Automatic Control AC_L15

Lead network design examples

Ex. 1 Lead

after steady state design

$$|L'(j\omega_{c,des})| = -3.33\,dB \qquad (\omega_{c,des} = 7\ rad/s)$$

$$\angle L'(j\omega_{c,des}) = -179^\circ$$

phase lead is needed $\qquad \Delta\varphi \cong 40^\circ$

$$-139^\circ$$

Lead network design

$m_D = 10 \qquad \omega_{norm} = 1$

$$\omega_D = \frac{\omega_{c,des}}{\omega_{norm}} = 7$$

$$C_D(s) = \frac{1 + \frac{s}{\omega_D}}{1 + \frac{s}{m_D \omega_D}}$$

After Lead network

$$L''(s) = L'(s)\, C_D(s)$$

$$|L''(j\omega_{c,des})| \cong -0{,}36\,dB$$

$$\angle L''(j\omega_{c,des}) \cong -140^\circ$$

$\rightarrow$ OK

$\downarrow$

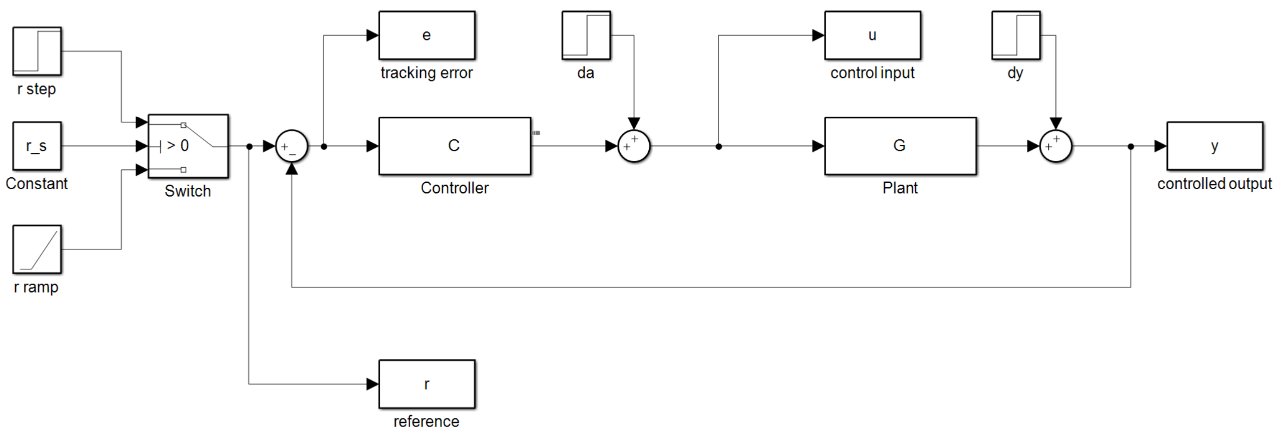
simulation

$\hat{S} = 28{,}46\,\%$ $\rightarrow$ ok

$t_r = 0{,}269\,s$ $\rightarrow$ ok $\qquad |e_r^\infty| = 0{,}1$ ok

```
clear all
close all
clc

s=tf('s');
% Plant tf
G=2/((1+0.2*s)*(1+0.1*s));

% steady state controller
Kc=5
C_SS=Kc/s;
L1=G*C_SS; % loop function update
figure, bode(L1)
%return

% transient requirements
T_p=3.67; %dB
S_p=5.1;  %dB
wc_des=7;

% nichols diagram for L1
figure(1)
nichols(L1,'b'), hold on
T_grid(T_p)
S_grid(S_p)
%return
% lead network design
mD=10
wnorm=1;
wD=wc_des/wnorm
C_D=(1+s/wD)/(1+s/(mD*wD));
L2=L1*C_D; % loop function update
C=C_SS*C_D; % controller tf update
figure(1)
nichols(L2,'r')
%return

% simulation with step reference signal
r_s = 1; % switch imposes step reference
rho = 1;
delta_a = 0;
delta_y = 0;
t_stop = 3;
sim('control_structure_sim')
figure
plot(r.time,r.data,'r','linewidth',1.5)
grid on
hold on
```

```
plot(y.time,y.data,'b','linewidth',1.5)
xlabel('t (s)')
ylabel('y(t)')
legend('r(t)','y(t)')
%return

% simulation with ramp reference signal
r_s = -1; % switch imposes ramp reference
rho = 1;
delta_a = 0;
delta_y = 0;
t_stop = 3;
sim('control_structure_sim')
figure
plot(r.time,r.data,'r','linewidth',1.5)
grid on
hold on
plot(y.time,y.data,'b','linewidth',1.5)
xlabel('t (s)')
ylabel('y(t)')
legend('r(t)','y(t)')
figure
plot(e.time,e.data,'b','linewidth',1.5)
grid on
xlabel('t (s)')
ylabel('e(t)')
```



Ex. 2 Lead

after steady state design

$$|L'(j\omega_{c,des})| = -30\,dB \qquad \omega_{c,des} = 18\,rad/s$$

$$\angle L'(j\omega_{c,des}) = -186^\circ$$

phase lead needed $\qquad \Delta\varphi \simeq 50^\circ \div 54^\circ$

$$-132{,}5^\circ \div -136{,}5$$

Lead network design

$$m_D = 10 \qquad \omega_{norm} = 3$$

$$\omega_D = \frac{\omega_{c,des}}{\omega_{norm}} =$$

After lead network

$$L''(s) = L'(s)\,C_D(s)$$

$$|L''(j\omega_{c,des})| = -20{,}6\,dB$$

$$\angle L''(j\omega_{c,des}) = -132^\circ \rightarrow ok$$

Gain adjustment required

$$K_1 = 10^{\frac{20{,}6}{20}} =$$

After K_1 $\rightarrow$ $L'''(s) = L''(s)\,K_1$

$$|L'''(j\omega_{c,des})| \simeq 0\,dB$$

$$\angle L'''(j\omega_{c,des}) = -132^\circ$$

$m_D = 16$ (16) $\omega_{norm} = 6$ (6)

$\omega_D = \frac{\omega_{c,des}}{\omega_{norm}} =$

after this lead network

$L''(s) = C_D(s)\, L'(s)$

$|L''(j\omega_{c,des})| = -15,2\,dB$

$\angle L''(j\omega_{c,des}) = -126°$

Gain adjustment

$K_1 = 10^{+\frac{15,2}{20}} =$

after K_1

$L'''(s) = L''(s)\, K_1$

$|L'''(j\omega_{c,des})| \cong 0\,dB$

$\angle L'''(j\omega_{c,des}) = -126°$

→ Run simulation

$\hat{S} = 26,1\,\%$ $t_{s,1\%} = 1,12\,s$

↓

slow transient

↓

increase ω_c

↓

increase $K_1 = 10^{\frac{17}{20}}$

$\hat{S} \cong 25,5\,\%$ NOK $t_{s,1\%} = 0,656\,s$ OK OK

$|Y_{da}^{\infty}| = 0,01612$

```
clear all
close all
clc

s=tf('s');
G=(s+1)/(s^2*(s-1));

% steady state controller
Kc =  10
C_SS=Kc;
L1=C_SS*G;% loop function update
figure
bode(L1)
%return

% transient requirements
T_p=2.67; %dB
S_p=4.35;  %dB
wc_des=18;

% nichols diagram for L1
figure(1)
nichols(L1,'b')
hold on
T_grid(T_p)
S_grid(S_p)
axis([-360 -90 -80 100])
%return

% lead network design
mD=16
wnorm=6;
wD=wc_des/wnorm
C_D=(1+s/wD)/((1+s/(mD*wD)));
L2=C_D*L1; % loop function update
C=C_D*C_SS;% controller tf update
figure(1), hold on
nichols(L2,'r')
%return

% gain adjustment
K=10^(17/20)
L3=K*L2; % loop function update
C=K*C;  % controller tf update
figure(1), hold on
nichols(L3,'k')
%return
```

```
% simulation with step reference signal
r_s = 1; % switch impose step reference
rho = 1;
delta_a = 0;
delta_y = 0;
t_stop = 5;
sim('control_structure_sim')
figure
plot(r.time,r.data,'r','linewidth',1.5)
grid on
hold on
plot(y.time,y.data,'b','linewidth',1.5)
xlabel('t (s)')
ylabel('y(t)')
legend('r(t)','y(t)')
%return

% simulation with disturbance da
r_s = 1; % switch impose step reference
rho = 0;
delta_a = 1;
delta_y = 0;
t_stop = 5;
sim('control_structure_sim')
figure
grid on
hold on
plot(y.time,y.data,'b','linewidth',1.5)
xlabel('t (s)')
ylabel('y(t)')
```