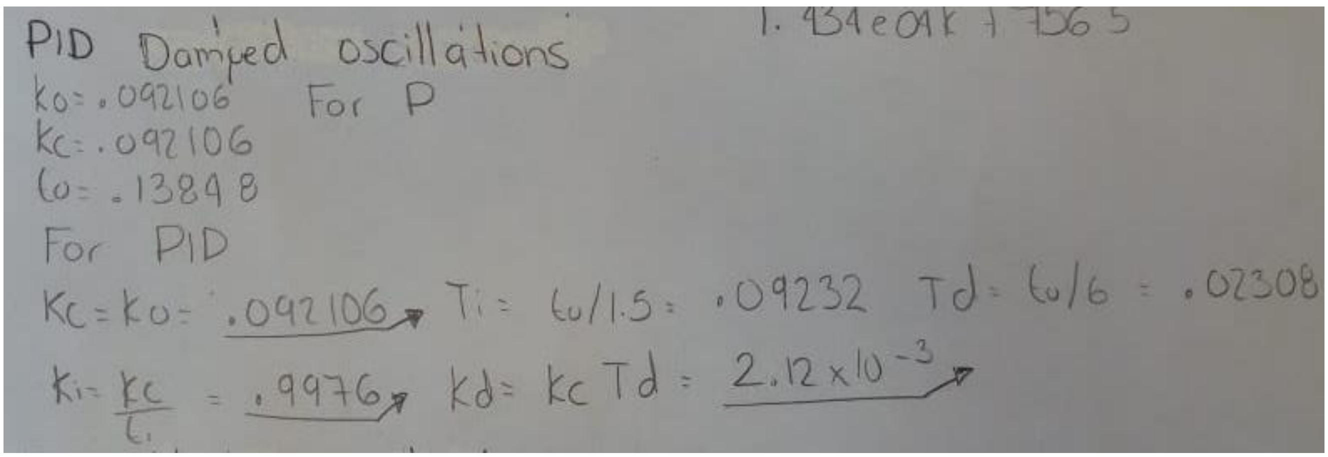
kc = .092106

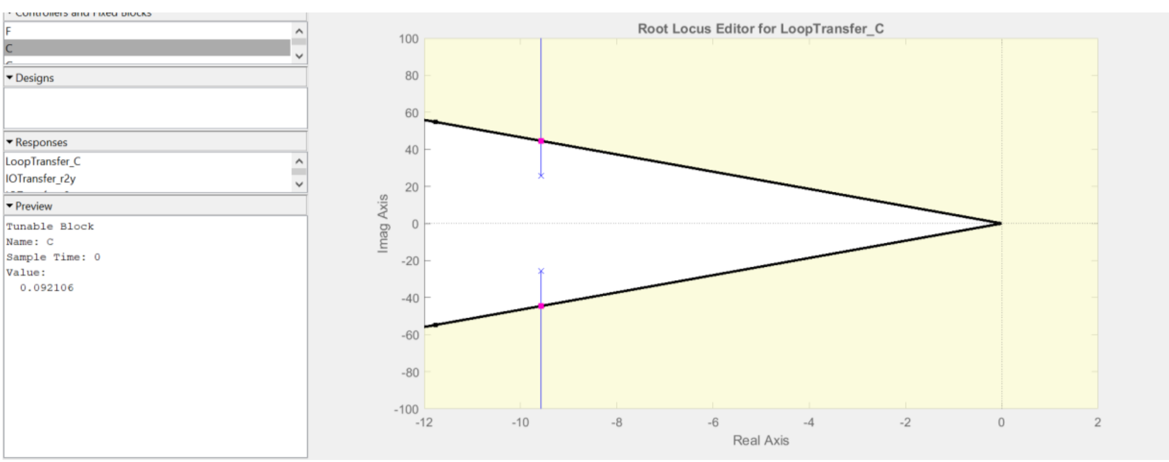
ti = .09232

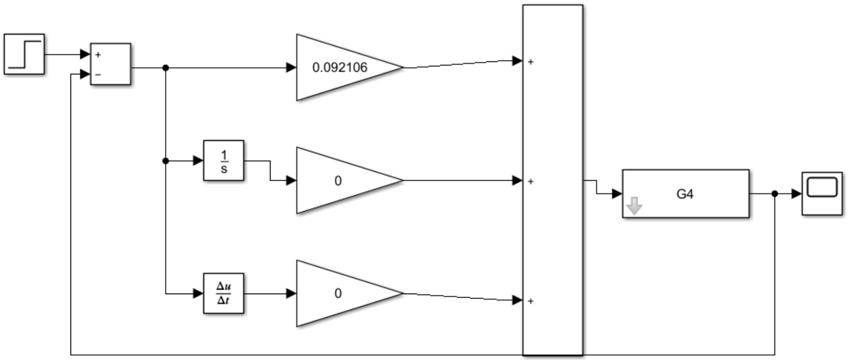
td = .02308

ki = .9976

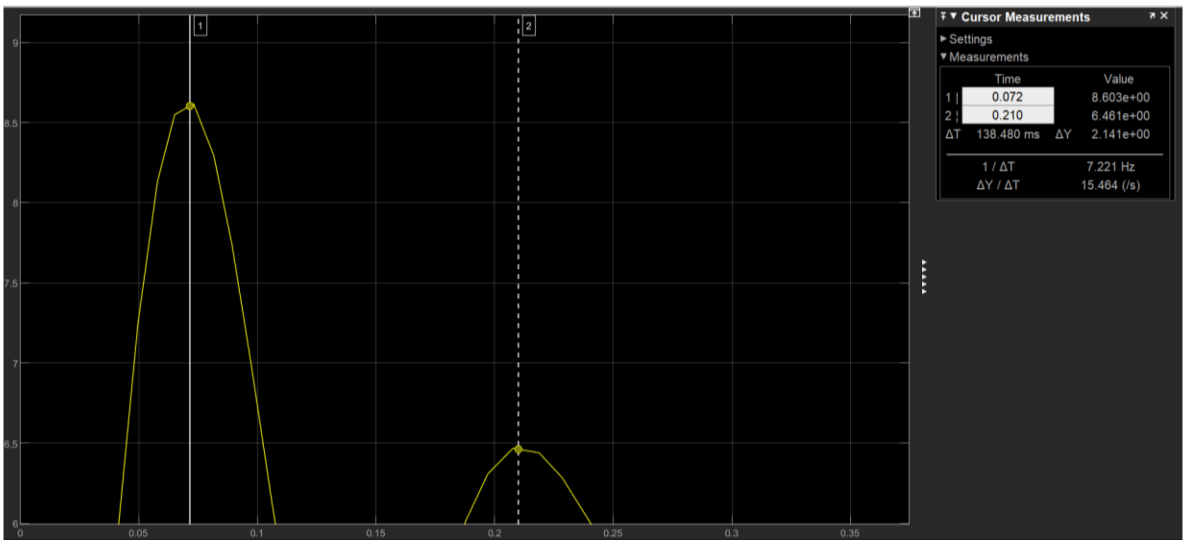
kd= 2.12e-03



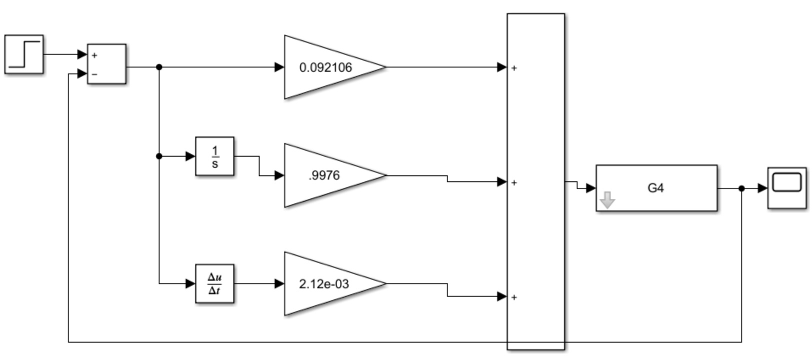




0.092106
0
0
G4



Cursor Measurements
Settings
Measurements
Time
Value
1 0.072 8.603e+00
2 0.210 6.461e+00
ΔT 138.480 ms ΔY 2.141e+00
1 / ΔT 7.221 Hz
ΔY / ΔT 15.464 (/s)



0.092106
.9976
2.12e-03
G4

PID - Algebraic method

K = 6.0497e-09

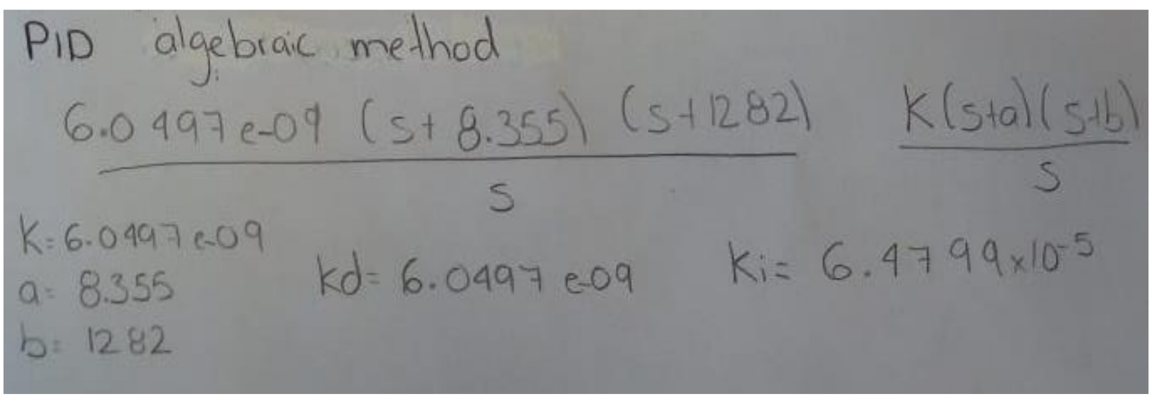
a = 8.355

b = 1282

kd = 6.0497e-09

kc= 7.8062e-06

ki=6.4799e-05



PID algebraic method

$$\frac{6.0497e\text{-}09\,(s+8.355)\,(s+1282)}{s} \qquad \frac{K(s+a)(s+b)}{s}$$

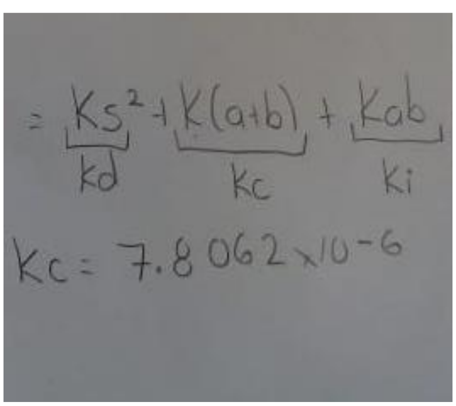
K: 6.0497 e-09

a: 8.355

b: 1282

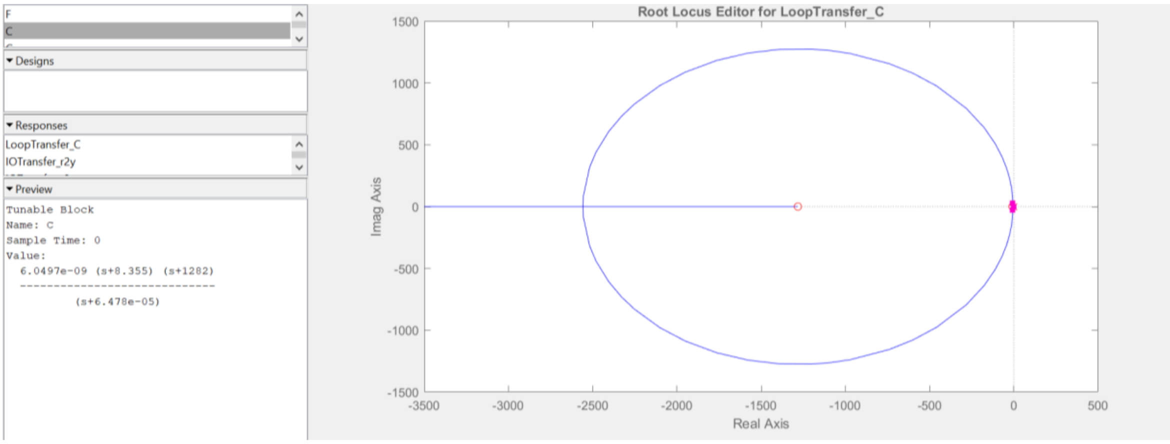
kd= 6.0497 e-09

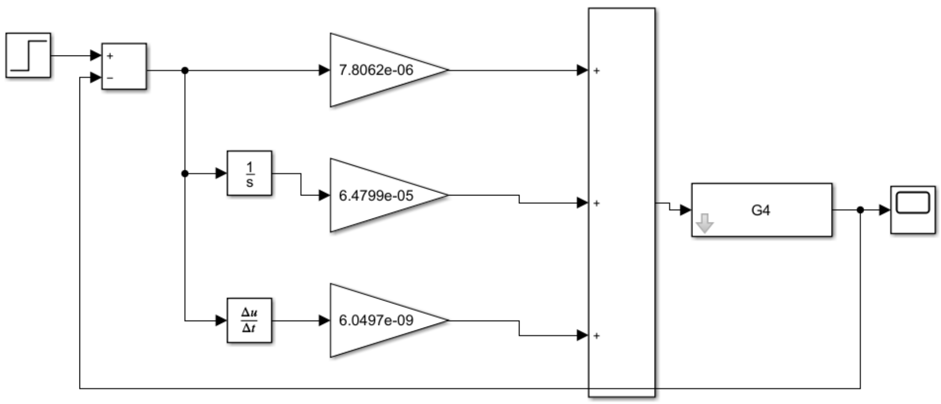
Ki= 6.4799×10^{-5}

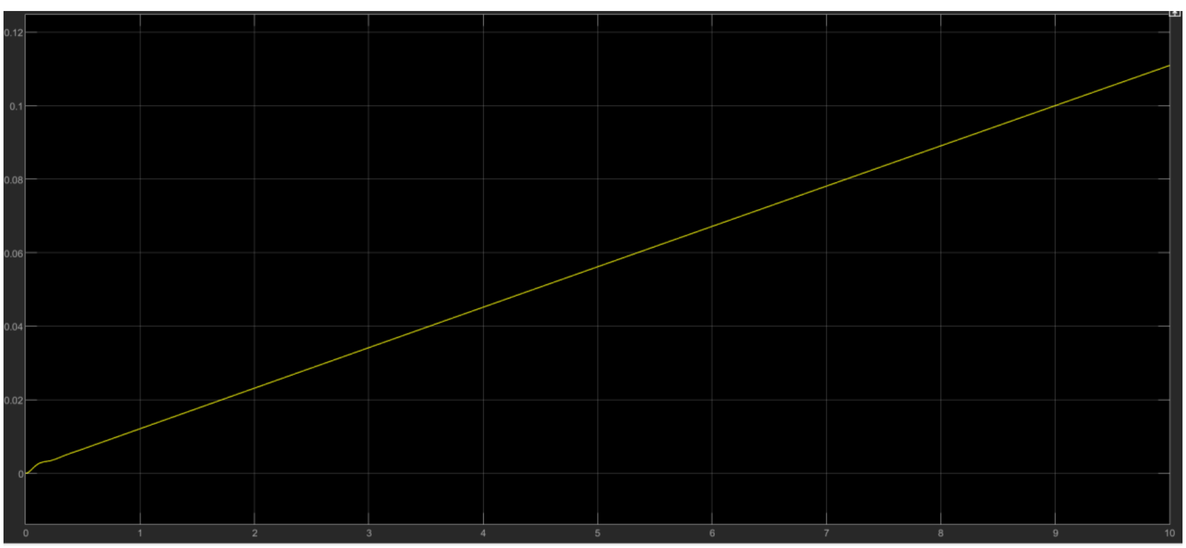


$$= \underbrace{Ks^2}_{kd} + \underbrace{K(a+b)}_{kc} + \underbrace{Kab}_{ki}$$

$Kc = 7.8062 \times 10^{-6}$







PID controller r(t)=at

kv = 18-91

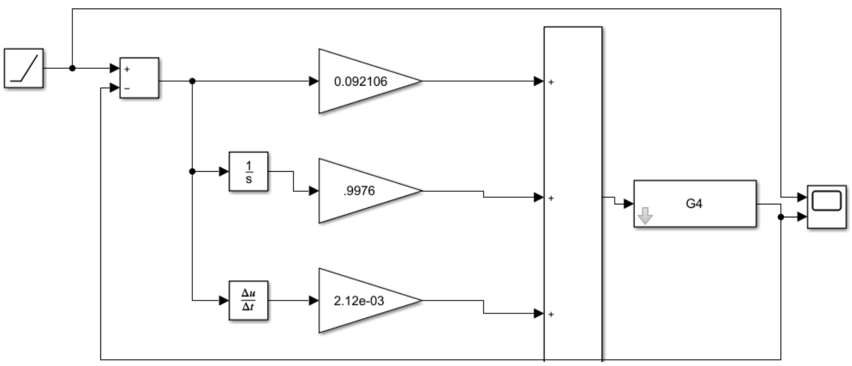
ess = .0528

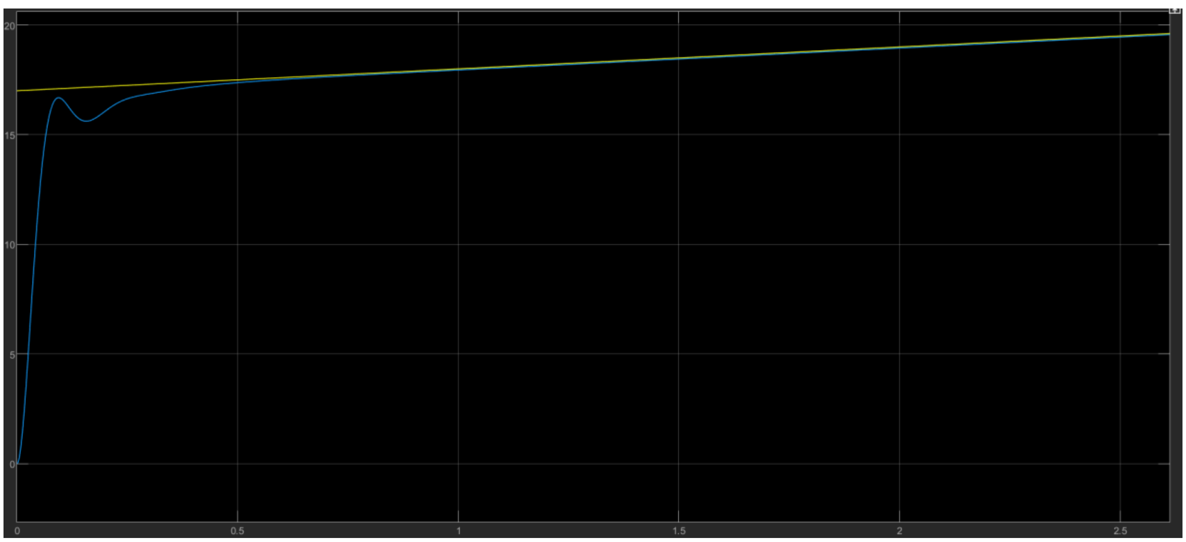
PID ramp

$$\lim_{s \to 0} \frac{\cancel{s}(Ks^2 + K_c s + K_i)}{s} \cdot \frac{1.434e04}{s^2 + 19.1s + 756.5} = \frac{14340 K_i}{756.5}$$

$K_i = .9976 \quad K_v = 18.91$

$$e_{ss} = \frac{1}{K_v} = .0528$$





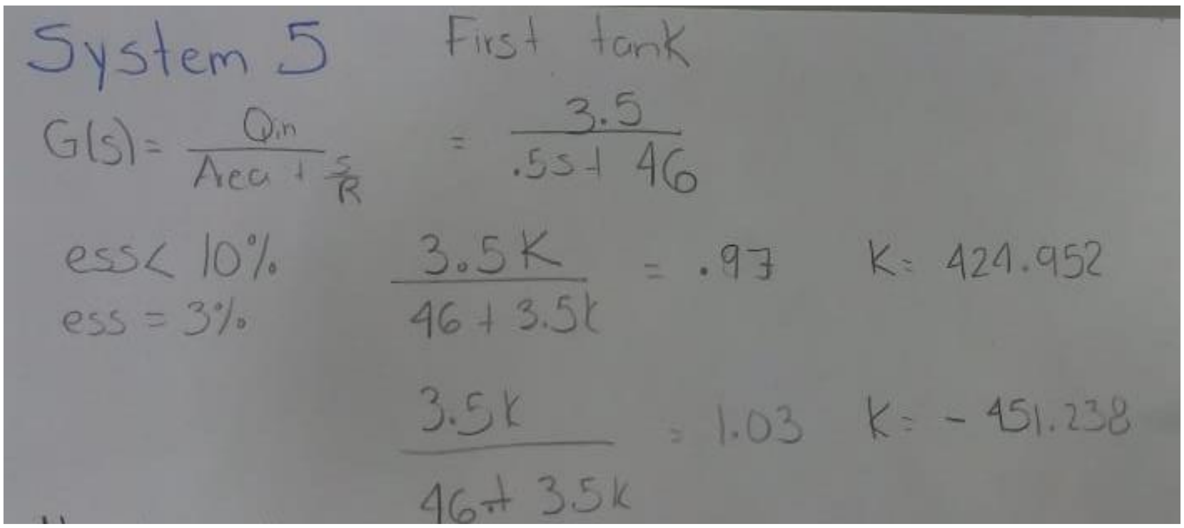
System 5

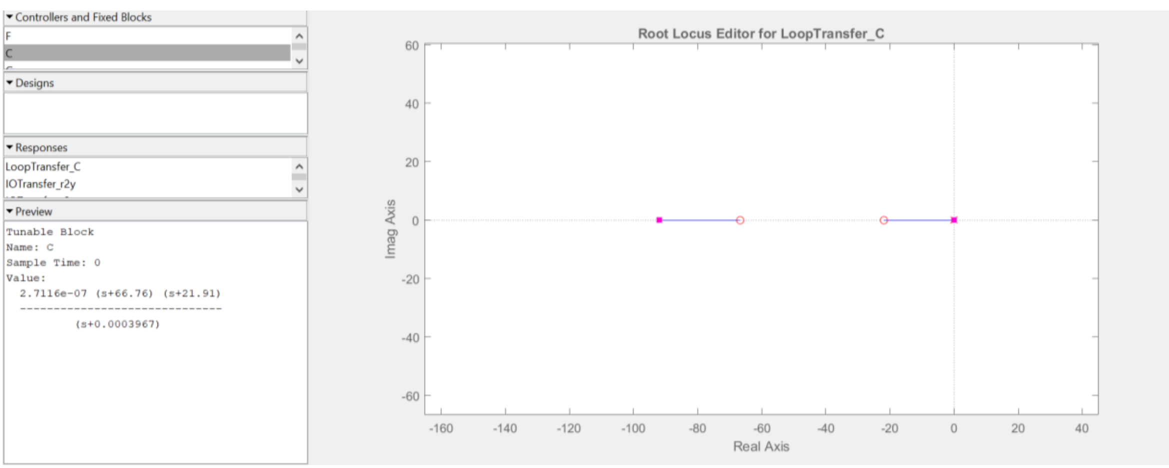
{n = 21}

H1 Ref_ 1 = 10.875

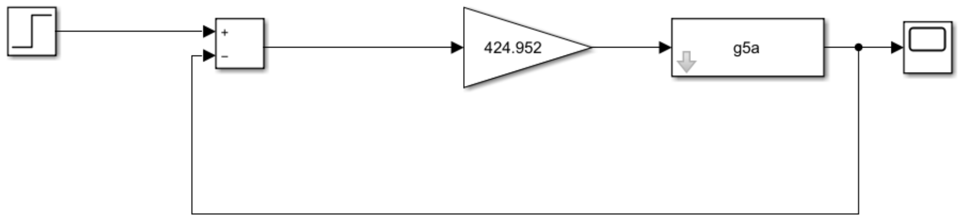
Symbolic transfer function

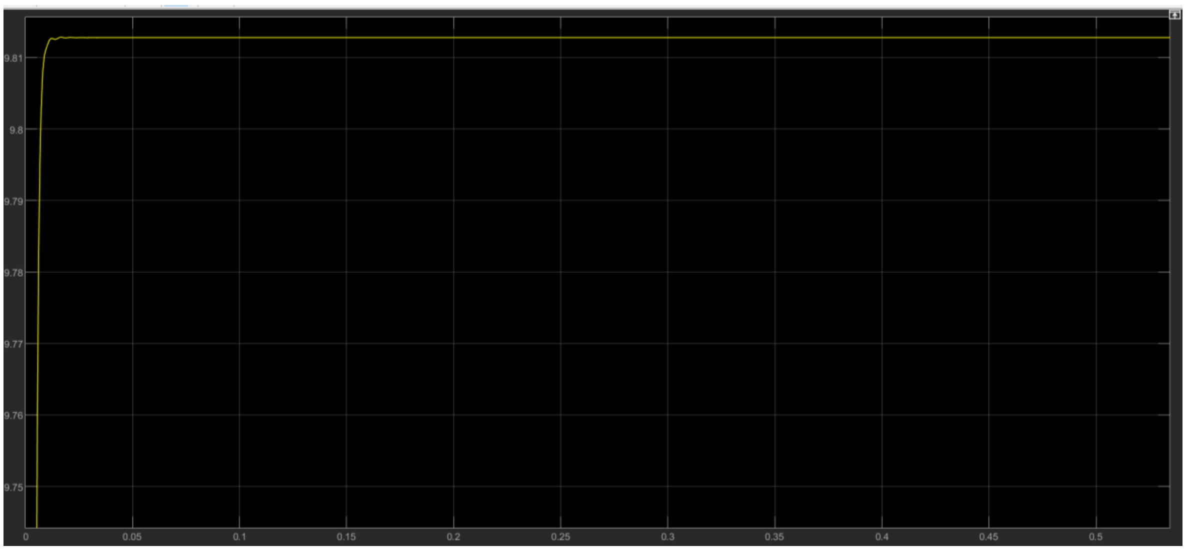
$$\frac{1}{Area1 + \frac{s}{R1}}$$





k = 424.952





PID - Algebraic method

K = 2.7116e-07

a = 66.76

b = 21.91

kd = 2.7116e-07

kc= 2.4043e-05

ki=3.9662e-04

Algeibrac PID

$$\frac{2.7116e\text{-}07\,(s+66.76)(s+21.91)}{s} = \frac{K(s+a)(s+b)}{s}$$

K= 2.7116 e-07

a= 66.76

b= 21.91

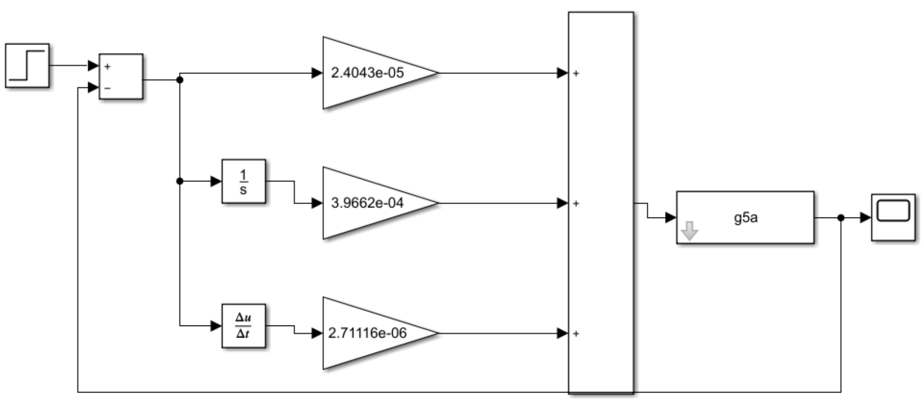
$$\underbrace{Ks^2}_{kd} + \underbrace{K(a+b)}_{Kc} + \underbrace{K\,ab}_{K_i}$$

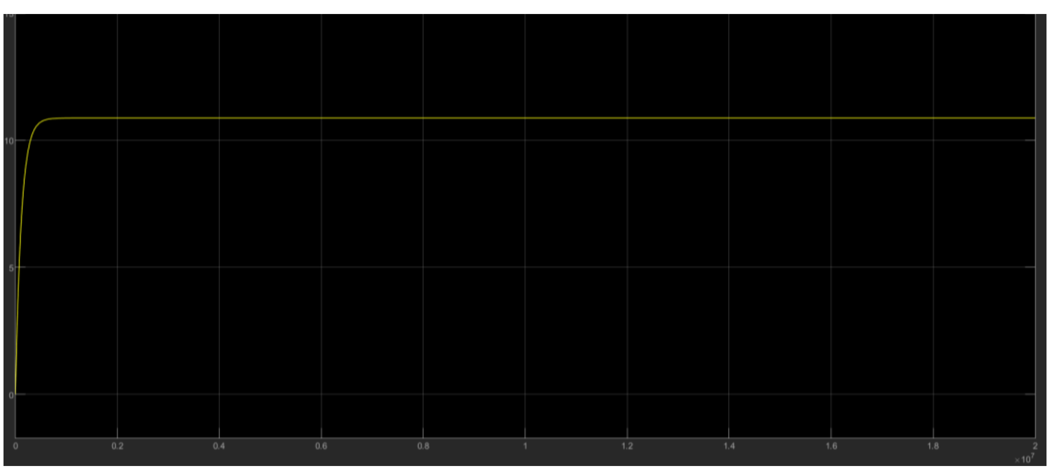
Kd = 2.7116e-07

Kc = 2.4043e-05

$K_i = 3.9662 \times 10^{-4}$

Ref_1 = 10.875

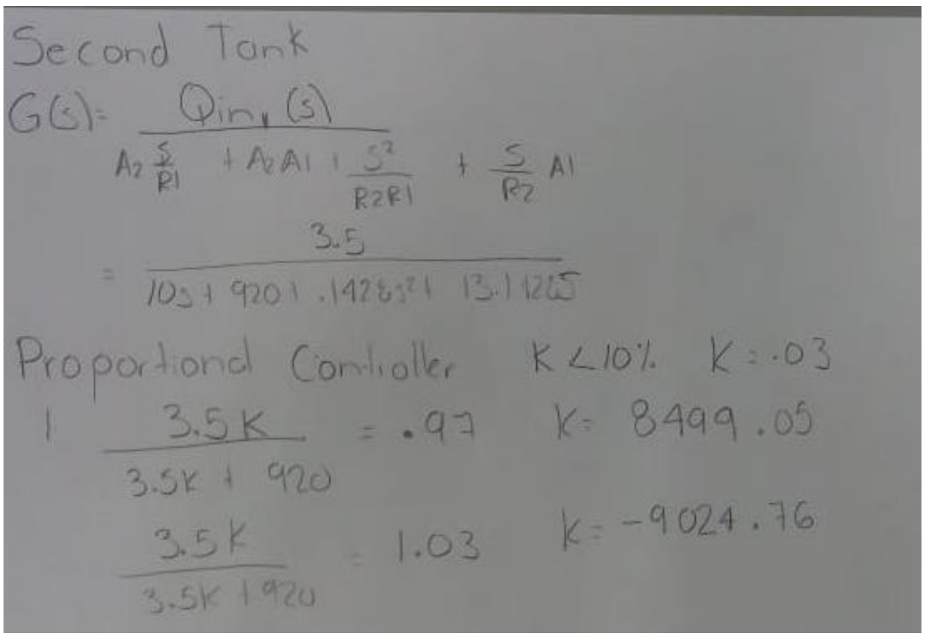


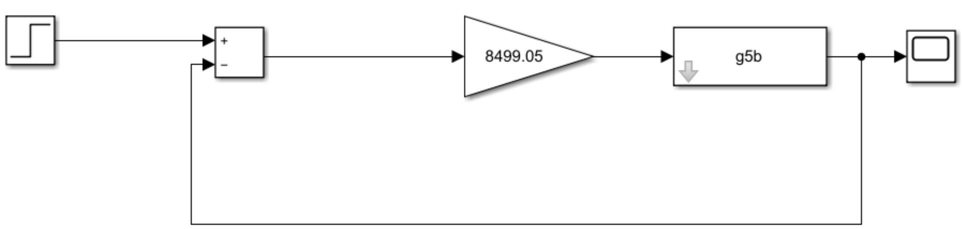


H2 Ref_2 = 13.775

Symbolic transfer function

$$\frac{Qin1}{\frac{A2s}{R1} + A2A1 + \frac{s^2}{R1R2} + \frac{A1s}{R2}}$$



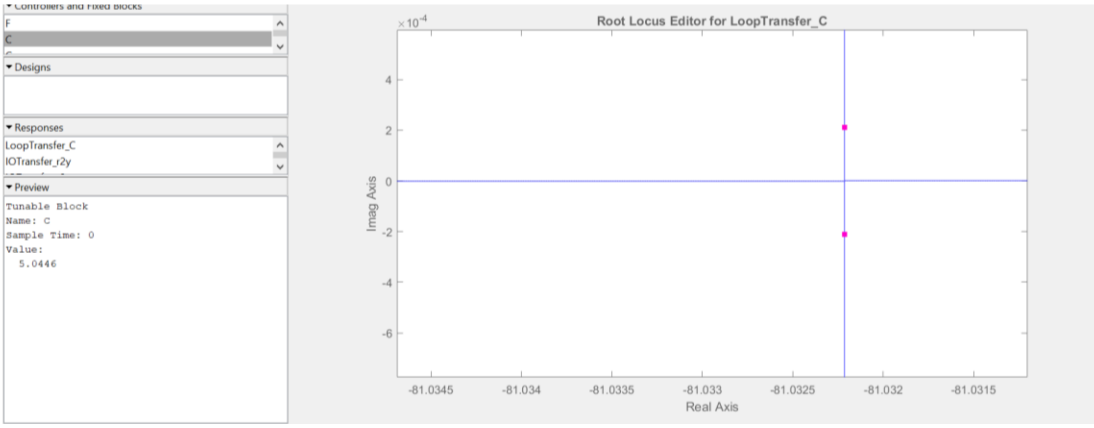


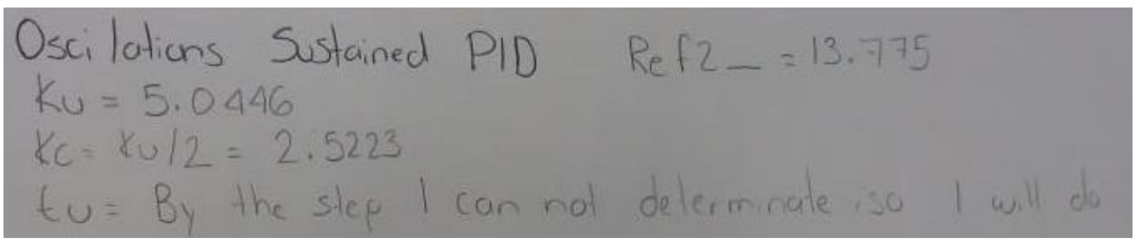
PID – Oscilations Sustained

ku = 5.0446

kc = 2.5223

tu= Using a step as a reference I can not determinate tu



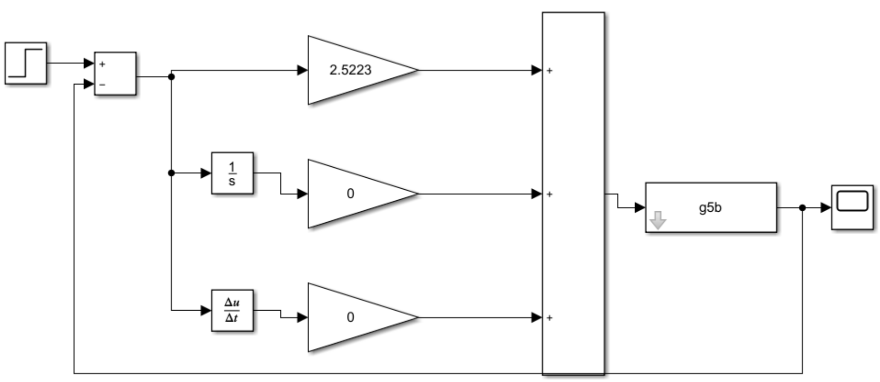


Oscilations Sustained PID   Ref2_ = 13.775

Ku = 5.0446

Kc = Ku/2 = 2.5223

tu = By the step I can not determinate, so I will do



PID - Algebraic method

K = 4.3023e-06

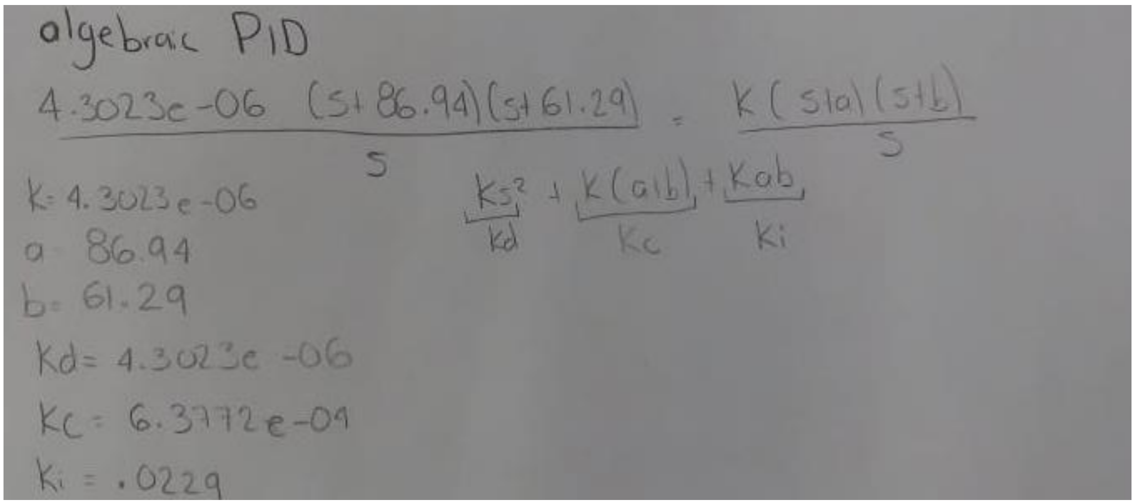
a = 86.94

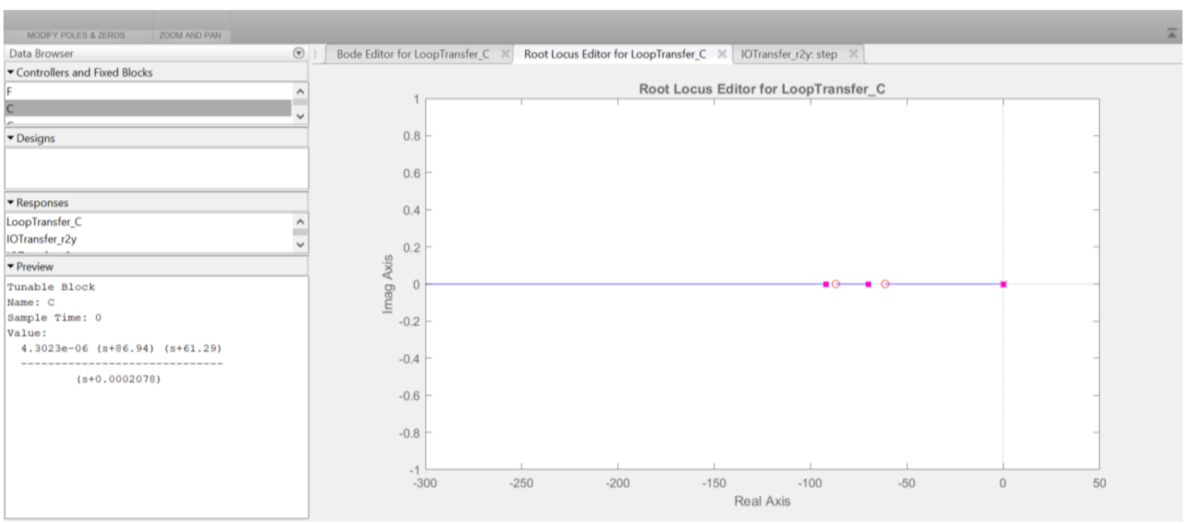
b = 61.29

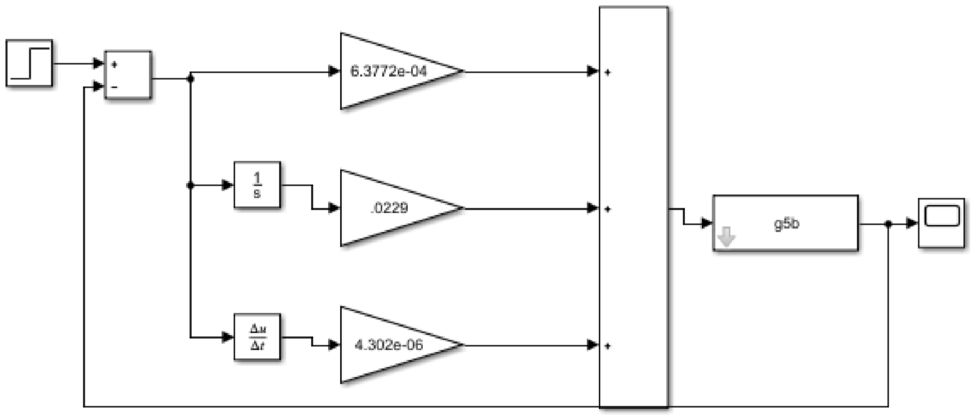
kd = 4.3023e-06

kc= 6.3772e-04

ki=.0229






6.3772e-04
.0229
4.302e-06
g5b