# Feedback Control Systems

# Complex Engineering Problem (Project)


## Phase 3 Report

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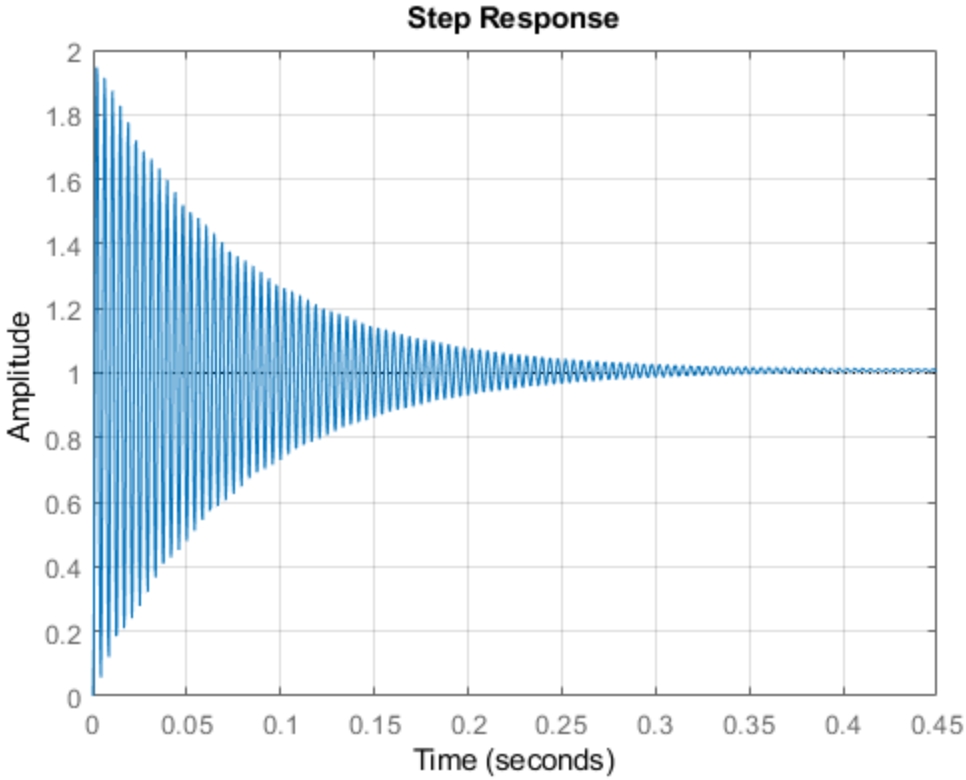
**Roll no:** 19I-0751

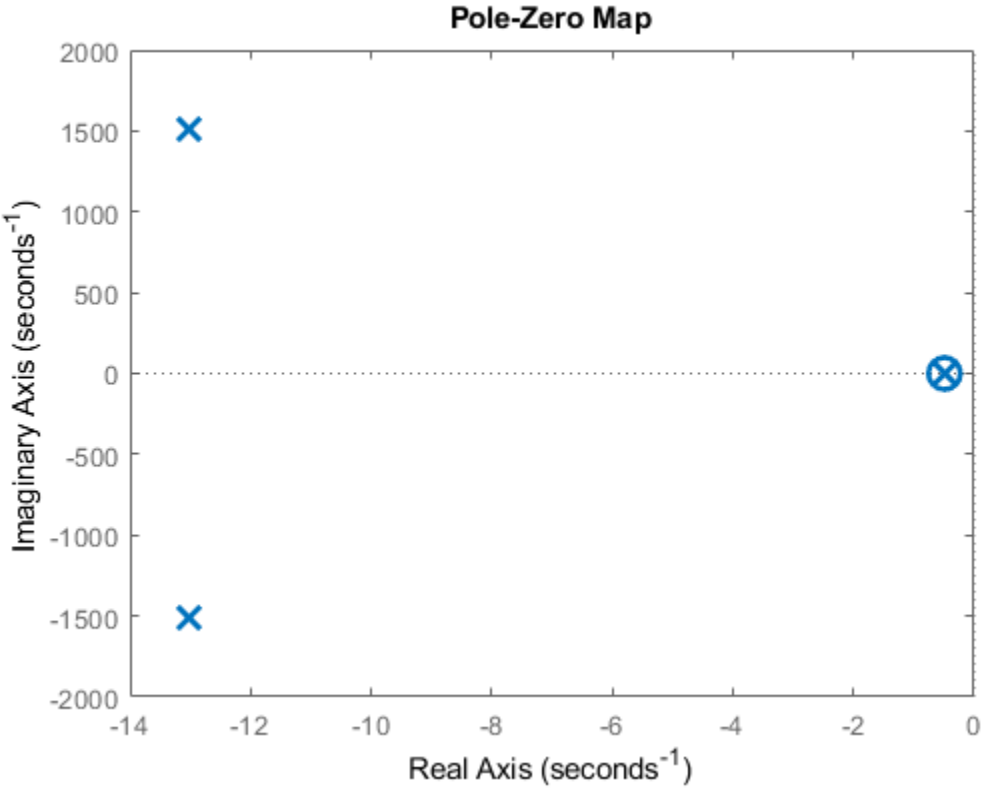
**Section:** A

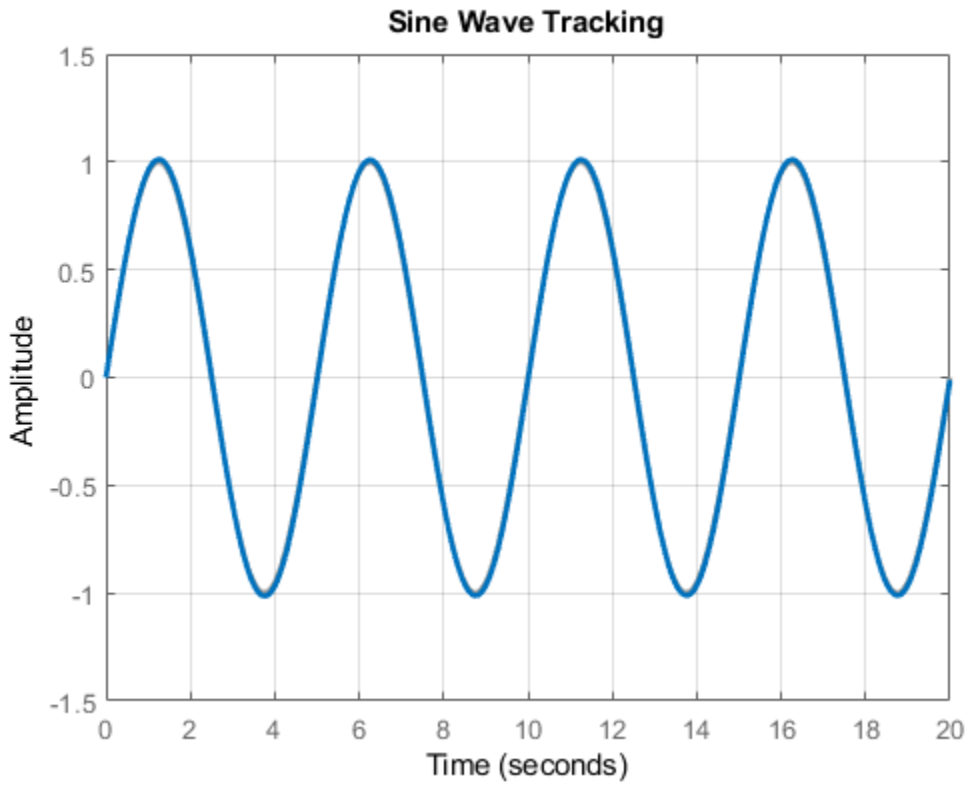
## PID Controller:

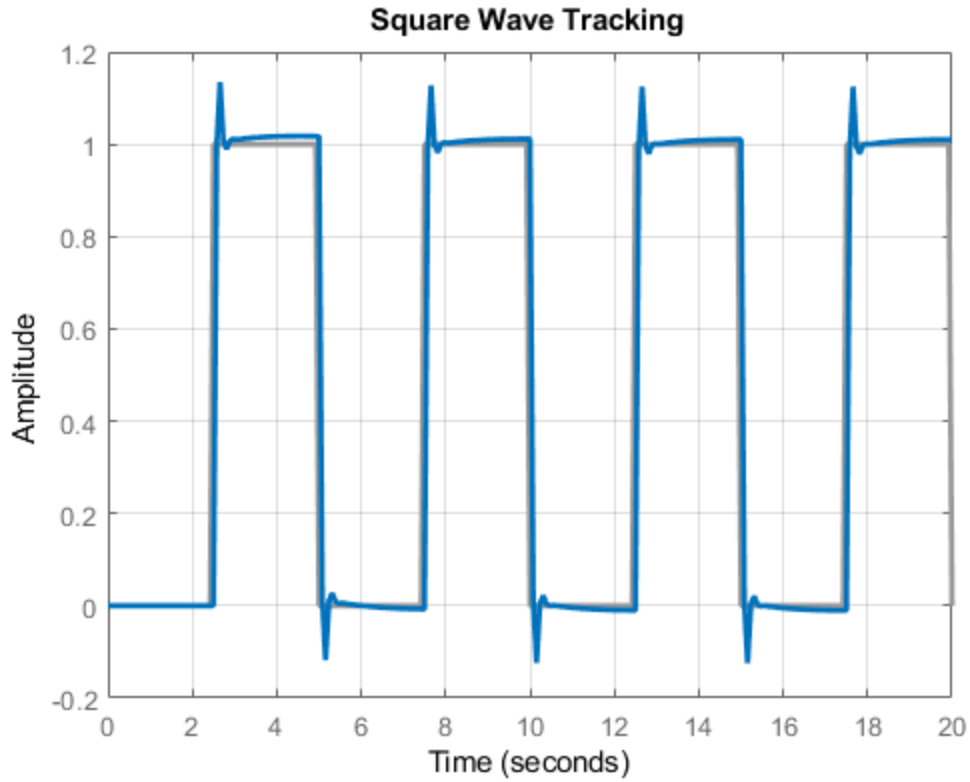
```
pidtune(G,'PID') % for getting the values of Kp, Ki and Kd
```

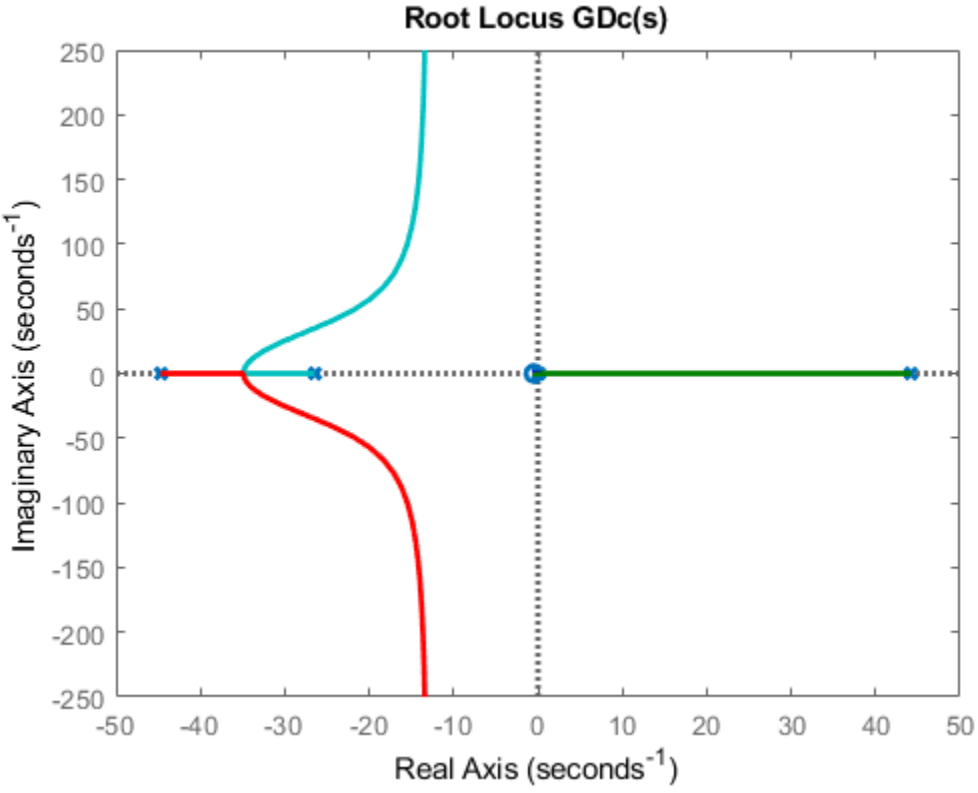
```
clear all;
s = tf('s');
G = (-153)/(s^3+27*s^2-1962*s-52320); % transfer function
t = 0:0.002:20;
[u,t] = gensig("sin",5,20); % generates signal
[y,t] = gensig("square",5,20);
Kp = -24.3;
Ki = -5.97;
Kd = -24.8;
H = 1;
Dc = Kp+Kd*s+Ki/s;
T = feedback(600*G*Dc,1);
figure(1);
step(T);
grid on
figure(2)
pzmap(T);
a = findobj(gca,'type','line'); % findobj locates graphics objects with specific properties
for i = 1:length(a)
    set(a(i),'markersize',12)
    set(a(i), 'linewidth',2)
end

figure(3)
lsim(T,u,t);
set(findall(gcf,'type','line'),'linewidth',2); % findall returns the objects that have the
specified
                                                % properties and sets them to the specified values
title("Sine Wave Tracking")
ylabel("Amplitude")
grid on
figure(4)
lsim(T,y,t);
set(findall(gcf,'type','line'),'linewidth',2);
title("Square Wave Tracking")
ylabel("Amplitude")
grid on
figure(5)
rlocus(G*Dc)
title('Root Locus GDc(s)')
set(findall(gcf,'type','line'),'linewidth',2);
```


Step Response
Amplitude
Time (seconds)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45


Pole-Zero Map
Imaginary Axis (seconds-1)
Real Axis (seconds-1)
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-14
-12
-10
-8
-6
-4
-2
0


Sine Wave Tracking
1.5
1
0.5
0
-0.5
-1
-1.5
Amplitude
0
2
4
6
8
10
12
14
16
18
20
Time (seconds)

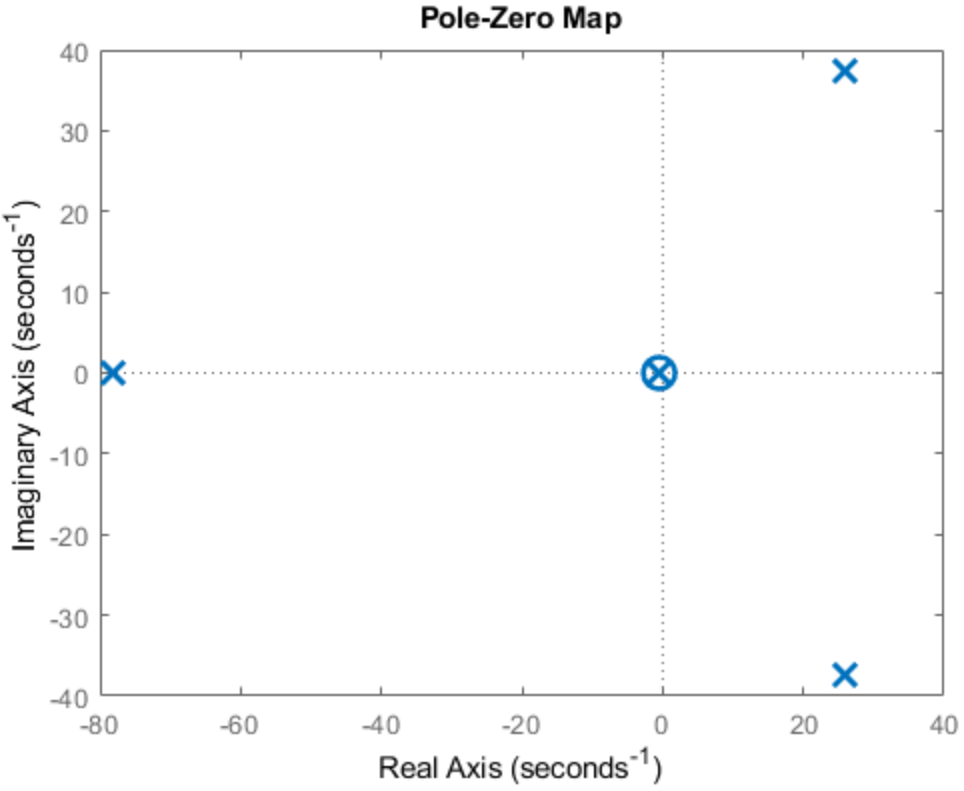

Square Wave Tracking
Amplitude
Time (seconds)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
2
4
6
8
10
12
14
16
18
20

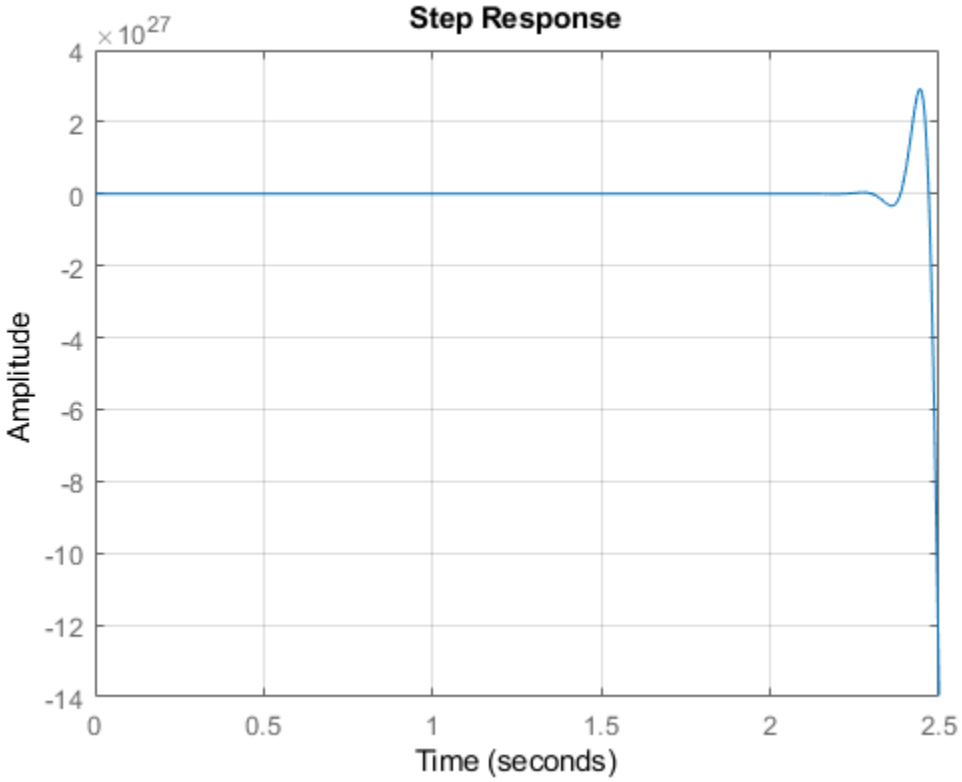

Root Locus GDc(s)
Imaginary Axis (seconds-1)
Real Axis (seconds-1)
250
200
150
100
50
0
-50
-100
-150
-200
-250
-50
-40
-30
-20
-10
0
10
20
30
40
50

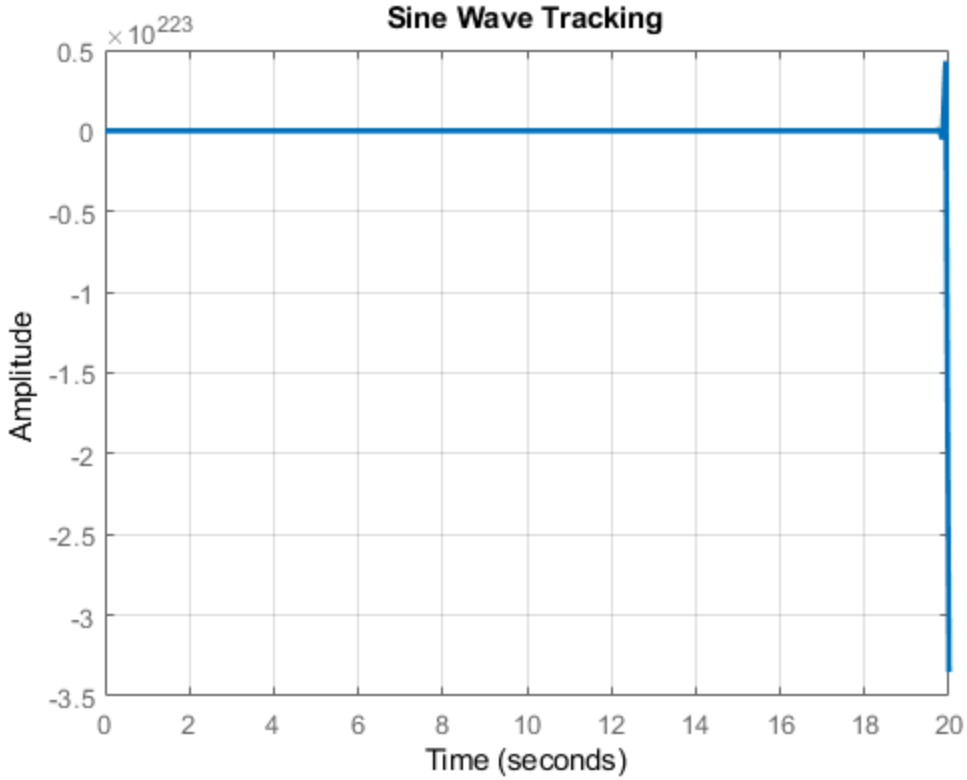
## PI Controller:

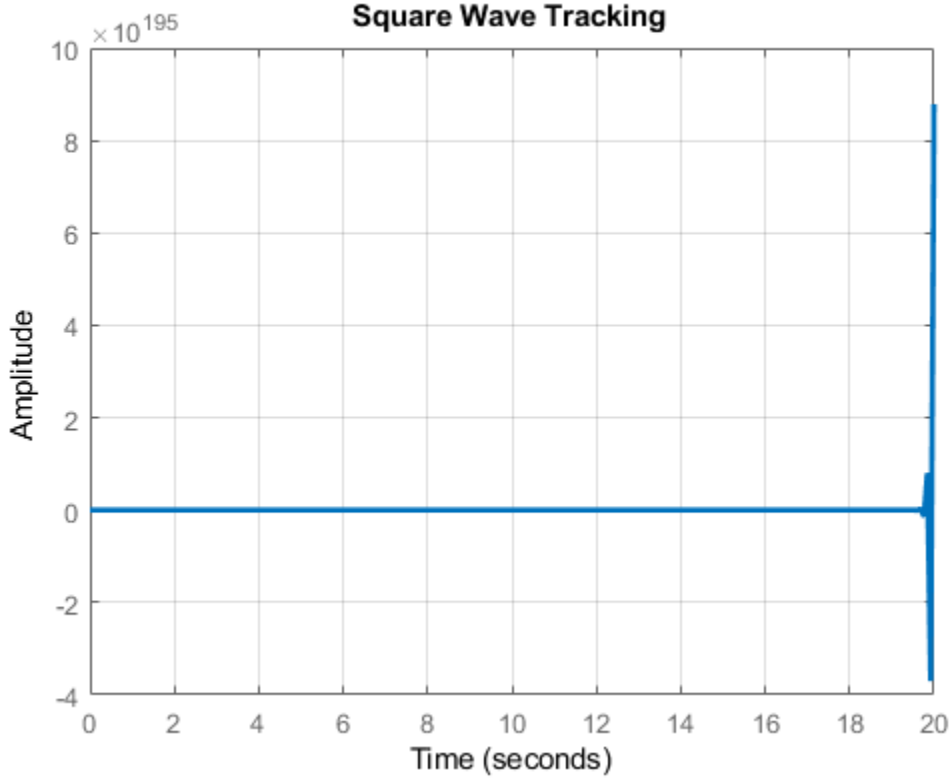
```
pidtune(G,'PI') % for getting the values of Kp and Ki
```

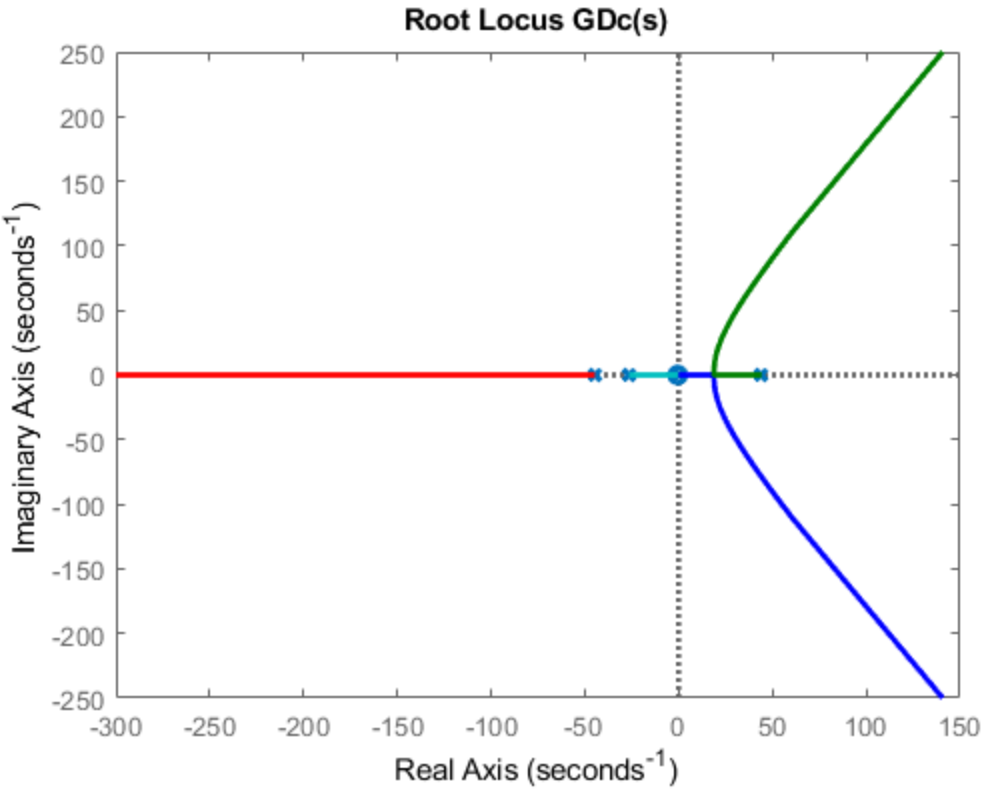
```
clear all;
s = tf('s');
G = (-153)/(s^3+27*s^2-1962*s-52320); % transfer function
t = 0:0.002:20;
[u,t] = gensig("sin",5,20); % generates signal
[y,t] = gensig("square",5,20);
Kp = -696;
Ki = -341;
H = 1;
Dc = Kp+Ki/s;
T = feedback(2*G*Dc,1);
figure(1);
pzmap(T);
a = findobj(gca,'type','line'); % findobj locates graphics objects with specific properties
for i = 1:length(a)
    set(a(i),'markersize',12)
    set(a(i), 'linewidth',2)
end
figure(2)
step(T);
grid on
figure(3)
lsim(T,u,t);
set(findall(gcf,'type','line'),'linewidth',2); % findall returns the objects that have the
specified
                                                % properties and sets them to the specified values
title("Sine Wave Tracking")
ylabel("Amplitude")
grid on
figure(4)
lsim(T,y,t);
set(findall(gcf,'type','line'),'linewidth',2);
title("Square Wave Tracking")
ylabel("Amplitude")
grid on
figure(5)
rlocus(G*Dc)
title('Root Locus GDc(s)')
set(findall(gcf,'type','line'),'linewidth',2);
```


Pole-Zero Map
Imaginary Axis (seconds-1)
Real Axis (seconds-1)
40
30
20
10
0
-10
-20
-30
-40
-80
-60
-40
-20
0
20
40


Step Response
×10^27
Amplitude
Time (seconds)
4
2
0
-2
-4
-6
-8
-10
-12
-14
0
0.5
1
1.5
2
2.5


Sine Wave Tracking
×10^223
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
Amplitude
0
2
4
6
8
10
12
14
16
18
20
Time (seconds)


Square Wave Tracking
×10^195
10
8
6
4
2
0
-2
-4
Amplitude
0
2
4
6
8
10
12
14
16
18
20
Time (seconds)


Root Locus GDc(s)
Imaginary Axis (seconds-1)
Real Axis (seconds-1)
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
-250
-200
-150
-100
-50
0
50
100
150

**Calculations:**

$M_p \leq 16\%$

$t_r < 0.3\,s$

$t_r = \frac{1.8}{\omega_n}$

$\omega_n = \frac{1.8}{t_r} = 6$

$M_p = e^{-\pi\zeta/\sqrt{1-\zeta^2}}$

$\ln(M_p) = \frac{-\pi\zeta}{\sqrt{1-\zeta^2}}$

$(-1.8322)^2 = \frac{\pi^2\zeta^2}{1-\zeta^2}$

$(1-\zeta^2)(3.361) = \pi^2\zeta^2$

$-\zeta^2 = \frac{-3.36}{3.36+\pi^2}$

$\zeta = 0.5$

$$G(s) = \frac{-153}{s^3 + 27s^2 - 1962s - 52320}, \quad H(s) = 1$$

$$TF = \frac{-153K}{s^3 + 27s^2 - 1962s - 52320 - 153K}$$

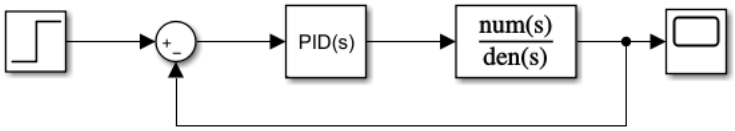
| | | |
|---|---|---|
| $s^3$ | 1 | $-1962$ |
| $s^2$ | 27 | $-52320 - 153K$ |
| $s^1$ | $\frac{105294 + 153K}{27}$ | 0 |
| $s^0$ | $-52320 - 153K$ | |

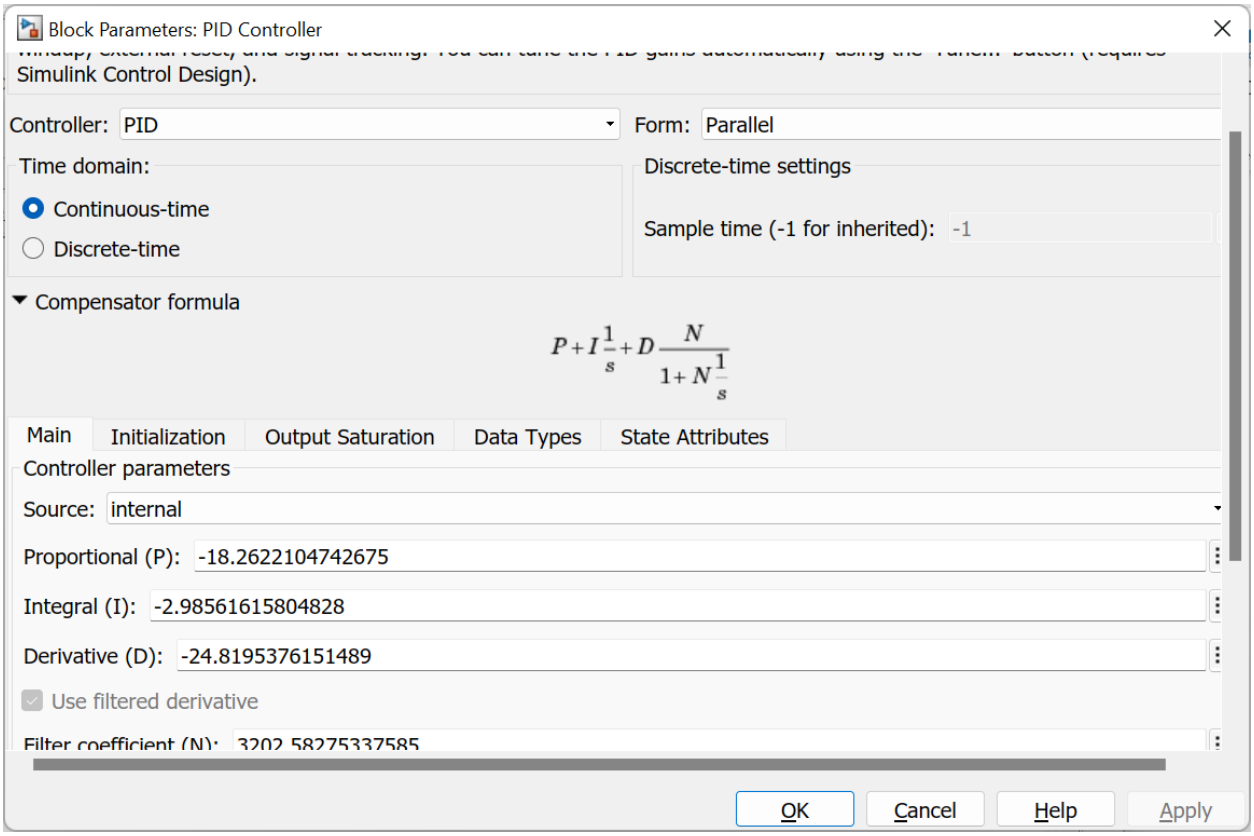
$$\frac{105294 + 153K}{27} > 0, \quad K > 0$$

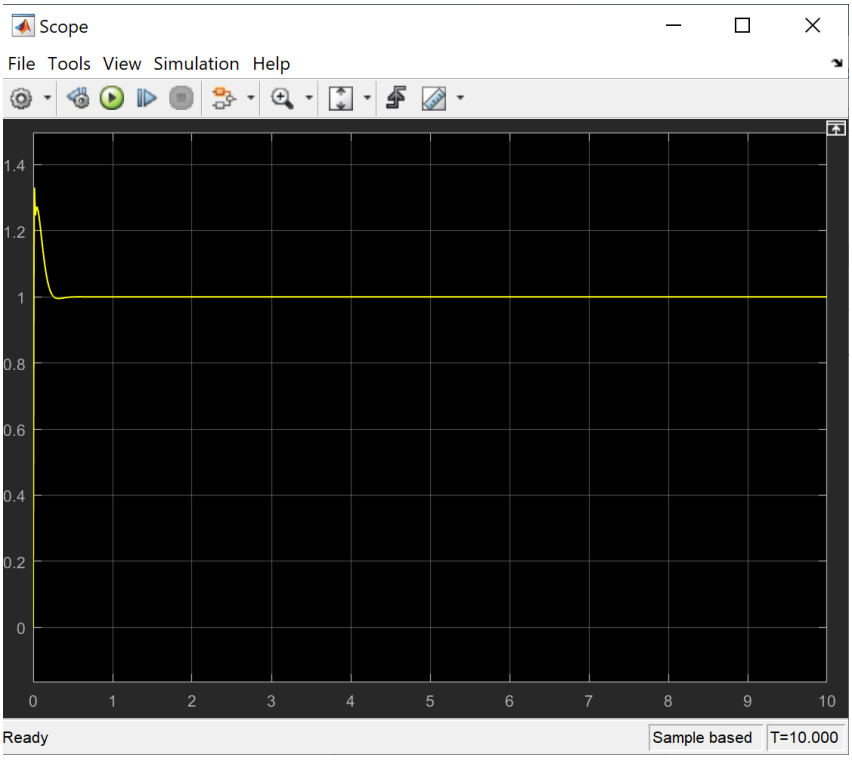
$$153K < -105294 \Rightarrow K < 688$$

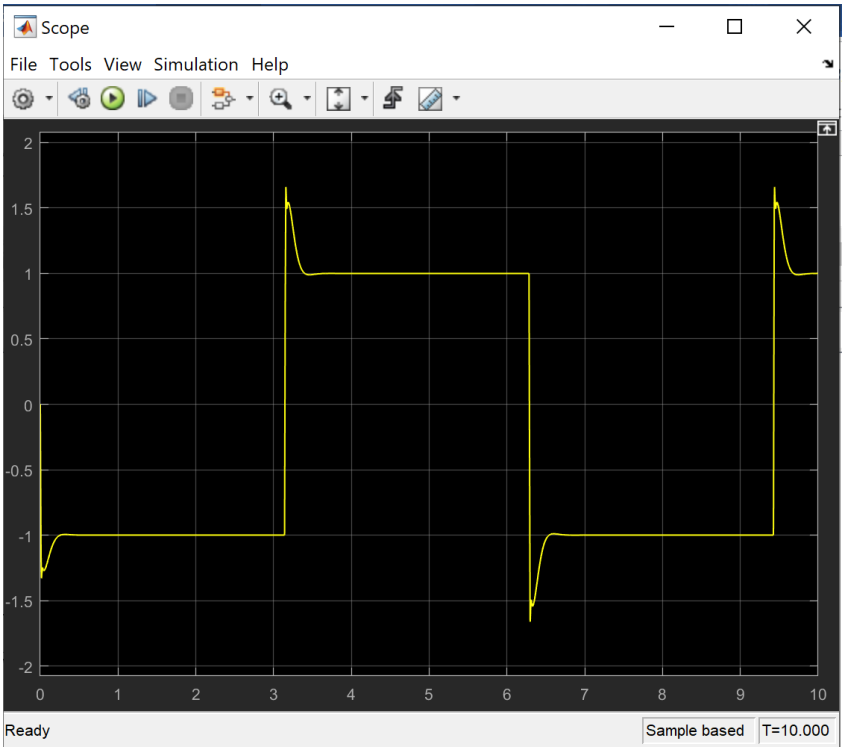
$$\therefore \quad 688 > K > 0$$

## Simulink:




Block Parameters: PID Controller
Simulink Control Design).
Controller: PID
Form: Parallel
Time domain:
Continuous-time
Discrete-time
Discrete-time settings
Sample time (-1 for inherited): -1
Compensator formula
$P+I\frac{1}{s}+D\frac{N}{1+N\frac{1}{s}}$
Main
Initialization
Output Saturation
Data Types
State Attributes
Controller parameters
Source: internal
Proportional (P): -18.2622104742675
Integral (I): -2.98561615804828
Derivative (D): -24.8195376151489
Use filtered derivative
Filter coefficient (N): 3202.58275337585
OK
Cancel
Help
Apply


Scope
File Tools View Simulation Help
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0 1 2 3 4 5 6 7 8 9 10
Ready
Sample based
T=10.000




## Analysis:

This system is an open loop unstable system. Different controllers were tried to see which one works best. It was observed that a PI controller would not work in this case as it was unstable for all values of K. After that PID controller was designed, which satisfied the system. The system perfectly tracked the sine and square waves. The values of Kp, Ki and Kd were obtained using the command 'pidtune'. It was also observed that for a high value of K, the controller tracked reference much better as increasing K reduces the error.