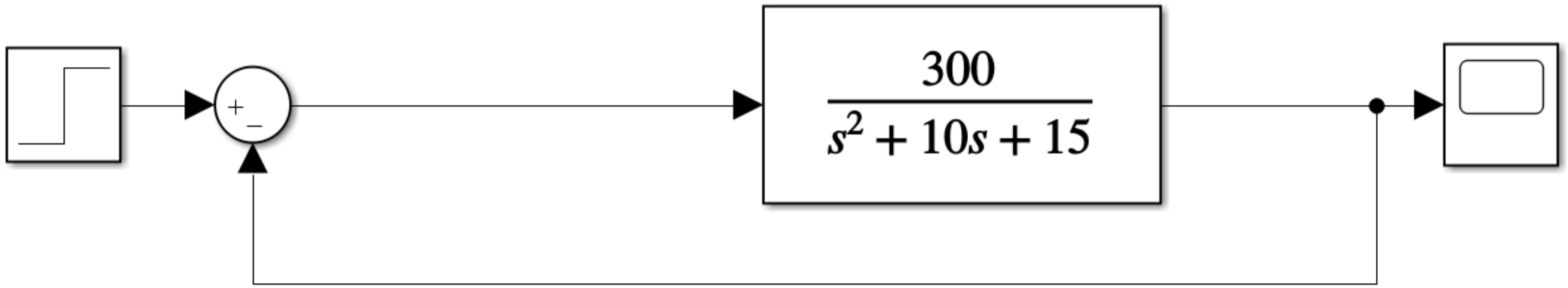
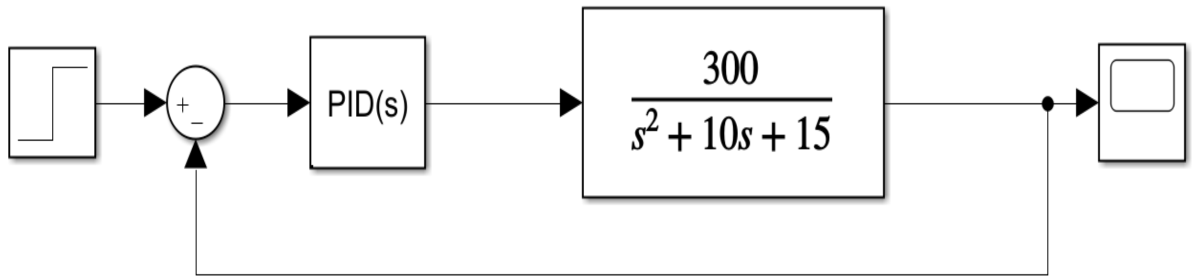
PID TUNING



+
–
300
s^2 + 10s + 15


+
−
PID(s)
$\frac{300}{s^2 + 10s + 15}$

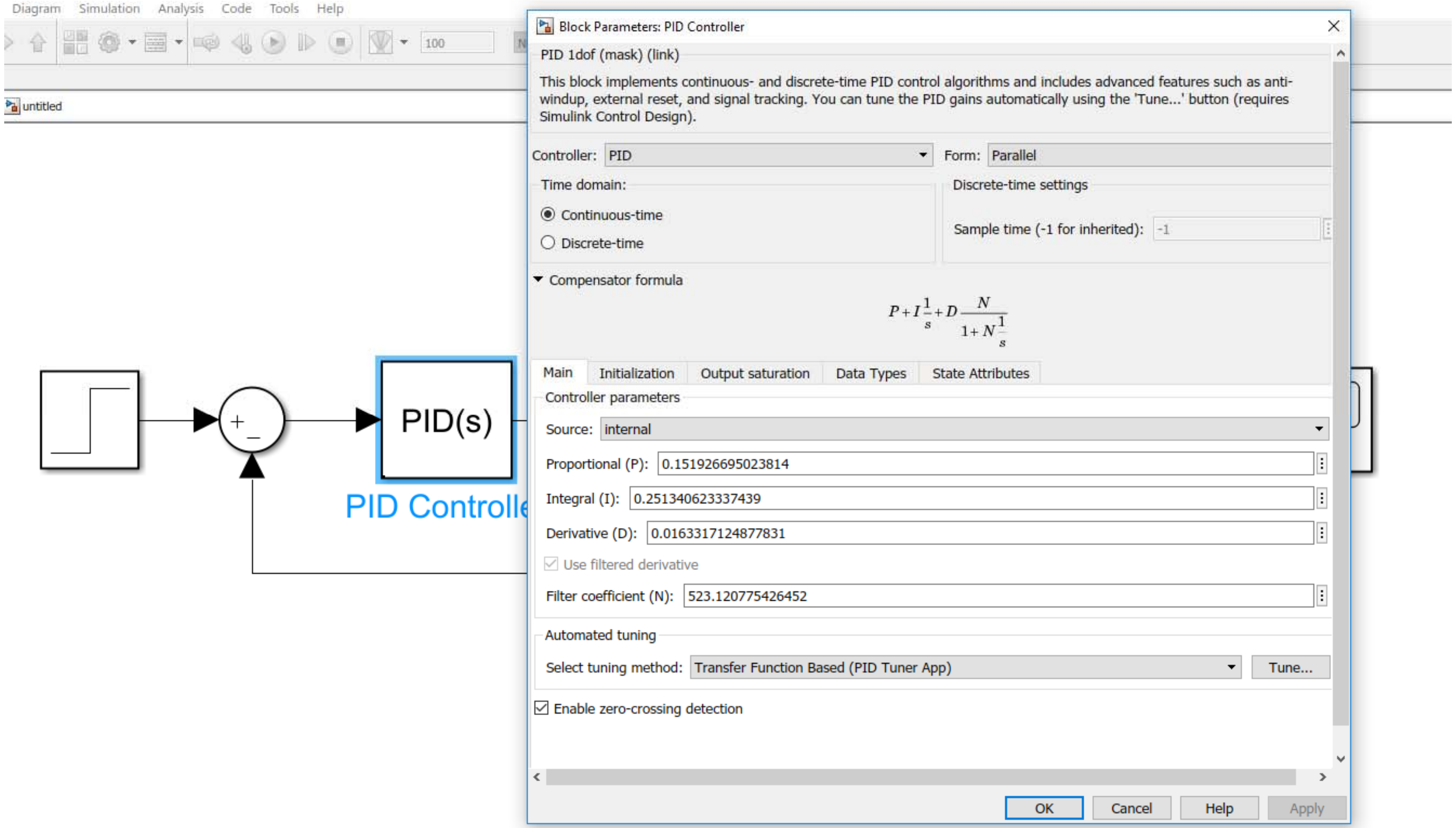
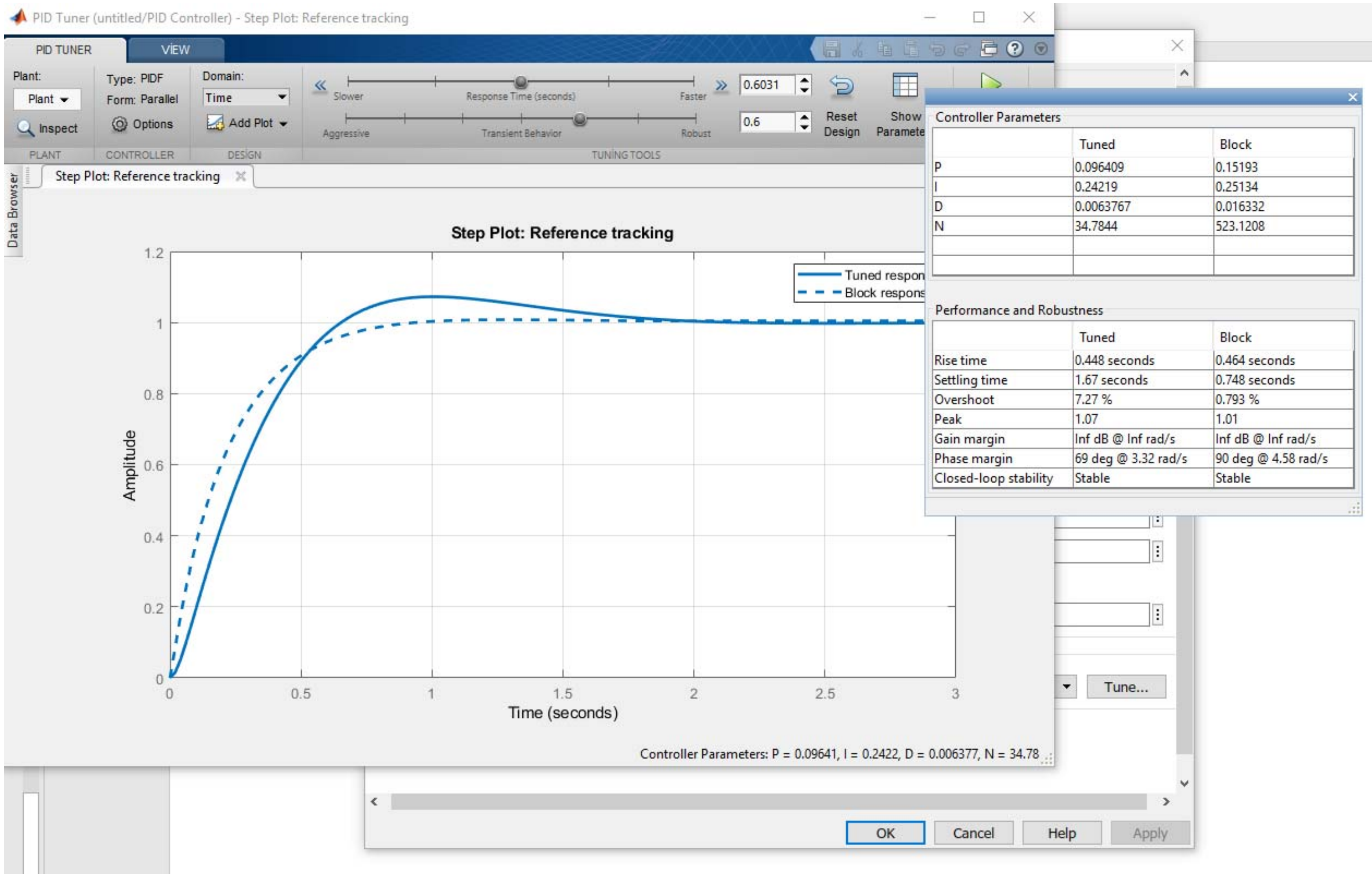


Diagram Simulation Analysis Code Tools Help
untitled
PID(s)
PID Controlle
Block Parameters: PID Controller
PID 1dof (mask) (link)
This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking. You can tune the PID gains automatically using the 'Tune...' button (requires 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): 0.151926695023814
Integral (I): 0.251340623337439
Derivative (D): 0.0163317124877831
Use filtered derivative
Filter coefficient (N): 523.120775426452
Automated tuning
Select tuning method: Transfer Function Based (PID Tuner App)
Tune...
Enable zero-crossing detection
OK Cancel Help Apply


PID Tuner (untitled/PID Controller) - Step Plot: Reference tracking
PID TUNER
VIEW
Plant:
Plant
Inspect
Type: PIDF
Form: Parallel
Options
Domain:
Time
Add Plot
Slower
Response Time (seconds)
Faster
0.6031
Aggressive
Transient Behavior
Robust
0.6
Reset Design
Show Paramete
PLANT
CONTROLLER
DESIGN
TUNING TOOLS
Data Browser
Step Plot: Reference tracking
Step Plot: Reference tracking
Tuned respon
Block respons
Amplitude
Time (seconds)
0
0.2
0.4
0.6
0.8
1
1.2
0
0.5
1
1.5
2
2.5
3
Controller Parameters: P = 0.09641, I = 0.2422, D = 0.006377, N = 34.78
Controller Parameters
Tuned
Block
P 0.096409 0.15193
I 0.24219 0.25134
D 0.0063767 0.016332
N 34.7844 523.1208
Performance and Robustness
Tuned
Block
Rise time 0.448 seconds 0.464 seconds
Settling time 1.67 seconds 0.748 seconds
Overshoot 7.27 % 0.793 %
Peak 1.07 1.01
Gain margin Inf dB @ Inf rad/s Inf dB @ Inf rad/s
Phase margin 69 deg @ 3.32 rad/s 90 deg @ 4.58 rad/s
Closed-loop stability Stable Stable
Tune...
OK
Cancel
Help
Apply

SisoTool

9-7. The loop transfer function of a system is

$$G(s)H(s) = \frac{1}{(2s+1)(s+1)(0.5s+1)}$$

Design a PD controller such that the $K_P = 9$ and the phase margin is greater than 25 degrees.

PD controller design

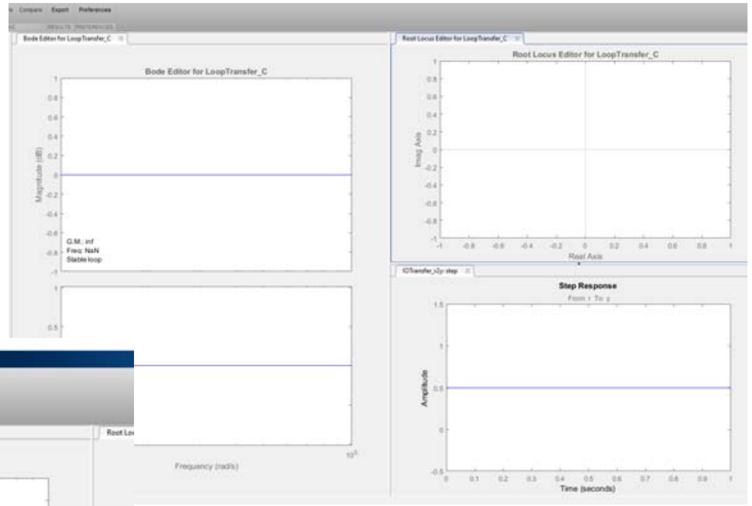
The open-loop transfer function of a system is:

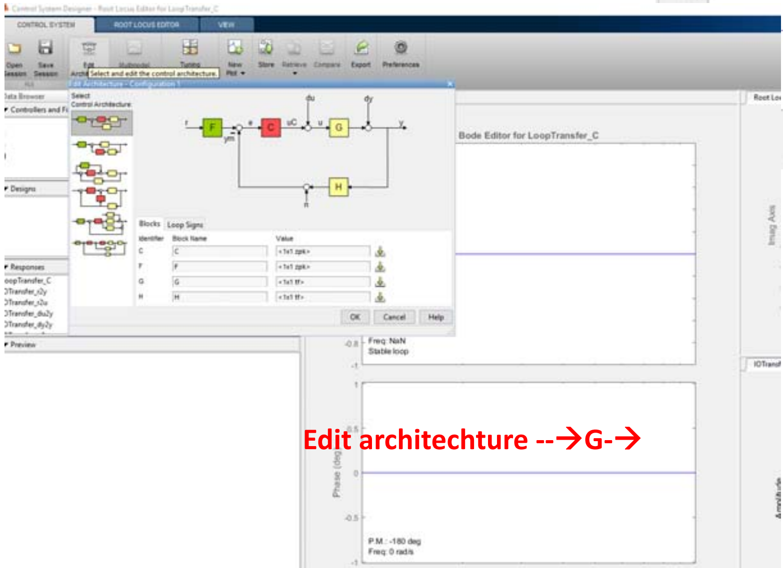
$$G(s)H(s) = \frac{1}{(2s+1)(s+1)(0.5s+1)}$$

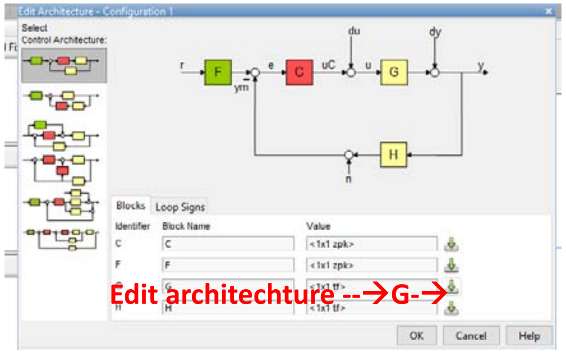
The solution is very similar to 9-4. The transfer functions are inserted into sisotool, where another real zero is added to represent the effect of K_d. That is $C(s) = K_p + K_d s = K_p(1 + K_d s / K_p)$, which is called the compensator transfer function in sisotool. The place of real zero is $Z = -K_p / K_d$, and the gain of the compensator is equal to K_p, as noted in the following sisotool window:

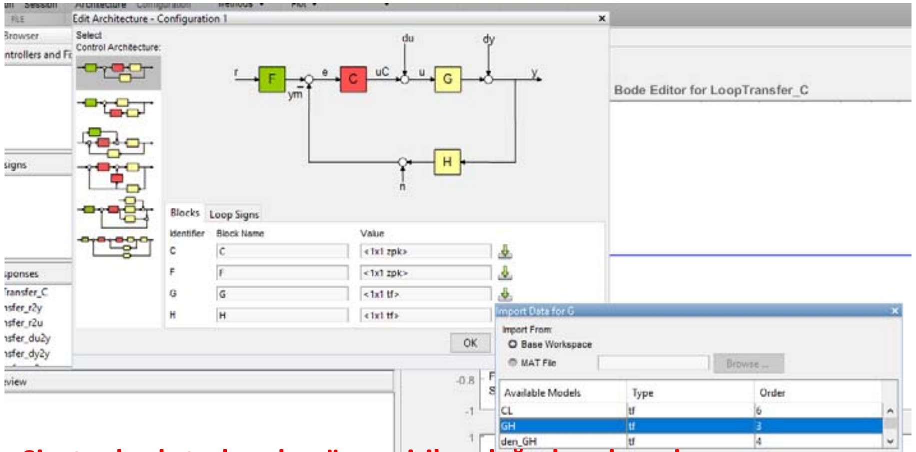
Preliminary MATLAB code for 9-7:

```
s = tf('s')
Kp = 1
num_GH= Kp*1;
den_GH=(2*s+1)*(s+1)*(0.5*s+1);
GH=num_GH/den_GH;
CL = GH/(1+GH)

Sisotool
```

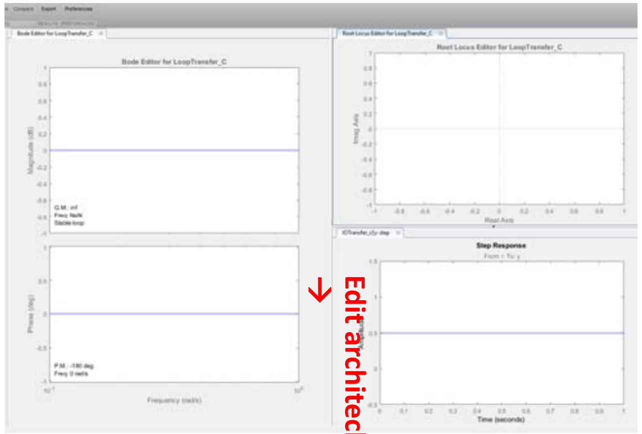




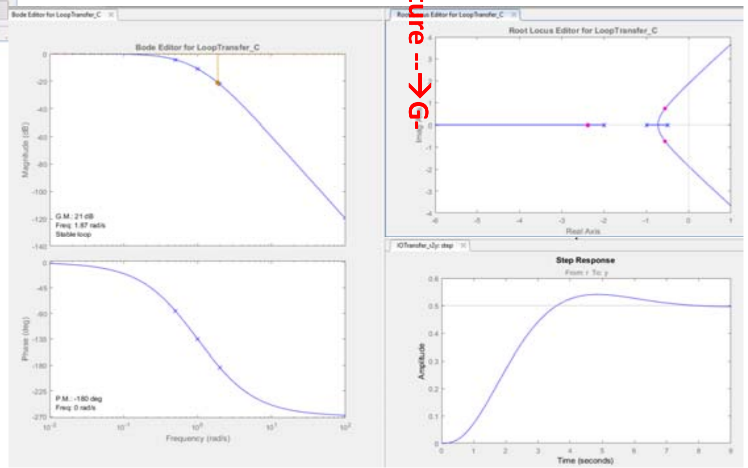




Sisotool çalıştırılmadan önce girilen değerler ekranda gösteriliyor. Buradan g için tasarladığımız GH ı seçip import ediyoruz. Ardından edit arch. Menüsüne OK deyip çıkıyoruz. Ekranın yeni haliyle güncellendiğini göreceğiz.

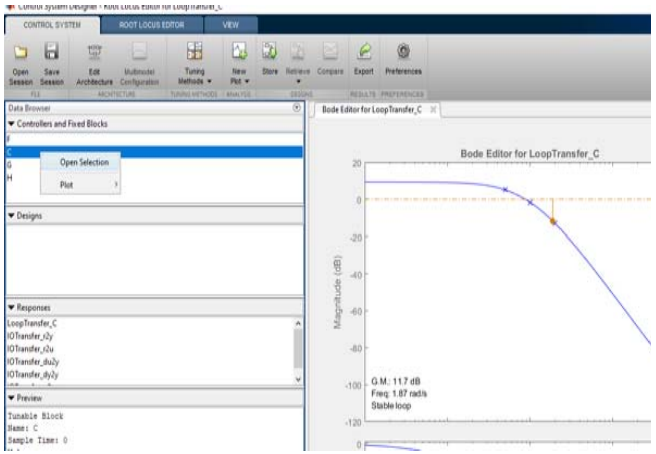


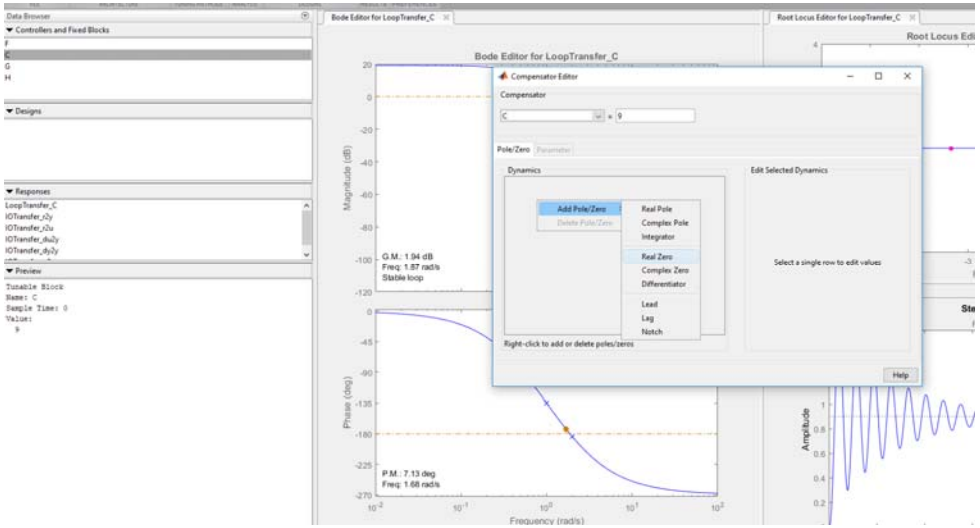
Edit architechture -->G-



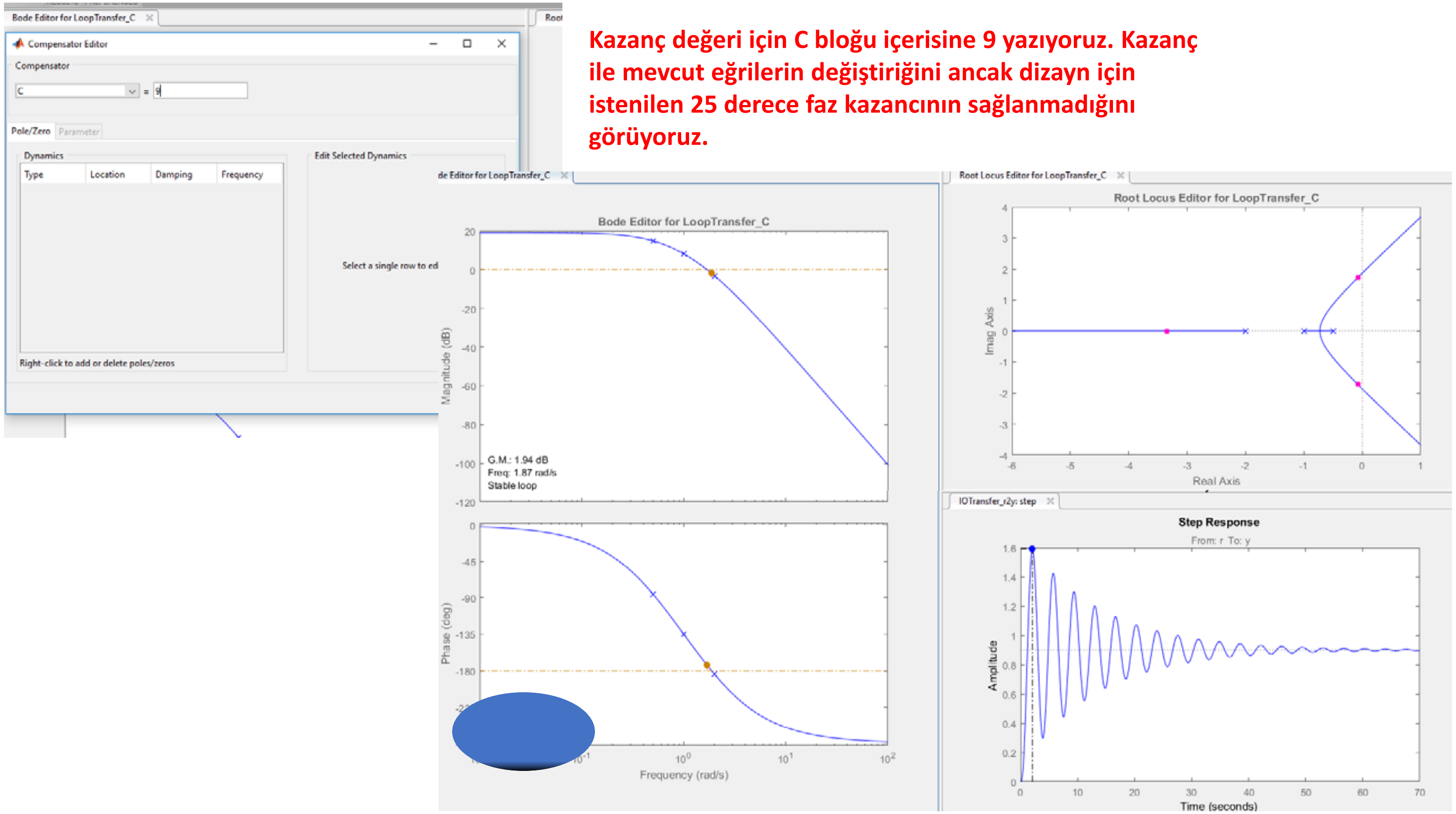
By fixing the gain to 9, and starting to change the zero location, PM can be adjusted to above 25 [deg] as required by the question. The current setting has a zero at -3.5, which resulted in 30 [deg] phase margin and 33.1 dB gain margin as seen in the following diagrams.

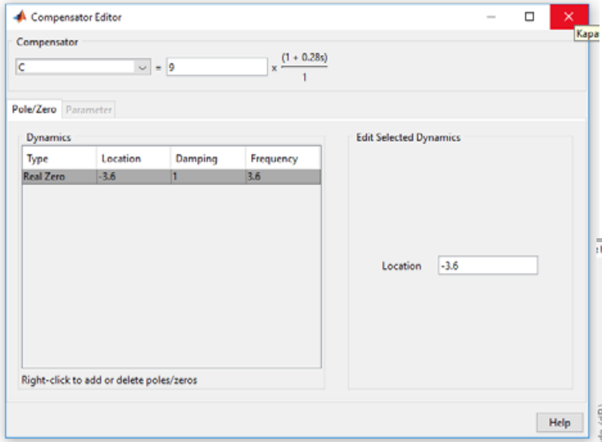
The design requires $K_p = 9$ **and** $K_d = -K_p / Z = -9/-3.6 = 2.5$



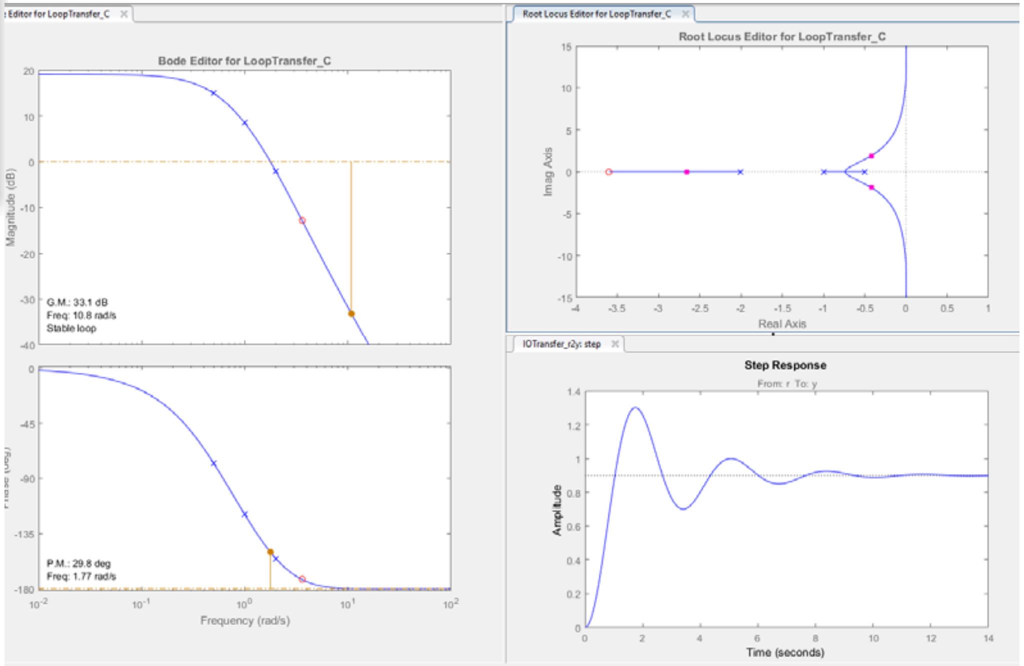


Kazanç değeri için C bloğu içerisine 9 yazıyoruz. Kazanç ile mevcut eğrilerin değiştiriğini ancak dizayn için istenilen 25 derece faz kazancının sağlanmadığını görüyoruz.



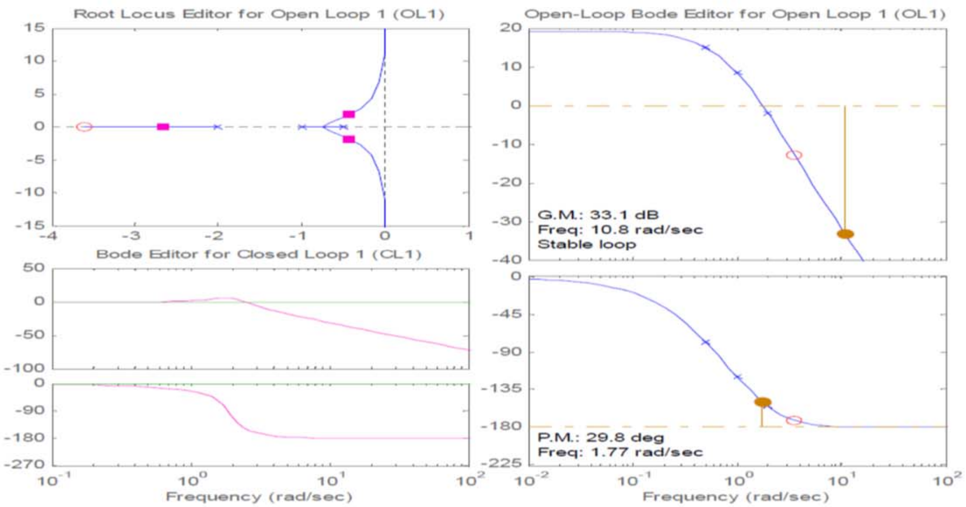


Kazanç değeri için C bloğu içerisine 9 ve gerçek sıfır kutubu için -3.6 değerini giriyoruz. Dizayn kriterini sağlamış oluyoruz. Farklı sıfır değerlerini girerek 25 dereceye yaklaşıldığını ya da uzaklaşıldığını görebilirsiniz. Aynı durumda farklı kutup ekleyerek de eğriler üzerinde değişimleri görebilirsiniz.



By fixing the gain to 9, and starting to change the zero location, PM can be adjusted to above 25 [deg] as required by the question. The current setting has a zero at -3.5, which resulted in 30 [deg] phase margin and 33.1 dB gain margin as seen in the following diagrams.

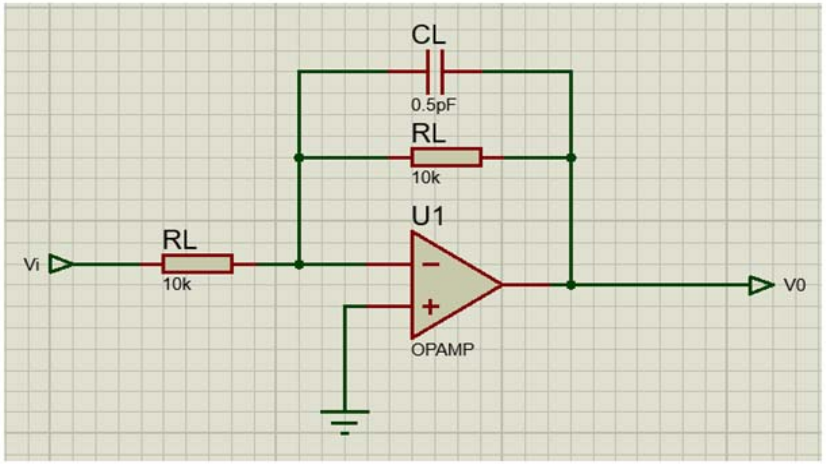
The design requires $K_p = 9$ **and** $K_d = -K_p / Z = -9/-3.6 = 2.5$



Preliminary MATLAB code for 9-7:

```
s = tf('s')
Kp = 1
num_GH= Kp*1;
den_GH=(2*s+1)*(s+1)*(0.5*s+1);

GH=num_GH/den_GH;
CL = GH/(1+GH)

Sisotool
```

Alçak Geçiren Filtrenin Transfer Fonksiyonunun Bulunması:



$$H(s) = \frac{V_0}{V_i} = -\frac{Z_0}{Z_i}$$

$$Z_i = R_L$$

$$Z_0 = R_L \, // \, \frac{1}{jwC_L} = \frac{R_L}{1 + jwC_L R_L}$$

Transfer Fonksiyonu

$$H(s) = -\frac{R_L}{R_L} * \frac{1}{1 + jwC_L R_L}$$

Kesim Frekansı

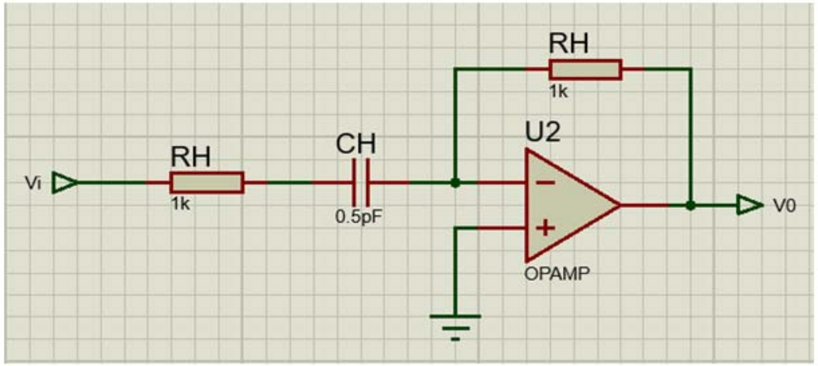
$$W = \frac{1}{R_L * C_L}$$

Kullanılan elemanların değerleri;

CH = **CL** = 0.5pf
RL = 10 k ohm
RH= 1 k ohm

Ro=2000 ohm;
Ri=1000 ohm;
R1=1000 ohm;
Rf=3000 ohm;

Yüksek Geçiren Filtrenin Transfer Fonksiyonunun Bulunması:



$$H(s) = \frac{V_0}{V_i} = -\frac{Z_0}{Z_i}$$

$$Z_i = R_H + \frac{1}{jwC_H}$$

$$Z_0 = R_H$$

Transfer Fonksiyonu

$$H(s) = \frac{jwC_H R_H}{1 + jwC_H R_H}$$

Kesim Frekansı

$$W = \frac{1}{R_H * C_H}$$

Kullanılan elemanların değerleri;

CH = **CL** = 0.5pf
RL = 10 k ohm
RH= 1 k ohm

Ro=2000 ohm;
Ri=1000 ohm;
R1=1000 ohm;
Rf=3000 ohm;

Band Geçiren Filtrenin Transfer Fonksiyonunun Bulunması:

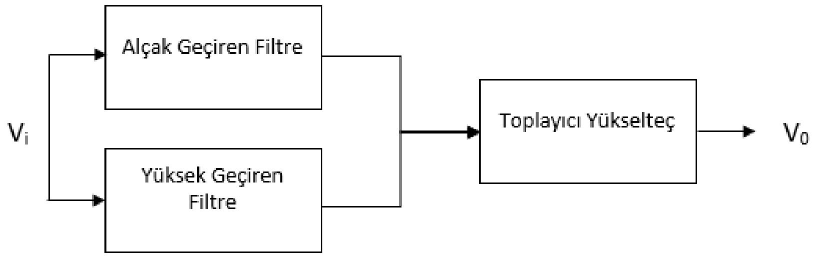
$$H(s)=\frac{V_0}{V_i}=\underbrace{\left(-\frac{1}{1+jwC_LR_L}\right)}_{\text{AGF}}*\underbrace{\left(-\frac{jwC_HR_H}{1+jwC_HR_H}\right)}_{\text{YGF}}*\underbrace{\left(-\frac{R_0}{R_i}\right)}_{\text{Faz Çeviren}}$$

Kullanılan elemanların değerleri;

CH = **CL** = 0.5pf
RL = 10 k ohm
RH= 1 k ohm

Ro=2000 ohm;
Ri=1000 ohm;
R1=1000 ohm;
Rf=3000 ohm;

Band Durduran Filtrenin Transfer Fonksiyonunun Bulunması:



$$H(s) = \frac{V_0}{V_i} = \left(-\frac{R_f}{R_1}\right) * \left[\underbrace{\left(-\frac{1}{1 + jwC_L R_L}\right)}_{\text{AGF}} + \underbrace{\left(-\frac{jwC_H R_H}{1 + jwC_H R_H}\right)}_{\text{YGF}}\right]$$

Kullanılan elemanların değerleri;

CH = **CL** = 0.5pf
RL = 10 k ohm
RH= 1 k ohm

Ro=2000 ohm;
Ri=1000 ohm;
R1=1000 ohm;
Rf=3000 ohm;

MATLAB KODU

```
a = 4;
RL=10000*a;
RH=1000*a;
CH=0.5*10^-6;
CL=0.5*10^-6;
Ro=2000;
Ri=1000;
R1=1000;
Rf=3000;

s = tf('s'); % s domaininde tanımlamak için

Wcl= 1 / ( RL * CL ) % alçak geçirenin kesim frekansı
Wch= 1 / ( RH * CH ) % yüksek geçirenin kesim
frekansı
Wo= sqrt(Wcl*Wch)   % Band geçirenin kesim frekansı
```

```
%Alçak Geçiren Filtre - Transfer fonksiyonu
Hag=(-1*(1/(1+(s * Wcl * CL * RL))))
figure(1);
bode(Hag)
%Yüksek Geçiren Filtre - Transfer fonksiyonu
Hyg=( -1 * ((s * Wch * CH * RH ) /(1+(s * Wcl * CH * RH))))
figure(2);
bode(Hyg)
%----------------------------------------% band geçiren
Hbg= (- Ro/Ri ) * Hag * Hyg

% band durduran
Hbd= (- Rf/R1 ) * ( Hag + Hyg )

% Bode diyagramları
figure(3);
bode(Hbd) % band durduran

figure(4);
bode(Hbg) % band geçiren
```

Wcl = 50
Wch = 500
Wo = 158.1139

Hag =

-1
-----
s + 1

Hyg =

-s

0.1 s + 1

Hbg =

-2 s

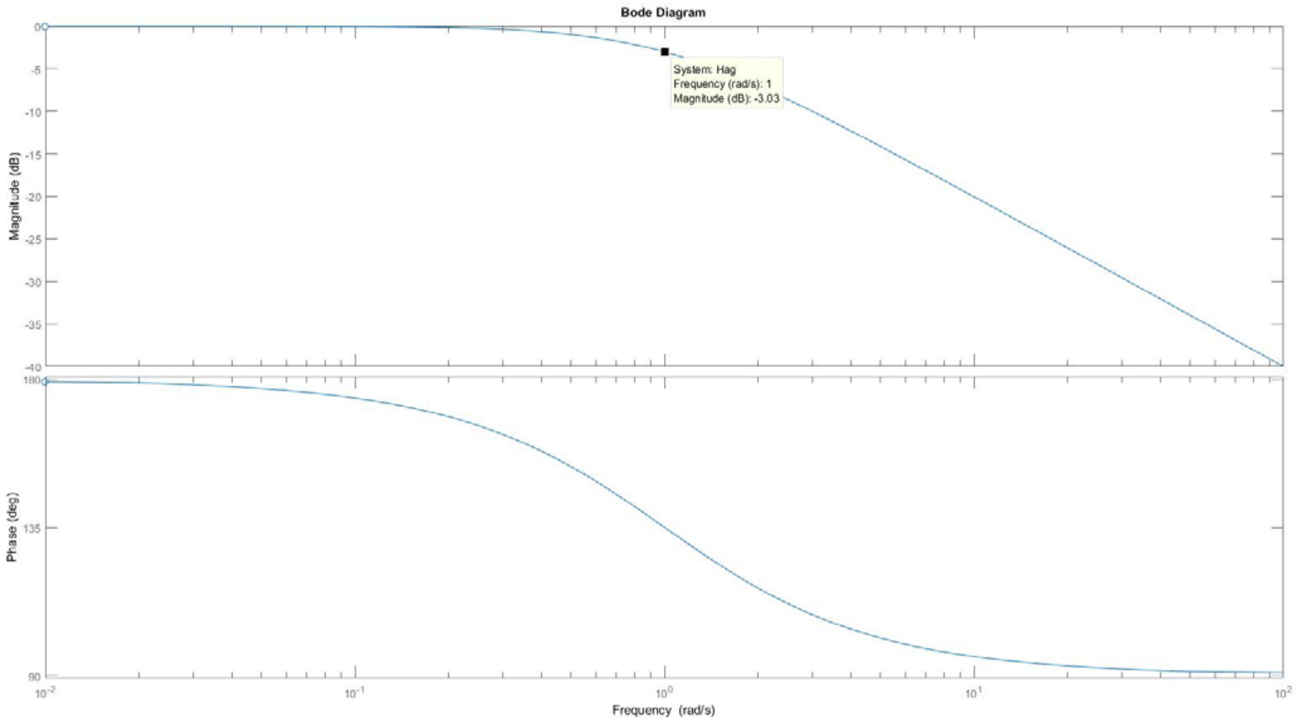
0.1 s^2 + 1.1 s + 1

Hbd =

3 s^2 + 3.3 s + 3

0.1 s^2 + 1.1 s + 1

%Alçak Geçiren Filtre - Transfer fonksiyonu
Hag=(-1*(1/(1+(s * Wcl * CL * RL))))



Wcl = 50
Wch = 500
Wo = 158.1139

Hag =
-1
-----
s + 1

Hyg =

-s

0.1 s + 1

Hbg =

-2 s

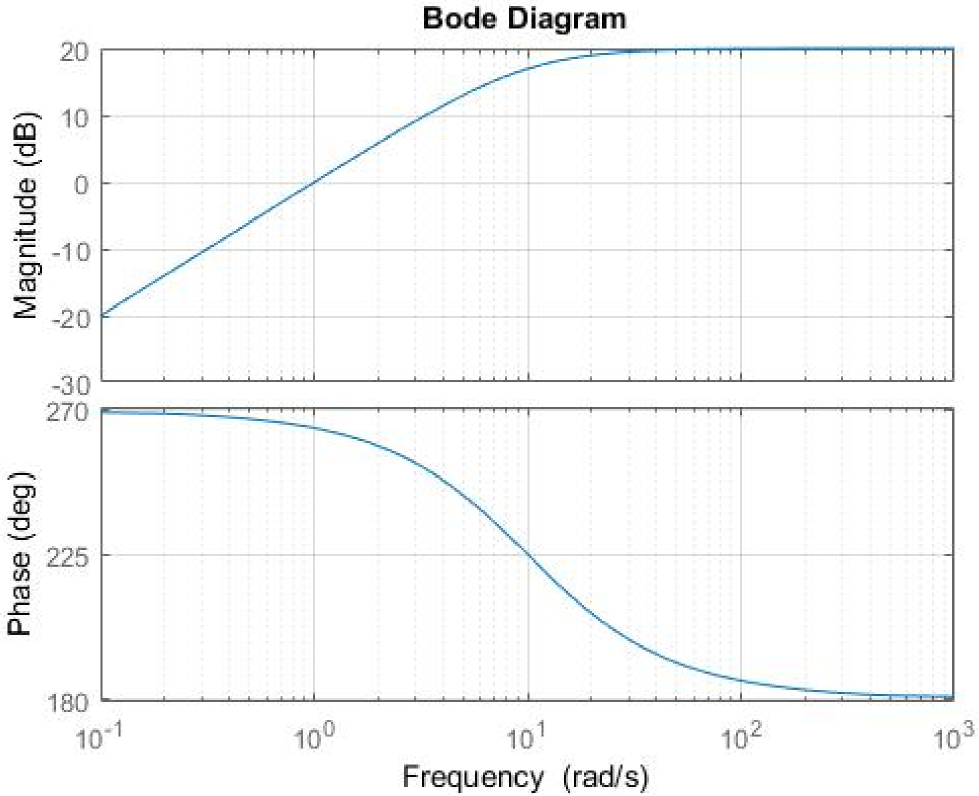
0.1 s^2 + 1.1 s + 1

Hbd =

3 s^2 + 3.3 s + 3

0.1 s^2 + 1.1 s + 1

%Yüksek Geçiren Filtre - Transfer fonksiyonu
Hyg=(-1 * ((s * Wch * CH * RH) /(1+(s * Wcl * CH * RH))))



Wcl =   50
Wch =   500
Wo = 158.1139

Hag =

$$\frac{-1}{s + 1}$$

Hyg =

$$\frac{-s}{0.1 s + 1}$$

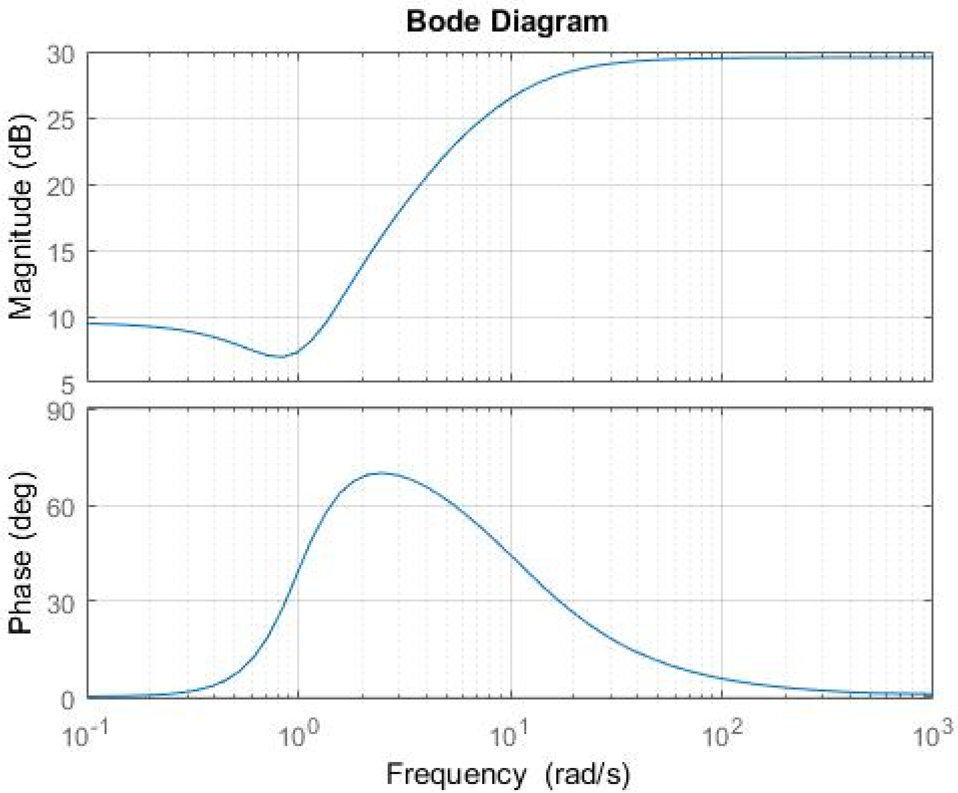
Hbg =

$$\frac{-2 s}{0.1 s^2 + 1.1 s + 1}$$

Hbd =

$$\frac{3 s^2 + 3.3 s + 3}{0.1 s^2 + 1.1 s + 1}$$

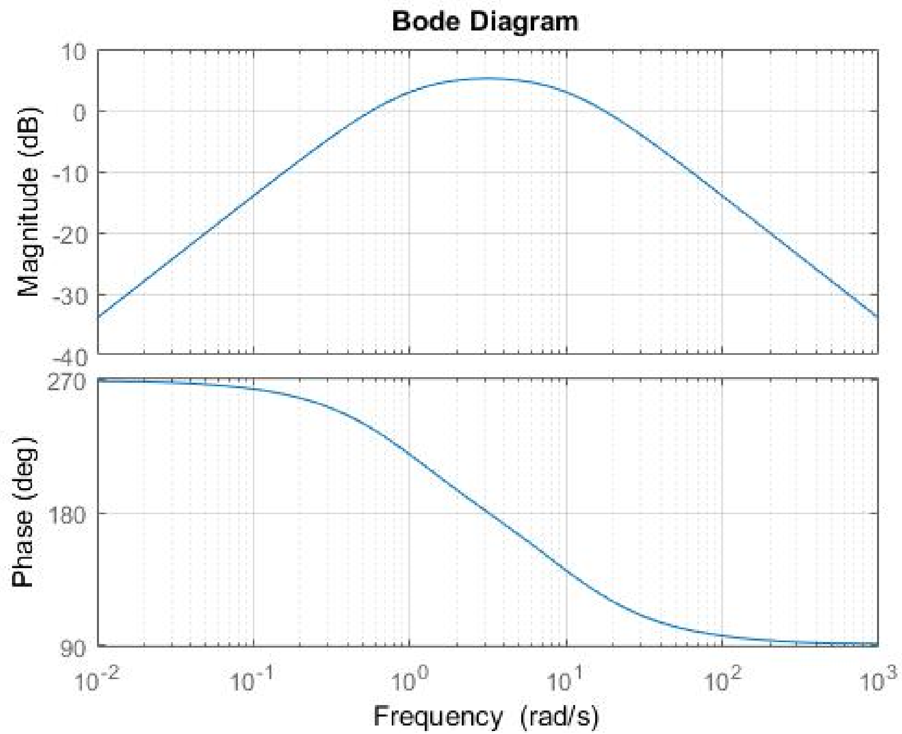
% band durduran
Hbd= (- Rf/R1) * (Hag + Hyg)



%--% band geçiren

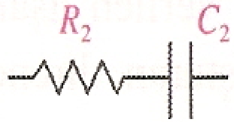
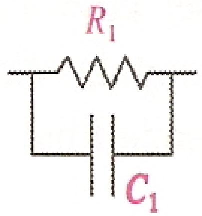
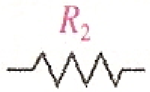
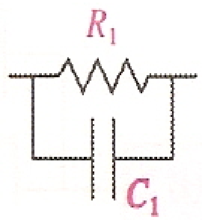
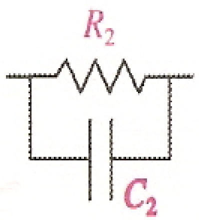
Hbg= (- Ro/Ri) * Hag * Hyg

```
Wcl =    50
Wch =   500
Wo =  158.1139

Hag =
  -1
 -----
 s + 1
Hyg =

   -s
 ---------
 0.1 s + 1

Hbg =

     -2 s
 -------------------
 0.1 s^2 + 1.1 s + 1

Hbd =

 3 s^2 + 3.3 s + 3
 -------------------
 0.1 s^2 + 1.1 s + 1
```



Tablo 4-1 İşaret Değiştirici İşlemsel Kuvvetlendirici Transfer Fonksiyonları

	Giriş Elemanı	Geribesleme Elemanı	Transfer Fonksiyonu	Açıklamalar
(a)	R_1 $Z_1 = R_1$	R_2 $Z_2 = R_2$	$-\dfrac{R_2}{R_1}$	İşaret değiştirici kazanç, örneğin $R_1 = R_2$ için $e_0 = -e_i$ (evirici)
(b)	R_1 $Z_1 = R_1$	C_2 $Y_2 = sC_2$	$\left(\dfrac{-1}{R_1C_2}\right)\dfrac{1}{s}$	Koordinat merkezinde kutup, ya da bir integratör.
(c)	C_1 $Y_1 = sC_1$	R_2 $Z_2 = R_2$	$(-R_2C_1)\,s$	Koordinat merkezinde sıfır, ya da bir türev alıcı.
(d)	R_1 $Z_1 = R_1$	R_2 C_2 $Y_2 = \dfrac{1}{R_2} + sC_2$	$\dfrac{-\dfrac{1}{R_1C_2}}{s + \dfrac{1}{R_2C_2}}$	$\dfrac{-1}{R_2C_2}$ 'de kutup, doğru akım kazancı $-R_2/R_1$.

	Giriş Elemanı	Geribesleme Elemanı	Transfer Fonksiyonu	Açıklamalar
(e)	 $Z_1 = R_1$	 $Z_2 = R_2 + \frac{1}{sC_2}$	$\frac{-R_2}{R_1}\left(\frac{s + 1/R_2C_2}{s}\right)$	Koordinat merkezinde bir kutup ve $-1/R_2C_2$'de bir sıfır, ya da PI kontrolörü.
(f)	 $Y_1 = \frac{1}{R_1} + sC_1$	 $Z_2 = R_2$	$-R_2C_1\left(s + \frac{1}{R_1C_1}\right)$	$-1/R_1C_1$'de bir sıfır, ya da PD kontrolörü.
(g)	 $Y_1 = \frac{1}{R_1} + sC_1$	 $Y_2 = \frac{1}{R_2} + sC_2$	$\frac{\frac{-C_1}{C_2}\left(s + \frac{1}{R_1C_1}\right)}{s + \frac{1}{R_2C_2}}$	$-1/R_2C_2$'de bir kutup ve $-1/R_1C_1$'de bir sıfır ya da faz ilerlemeli gerilemeli kontrolör.

$$G_c(s) = \frac{E_o(s)}{E_{in}(s)} = \frac{R_2}{R_1} + \frac{R_2}{R_1 C_2 s} \tag{9-25}$$

Comparing Eq. (9-24) with Eq. (9-25), we have

$$K_P = \frac{R_2}{R_1} \quad K_I = \frac{R_2}{R_1 C_2} \tag{9-26}$$

The transfer function of the three-op-amp circuit in Fig. 9-16(b) is

$$G_c(s) = \frac{E_o(s)}{E_{in}(s)} = \frac{R_2}{R_1} + \frac{1}{R_i C_i s} \tag{9-27}$$

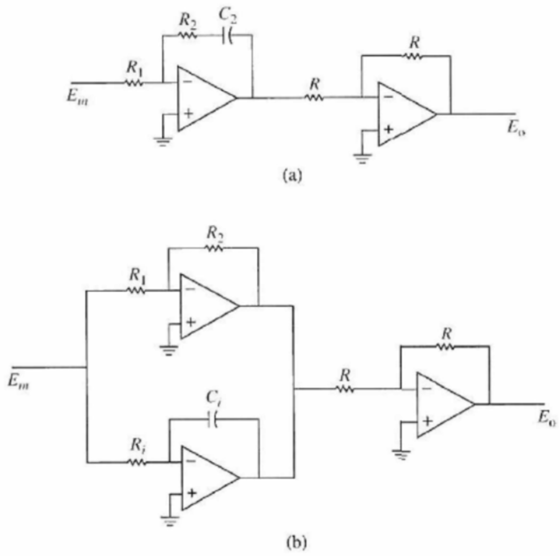


Figure 9-16 Op-amp-circuit realization of the PI controller, $G_c(s) = K_P + \frac{K_I}{s}$. (a) Two-op-amp circuit. (b) Three-op-amp circuit.

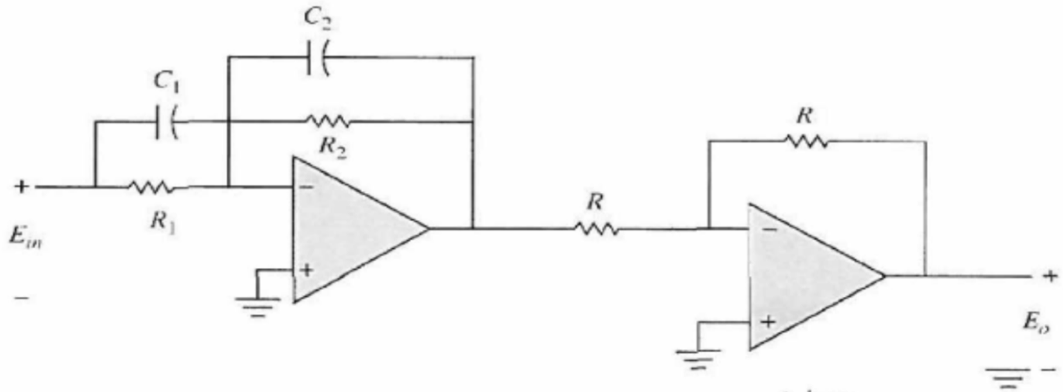


Figure 9-26 Op-amp circuit implementation of $G(s) = K_c \dfrac{s + z_1}{s + P_1}$.

$$G_c(s) = \frac{E_o(s)}{E_{in}(s)} = \frac{C_1}{C_2} \frac{s + \dfrac{1}{R_1 C_1}}{s + \dfrac{1}{R_2 C_2}} \tag{9-60}$$

Comparing the last two equations, we have

$$\begin{aligned} K_c &= C_1/C_2 \\ z_1 &= 1/R_1 C_1 \\ p_1 &= 1/R_2 C_2 \end{aligned} \tag{9-61}$$

We can reduce the number of design parameters from four to three by setting $C = C_1 = C_2$. Then Eq. (9-60) is written as

$$\begin{aligned} G_c(s) &= \frac{R_2}{R_1}\left(\frac{1 + R_1 Cs}{1 + R_2 Cs}\right) \\ &= \frac{1}{a}\left(\frac{1 + aTs}{1 + Ts}\right) \end{aligned} \tag{9-62}$$