Scilab Manual for Control System Design by Prof Dilip Pawar Instrumentation Engineering Bharati Vidyapeeth College Of Engineering, Navi Mumbai[1]

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Experiment: 1

State model for SISO and MIMO Systems

Scilab code Solution 1.1 a

```
1 // Scilab : 6.0.0
2 // OS: Windows 7, 64 bit
3 // Lab 1 a): To obtain State - Space Model of given
     system
4
5 clc ;
6 clear all;
7
8
9 // Define the Numerator and Denominator Polynomials
     of Transfer Function, G(s)
10 num=poly([30 10],"s","coeff");    //Defines the
     numerator of G(s)
11 den=poly([0 8 6 1],"s","coeff"); //Defines the
     denominator of G(s)
12
13 // Obtain the Contollable Phase Variable Form
14 sys=cont_frm(num,den);
15 [A,B,C,D]=abcd(sys)
```

```
16 disp(D,"D",C,"C",B,"B",A,"A")
17
18 // Result
19
20 // A
21
22 //    0.    1.    0.
23 //    0.    0.    1.
24 //    0.   -8.   -6.
25
26 // B
27
28 //   0.
29 //   0.
30 //   1.
31
32 // C
33
34 //    30.    10.    0.
35
36 // D
37
38 //   0.
```

Experiment: 2

Similarity Transformation

Scilab code Solution 2.2 a

```
1 // Scilab : 6.0.0
2 // OS: Windows 7, 64 bit
3 // Lab 2 a): To obtain Similar State - Space Model
     of given system
4
5 clc ;
6 clear all;
7
8 // A system having the form xdot=Ax+Bu and y=Cx+du,
     where
9 A=[-2,1;-3,0]; B=[4;5]; C=[1,0]; D=0;//and
10 //The transformation Matrix P is taken as -
11 P = [2,1;4,3];
12 //the given system can be transformed to a similar
     system as -
13 AA=inv(P)*A*P
14 BB=inv(P)*B
15 CC=C*P
16 disp(C,"CC",B,"BB", A,"AA")
17 // Check the eigenvalues of both systems
18 EV1=spec(A); EV2=spec(AA);
```

```
19 disp(EV2,"Eigenvalues of System2", EV1,"Eigenvalues
   of System1")
20 // If both eigenvalues are same then systems are
   similar
21
22 // Result
23
24 // AA
25 //
26 //   -2.    1.
27 //   -3.    0.
28 //
29 // BB
30 //
31 //    4.
32 //    5.
33 //
34 // CC
35 //
36 //    1.    0.
37 //
38 // Eigenvalues of System1
39 //
40 //   -1. + 1.4142136i
41 //   -1. - 1.4142136i
42 //
43 // Eigenvalues of System2
44 //
45 //   -1. + 1.4142136i
46 //   -1. - 1.4142136i
47 //
```

Experiment: 3

Controllability and Observability

Scilab code Solution 3.3 a

```
1 // Scilab : 6.0.0
2 // OS: Windows 7, 64 bit
3 // Lab 3 a): To Check the Controllability of given
     system by Gilbert's Test
4
5 clc ;
6 clear all;
7
8 // Let the system is described by state equations
9 A=[0,1,0;0,0,1;-6,-11,-6];
10 B=[0;0;1];
11 // Solution: -
12 // Gilbert's Test is required to find canonical
     state variable form as -
13 // Given system is in Phase Variable form, therefore
      Vander Monde Matrix is
14 // required as an Modal Matrix
15 // Find the eigenvalues and eigenvectors of matrix A
16 [V,D]=spec(A);
```

```
17 // Forming the Vander Monde Matrix from the
      eigenvalues as -
18 d = diag(D); dd=(d.^2);
19 M=[1,1,1;d';dd'];
20 Minv=inv(M);
21 // Finding the Bcap
22 Bcap=Minv*B;
23 disp(Bcap,"Bcap")
24 // Check the contents of B vector, whether any
      element is zero,
25 // if not then system is controllable
26 // Result
27
28 // Bcap
29 //
30 //    0.5
31 //   -1.
32 //    0.5
```

Experiment: 4

Pole-Placement with State Feedback

Scilab code Solution 4.4 a

```
1  // Scilab : 6.0.0
2  // OS: Windows 7, 64 bit
3  // Lab 4 a): To find a gain matrix K, by usinf Pole-
       placement by state feedback
4
5  clc ;
6  clear all;
7
8  // Problem: Consider the system as
9  //   .
10 //  X = AX + Bu
11 // where A = [0,1,0;0,0,1;-1,-5,-6]; B = [0;0;1];
12 // By using state feedback control u= - Kx, it is
       desired to have the closed
13 // - loop poles at s1 = -2+j*4; s2 = -2-j*4; and s3
       = -10;
14 // Determine the state feedback-gain matrix K with
       SCILAB
15
```

```
16 // First define the given A, B matrices as -
17 A = [0,1,0;0,0,1;-1,-5,-6];
18 B = [0;0;1];
19 // Then define the closed - loop poles as -
20 s1=-2+%i*4; s2=-2-%i*4; s3=-10;
21 S=[s1,s2,s3];
22 // Then invoking commands 'ppol' as -
23 K=ppol(A,B,S)
24 disp(K,"K")
25
26 // Result
27
28 // K
29 //
30 //    199.    55.    8.
```

Experiment: 5

Lead Compensator Design by Root – Locus

Scilab code Solution 5.5 To design a Lead Compensator by Root Locus technique

```
1  // Scilab : 6.0.0
2  // OS: Windows 7, 64 bit
3  // Lab 5: To design a Lead Compensator by Root-Locus
       technique
4
5  clc ;
6  clear all;
7
8
9
10 s=%s;
11 G=syslin('c',1/s^2)      // Transfer Function of Un-
       compensated System
12 Gc=syslin('c',(s+1.15)/((s^2)*(s+4.2))) // Transfer
       Function of Compensated System
13 // Root - Locus of Un-Compensated System
14 figure(0)
15 clf, evans(G), xgrid(5, 1, 7)
```

```
16
17 // Root - Locus of Compensated System
18 figure(1)
19 clf, evans(Gc), xgrid(5, 1, 7)
20 replot([-4.5,-10,0.5,10])
21
22 // Step Response of Un-Compensated System
23 figure(2)
24 t= 0:0.1:100;
25 x=[csim('step',t,G/(1+G),[0;0;0])]';
26 plot2d(t',x),
27 xlabel("t", "fontsize", 2,"color", "blue");
28 ylabel("Amplitude", "fontsize", 2, "color", "blue");
29 xgrid(5, 1, 7)
30 xtitle( 'Step Response of Un-Compensated System');//
     , 'X axis', 'Y axis');
31 // Step Response of Compensated System
32 figure(3)
33 t= 0:0.1:100;
34 x=[csim('step',t,Gc/(1+Gc),[0;0;0])]';
35 plot2d(t',x),
36 xlabel("t", "fontsize", 2,"color", "blue");
37 ylabel("Amplitude", "fontsize", 2, "color", "blue");
38 xtitle( 'Step Response of Compensated System');//, '
     X axis', 'Y axis');
39 xgrid(5, 1, 7)
```

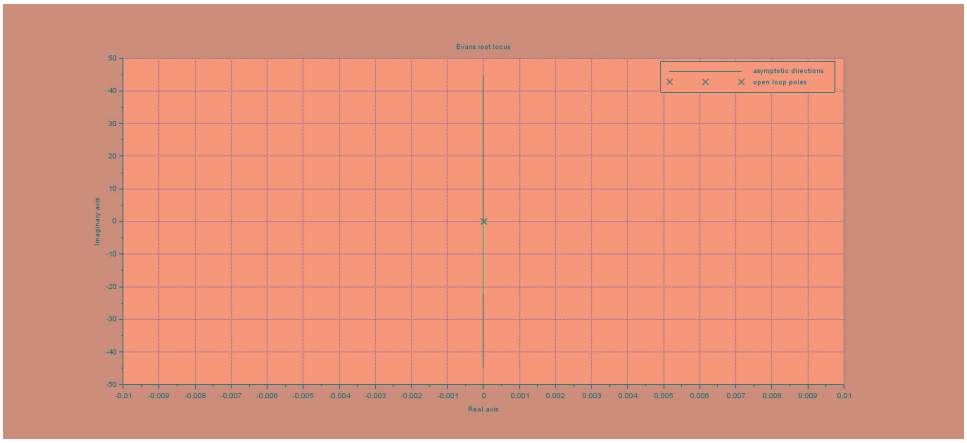


Figure 5.1: To design a Lead Compensator by Root Locus technique

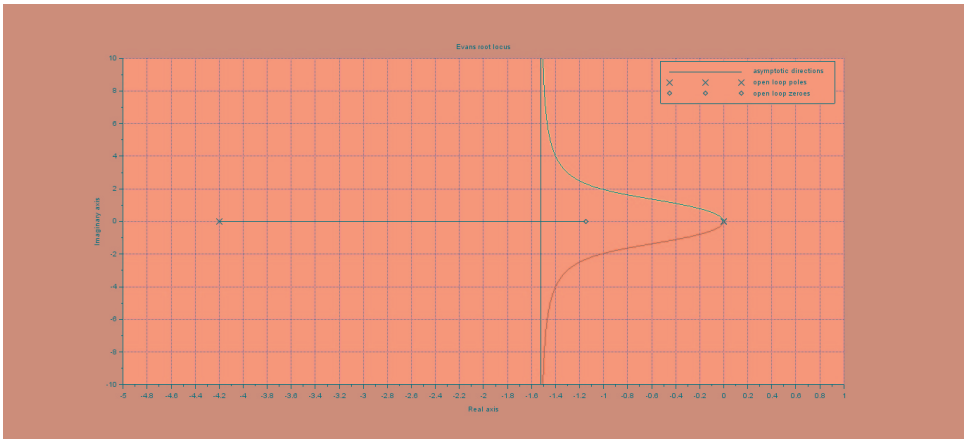


Figure 5.2: To design a Lead Compensator by Root Locus technique

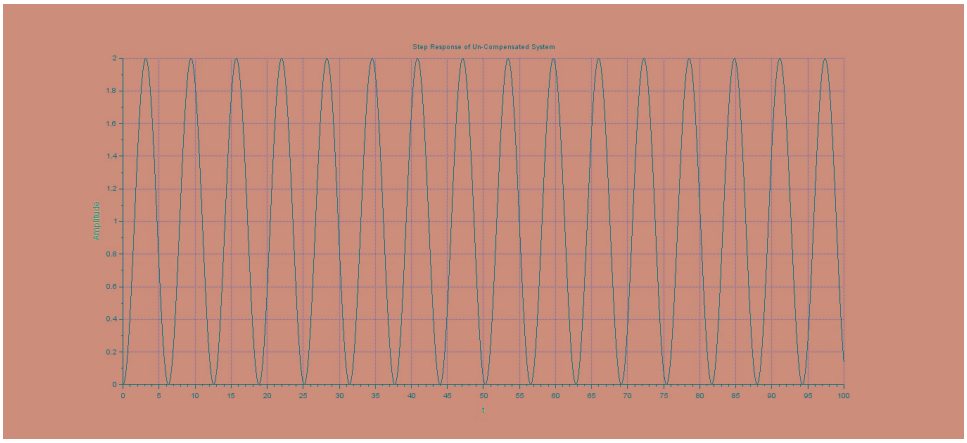


Figure 5.3: To design a Lead Compensator by Root Locus technique

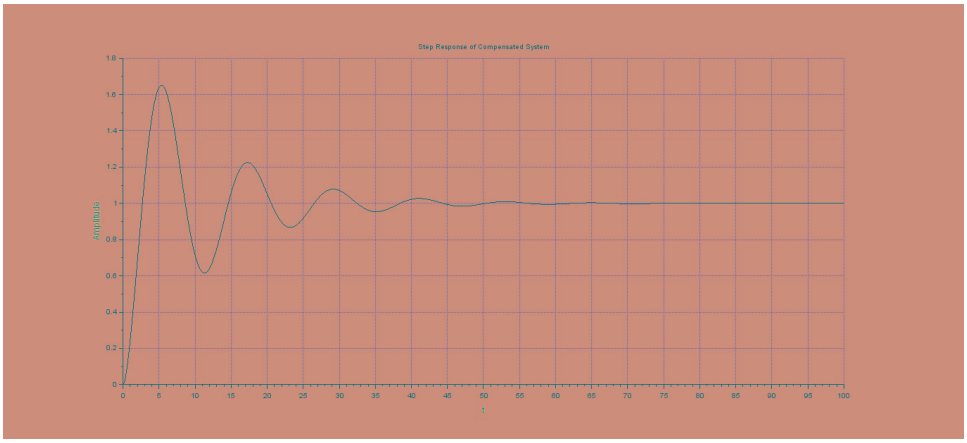


Figure 5.4: To design a Lead Compensator by Root Locus technique

Experiment: 6

Lag Compensator Design by Root – Locus

Scilab code Solution 6.6 To design a Lag Compensator by Root Locus technique

```
1  // Scilab : 6.0.0
2  // OS: Windows 7, 64 bit
3  // Lab 6: To design a Lag Compensator by Root-Locus
       technique
4
5  clc ;
6  clear all;
7
8  s=%s;
9  G=syslin('c',1/(s*(s+1)*(s+4))) // Transfer Function
       of Un-Compensated System
10 Gc=syslin('c',(s+0.2)/((s+0.02)*s*(s+1)*(s+4))) //
       Transfer Function of Compensated System
11 // Root - Locus of Un-Compensated System
12 figure(0)
13 clf, evans(G), xgrid//(5, 1, 7)
14 replot([-4.5,-10,0.5,10])
15 // Step Response of Un-Compensated System
```

```
figure(1)
t= 0:0.1:100;
x=[csim('step',t,G/(1+G),[0;0;0])]';
plot2d(t',x),xgrid//(5, 1, 7)
xlabel("t", "fontsize", 2,"color", "blue");
ylabel("Amplitude", "fontsize", 2, "color", "blue");
xtitle( 'Step Response of Un-Compensated System');

// Root - Locus of Compensated System
figure(2)
clf, evans(Gc), xgrid//(5, 1, 7)

replot([-4.5,-6,0.5,6])
// Step Response of Compensated System
figure(3)
t= 0:0.1:100;
x=[csim('step',t,Gc/(1+Gc))]';
plot2d(t',x),xgrid//(5, 1, 7)
xlabel("t", "fontsize", 2,"color", "blue");
ylabel("Amplitude", "fontsize", 2, "color", "blue");
xtitle( 'Step Response of Compensated System');
```

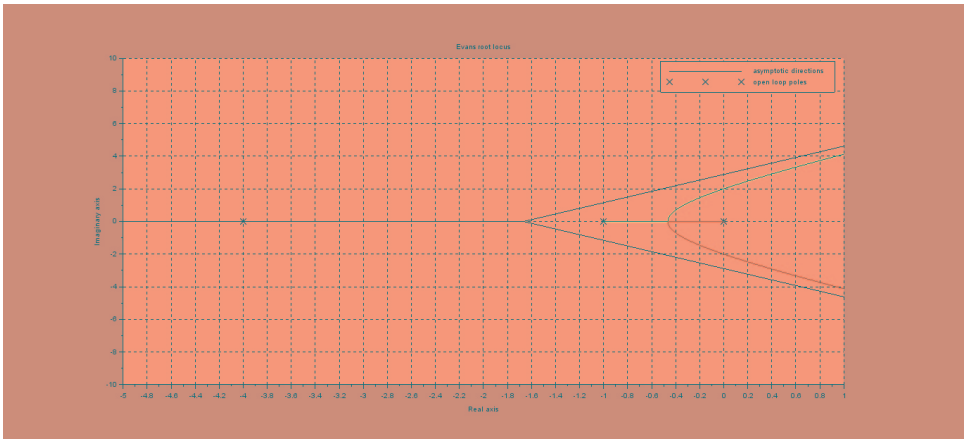


Figure 6.1: To design a Lag Compensator by Root Locus technique

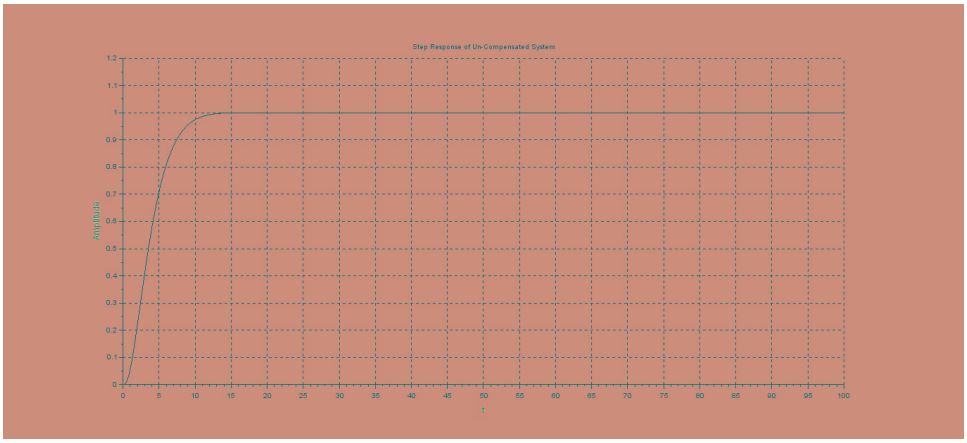


Figure 6.2: To design a Lag Compensator by Root Locus technique

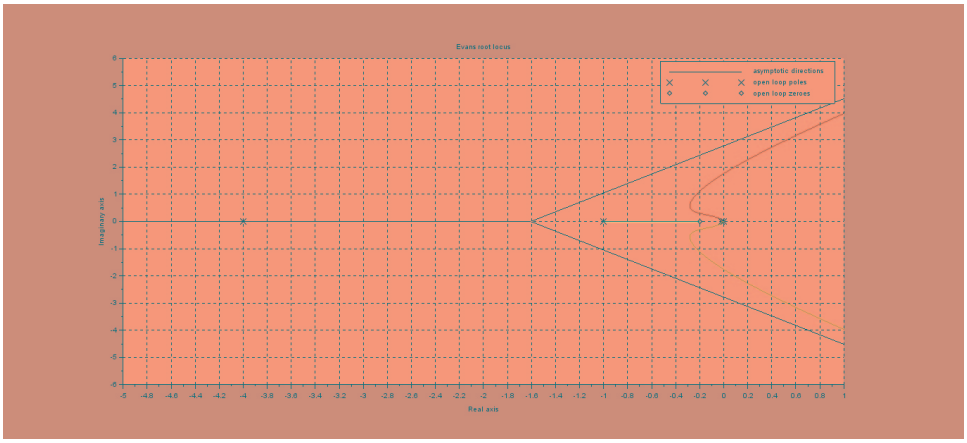


Figure 6.3: To design a Lag Compensator by Root Locus technique

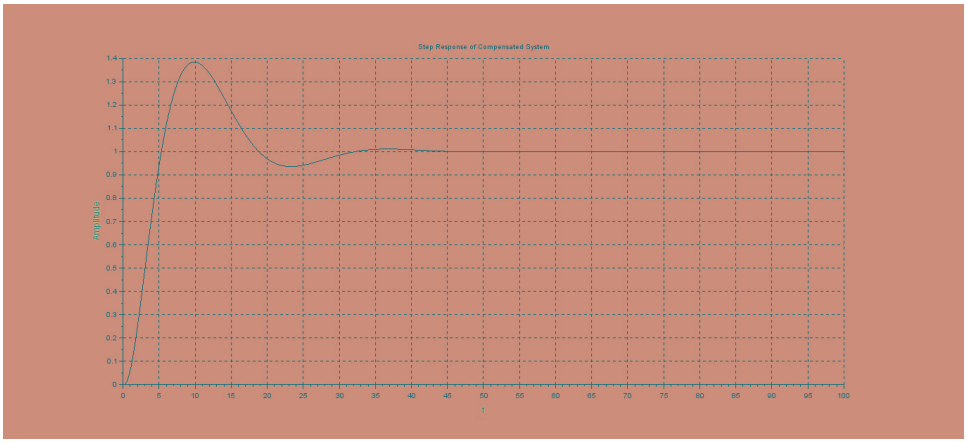


Figure 6.4: To design a Lag Compensator by Root Locus technique

Experiment: 7

Time Delay or Transportation Lag

Scilab code Solution 7.7 To Study the Effect of Time Delay on System Response

```
1  // Scilab : 6.0.0
2  // OS: Windows 7, 64 bit
3  // Lab 7: To Study the Effect of Time Delay on
       System Response
4  clc ;
5  clear all;
6
7  // For T = 0, i.e. No Delay
8  s=poly(0,'s')
9  // Transfer Function of Open-Loop System with T=0
10 G1=syslin('c',exp(0)*10/((s)*(s+1)));
11 figure(0)
12 bode(G1,0.1,100)
13 [gm1,frg1]=g_margin(G1);
14 disp(gm1,"Gain Margin,T=0",frg1,"Phase Cut-off
       Frequency, T=0")
15 show_margins(G1)
16 [phm1,frp1]=p_margin(G1);
```

```
17 disp(phm1,"Phase Margin, T=0",frp1,"Gain Cut-off
     Frequency, T=0")
18 show_margins(G1)
19
20 // For Time Delay T = 0.1
21 T=0.1;
22 nTd=[1-T*s/2]; dTd=[1+T*s/2];// Num and Den of Delay
      System by Pade
23 sysTd=syslin('c',nTd/dTd);
24 G2=syslin('c',(sysTd*10)/((s)*(s+1)));
25 figure(1)
26 bode(G2,0.1,100)
27 [gm2,frg2]=g_margin(G2);
28 disp(gm2,"Gain Margin, T=0.1",frg2,"Phase Cut-off
     Frequency, T=0.1")
29 show_margins(G2)
30 [phm2,frp2]=p_margin(G2);
31 disp(phm2,"Phase Margin, T=0.1",frp2,"Gain Cut-off
     Frequency, T=0.1")
32 show_margins(G2)
33
34 // Results
35 // Frequency Response Specifications of Un-
     Compensated System
36 //Phase Cut-off Frequency, T=0
37 //
38 //     []
39 //
40 // Gain Margin,T=0
41 //
42 //    Inf
43 //
44 // Gain Cut-off Frequency, T=0
45 //
46 //    0.4908709
47 //
48 // Phase Margin, T=0
49
```

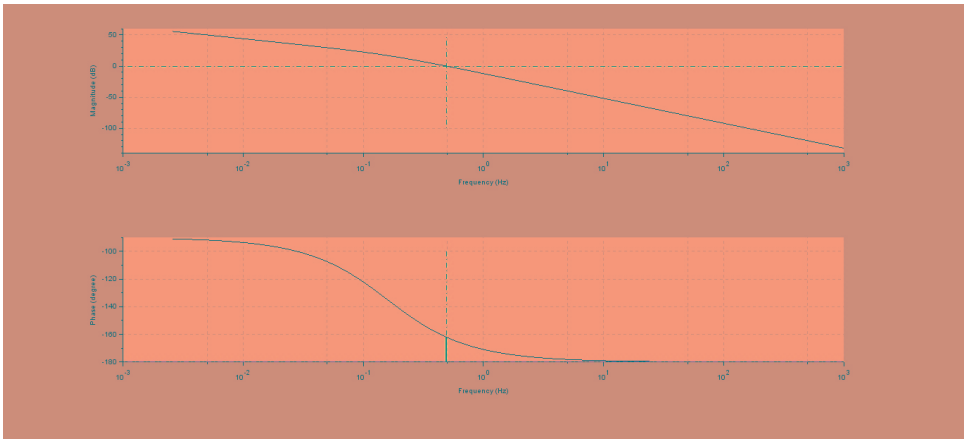


Figure 7.1: To Study the Effect of Time Delay on System Response

```
50 //    17.964236
51 // Frequency Response Specifications of Compensated
       System
52
53 // Phase Cut-off Frequency, T=0.1
54 //
55 //    0.4971165
56 //
57 // Gain Margin, T=0.1
58 //
59 //    0.2093087
60 //
61 // Gain Cut-off Frequency, T=0.1
62 //
63 //    0.4908709
64 //
65 // Phase Margin, T=0.1
66
67 //    0.4310002
```

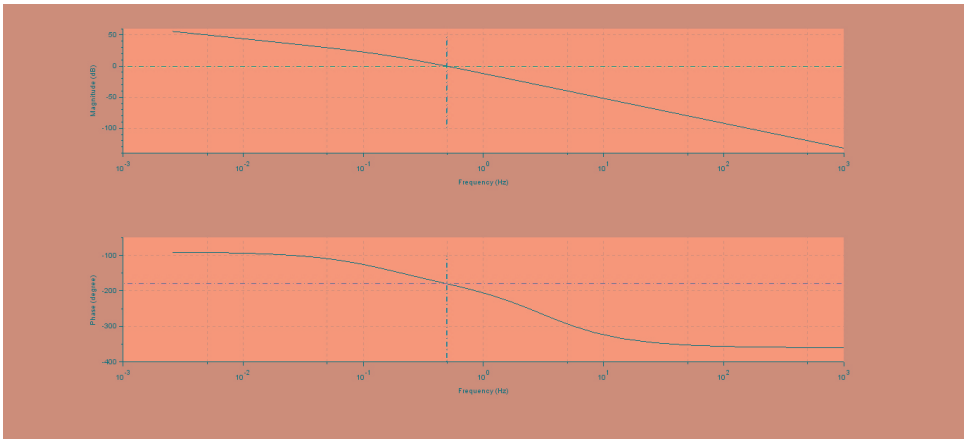


Figure 7.2: To Study the Effect of Time Delay on System Response

Experiment: 8

Lead Compensator Design by Bode Plot Technique

Scilab code Solution 8.8 To design a Lead Comensator by Bode plot technique

```
1  // Scilab : 6.0.0
2  // OS: Windows 7, 64 bit
3  // Expt. No. 8: To design a Lead Comensator by Bode-
       plot technique
4
5  clc
6  close
7  clf();
8
9  s=poly(0,'s')
10 // Transfer Function of Open-Loop System
11 G=syslin('c',12/((s)*(s+1)))
12 figure(0)
13 bode(G,0.1,100)
14 [gm,frg]=g_margin(G);
15 disp(gm,"Gain Margin",frg,"Phase Cut-off Frequency")
16 show_margins(G)
17 [phm,frp]=p_margin(G);
```

```
18 disp(phm,"Phase Margin",frp,"Gain Cut-off Frequency"
   )
19 show_margins(G)
20
21 // Transfer Function of Open-Loop Compensated System
   , GGc
22 GGc=syslin('c',12*(1+0.385*s)/((s)*(s+1)*(1+0.125*s)
   ))
23
24 // Bode - Plot of Compensated System
25 figure(1)
26 bode(GGc,0.1,100)
27 [gm,frg]=g_margin(GGc);
28 disp(gm,"Gain Margin",frg,"Phase Cut-off Frequency")
29 show_margins(GGc)
30 [phm,frp]=p_margin(GGc);
31 disp(phm,"Phase Margin",frp,"Gain Cut-off Frequency"
   )
32 show_margins(GGc)
33
34 // Step Response of Coles-Loop Un-Compensated System
35 figure(2)
36 t= 0:0.1:10;
37 x=[csim('step',t,G/(1+G))]';
38 plot2d(t',x),xgrid(5, 1, 7)
39 xlabel("t", "fontsize", 2,"color", "blue");
40 ylabel("Amplitude", "fontsize", 2, "color", "blue");
41 xtitle( 'Step Response of Un-Compensated System');
42
43 // Step Response of Close-Loop Compensated System
44 figure(3)
45 t= 0:0.1:10;
46 x=[csim('step',t,GGc/(1+GGc))]';
47 plot2d(t',x),xgrid(5, 1, 7)
48 xlabel("t", "fontsize", 2,"color", "blue");
49 ylabel("Amplitude", "fontsize", 2, "color", "blue");
50 xtitle( 'Step Response of Compensated System');
51 // Results
```

```
52 // Frequency Response Specifications of Un-
      Compensated System
53 //Phase Cut-off Frequency
54 //
55 //     []
56 //
57 // Gain Margin
58 //
59 //    Inf
60 //
61 // Gain Cut-off Frequency
62 //
63 //    0.5399649
64 //
65 // Phase Margin
66 //
67 //    16.422908
68
69 // Frequency Response Specifications of Compensated
      System
70
71 // Phase Cut-off Frequency
72 //
73 //     []
74 //
75 // Gain Margin
76 //
77 //    Inf
78 //
79 // Gain Cut-off Frequency
80 //
81 //    0.720447
82 //
83 // Phase Margin
84 //
85 //    43.107374
```

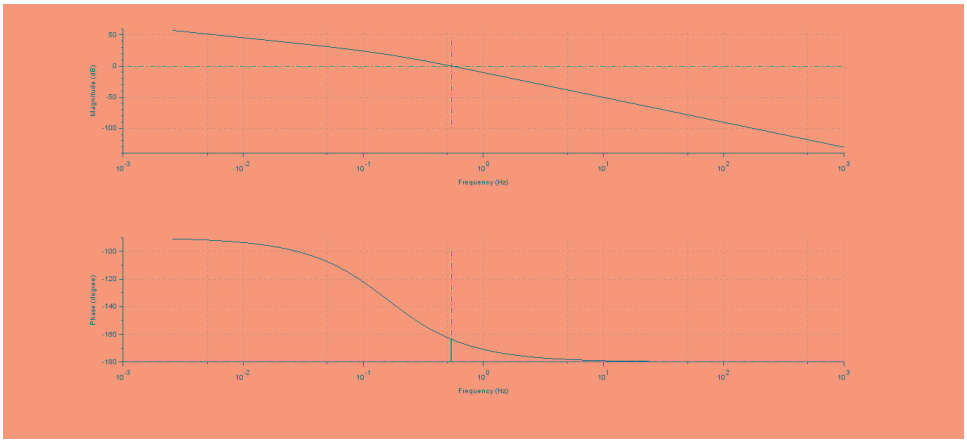


Figure 8.1: To design a Lead Comensator by Bode plot technique

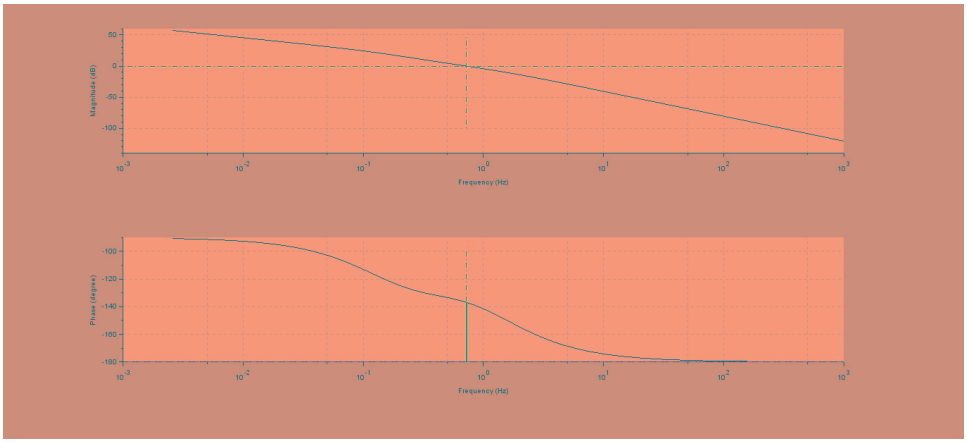


Figure 8.2: To design a Lead Comensator by Bode plot technique

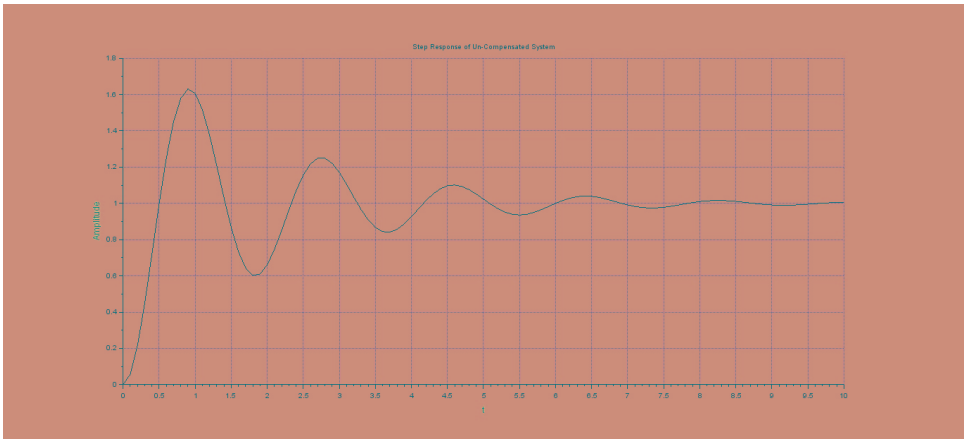


Figure 8.3: To design a Lead Comensator by Bode plot technique

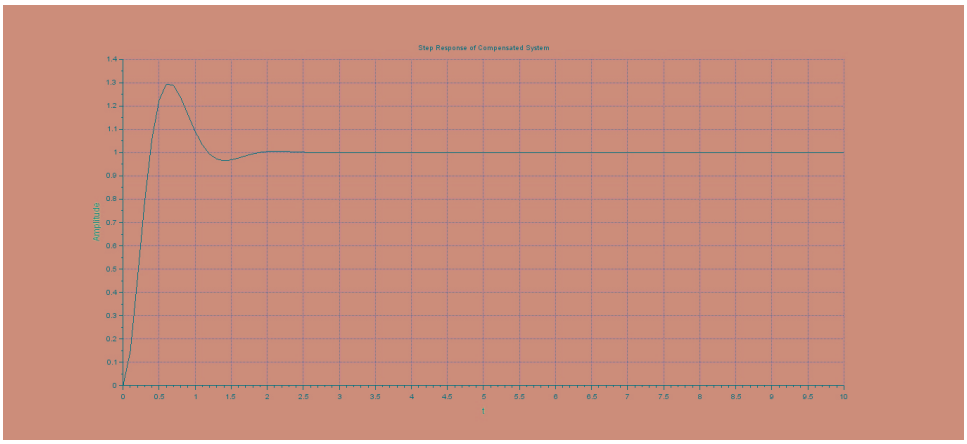


Figure 8.4: To design a Lead Comensator by Bode plot technique

Experiment: 9

Lag Compensator Design by Bode Plot Technique

Scilab code Solution 9.9 To design a Lag Compensator by Bode plot technique

```
1  // Scilab : 6.0.0
2  // OS: Windows 7, 64 bit
3  // Expt. No. 9: To design a Lag Compensator by Bode-
       plot technique
4
5  clc
6  close
7  clf();
8
9  s=poly(0,'s')
10 // Transfer Function of Open-Loop System
11 G=syslin('c',30/((s)*(0.1*s+1)*(0.2*s+1)))
12 figure(0)
13 // Bode - Plot of Un-Compensated System
14 bode(G,0.1,100)
15
16 [gm,frg]=g_margin(G);
17 disp(gm,"Gain Margin",frg,"Phase Cut-off Frequency")
```

```
18 show_margins(G)
19 [phm,frp]=p_margin(G);
20 disp(phm,"Phase Margin",frp,"Gain Cut-off Frequency"
   )
21 show_margins(G)
22
23 // Transfer Function of Open-Loop Compensated System
   , GGc
24 GGc=syslin('c',30*(1+3.33*s)/((s)*(0.1*s+1)*(0.2*s
   +1)*(1+33.3*s)))
25
26 // Bode - Plot of Compensated System
27 figure(1)
28 bode(GGc,0.1,100)
29
30 [gm,frg]=g_margin(GGc);
31 disp(gm,"Gain Margin",frg,"Phase Cut-off Frequency")
32 show_margins(GGc)
33 [phm,frp]=p_margin(GGc);
34 disp(phm,"Phase Margin",frp,"Gain Cut-off Frequency"
   )
35 show_margins(GGc)
36
37 // Step Response of Closed-Loop Un-Compensated
   System
38 figure(2)
39 t= 0:0.1:10;
40 x=[csim('step',t,G/(1+G))]';
41 plot2d(t',x),xgrid(5, 1, 7)
42 xlabel("t", "fontsize", 2,"color", "blue");
43 ylabel("Amplitude", "fontsize", 2, "color", "blue");
44 xtitle( 'Step Response of Un-Compensated System');
45
46 // Step Response of Closed-Loop Compensated System
47 figure(3)
48 t= 0:0.1:10;
49 x=[csim('step',t,GGc/(1+GGc))]';
50 plot2d(t',x),xgrid(5, 1, 7)
```

```
51 xlabel("t", "fontsize", 2,"color", "blue");
52 ylabel("Amplitude", "fontsize", 2, "color", "blue");
53 xtitle( 'Step Response of Compensated System');
54
55 // Result
56 // Frequency Response Specifications of Un-
      Compensated System
57 //Phase Cut-off Frequency
58 //
59 //   1.1253954
60 //
61 // Gain Margin
62 //
63 //   -6.0205999
64 //
65 // Gain Cut-off Frequency
66 //
67 //   1.555363
68 //
69 // Phase Margin
70 //
71 //   -17.245408
72 // Frequency Response Specifications of Compensated
      System
73
74 // Phase Cut-off Frequency
75 //
76 //   1.0788163
77 //
78 // Gain Margin
79 //
80 //   13.24356
81 //
82 // Gain Cut-off Frequency
83 //
84 //   0.4129329
85 //
86 // Phase Margin
```

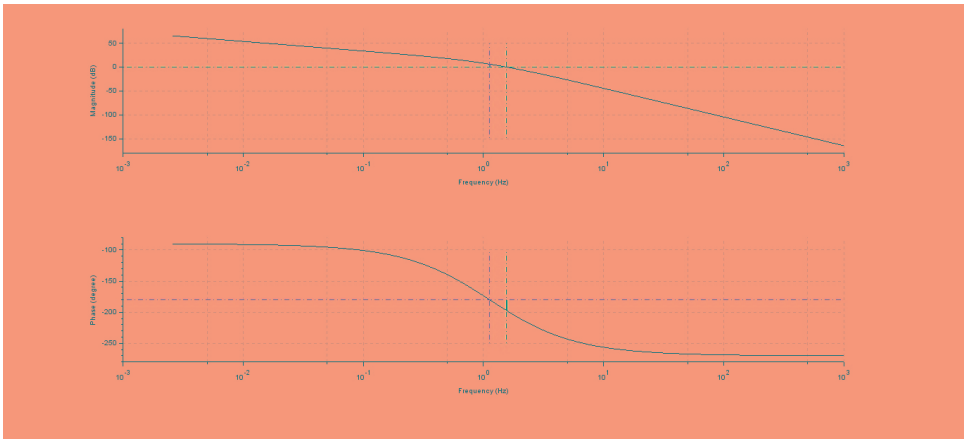


Figure 9.1: To design a Lag Compensator by Bode plot technique

```
87 //
88 //    42.090918
89 //
```

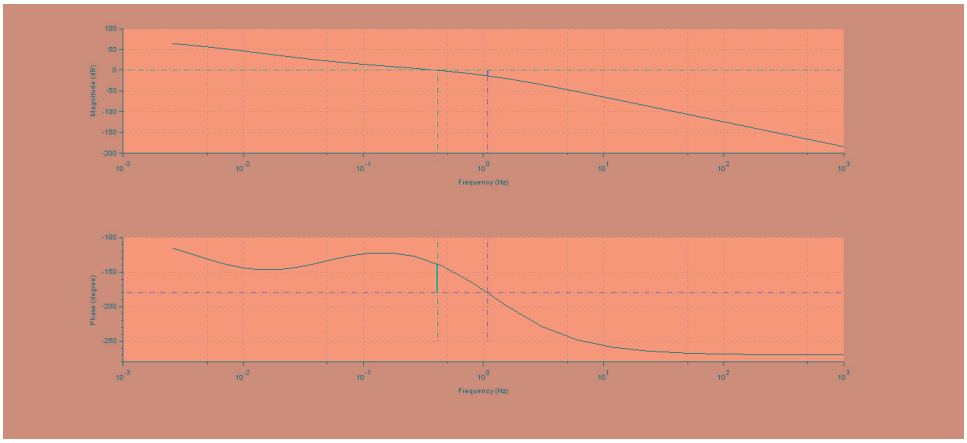


Figure 9.2: To design a Lag Compensator by Bode plot technique

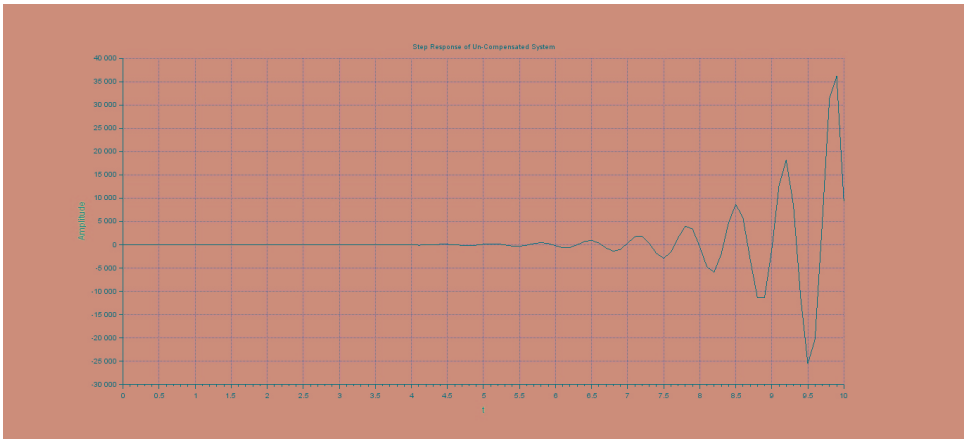


Figure 9.3: To design a Lag Compensator by Bode plot technique

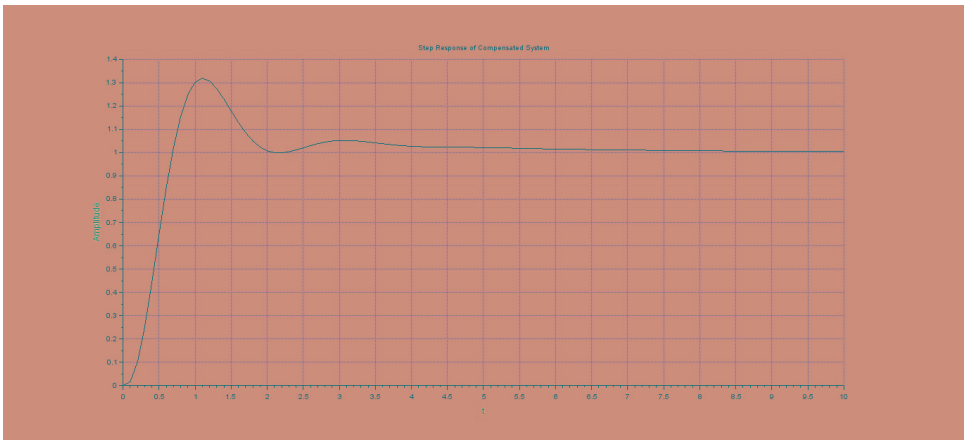


Figure 9.4: To design a Lag Compensator by Bode plot technique

Experiment: 10

PID Controller Design

This code can be downloaded from the website wwww.scilab.in

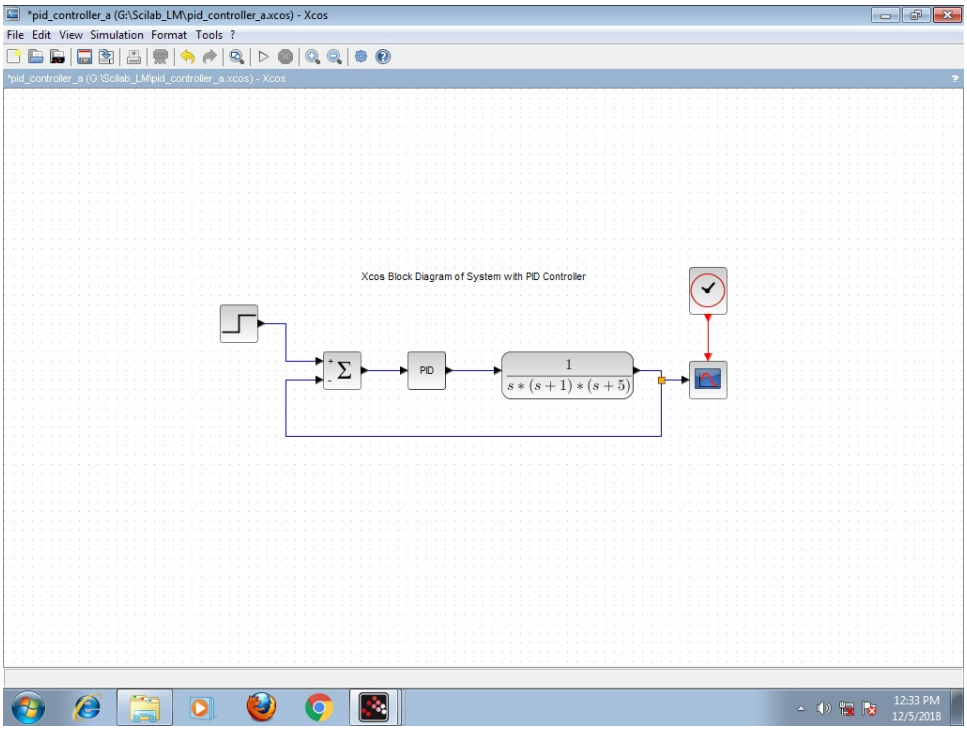


Figure 10.1: To design a PID Controller by using Ziegler Nichols tuning rules

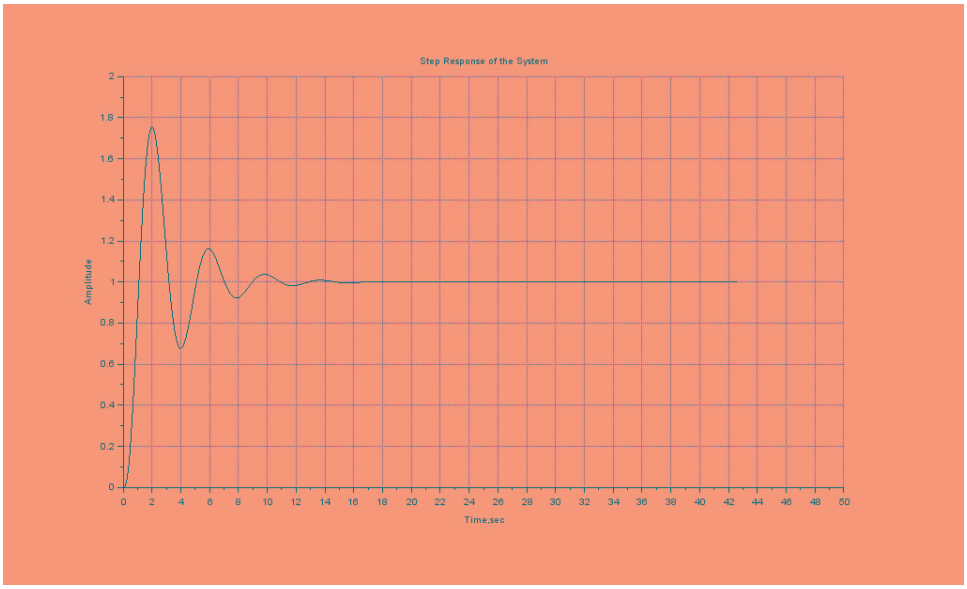


Figure 10.2: To design a PID Controller by using Ziegler Nichols tuning rules

Experiment: 11

Servomechanism or Tracking Problem

This code can be downloaded from the website wwww.scilab.in

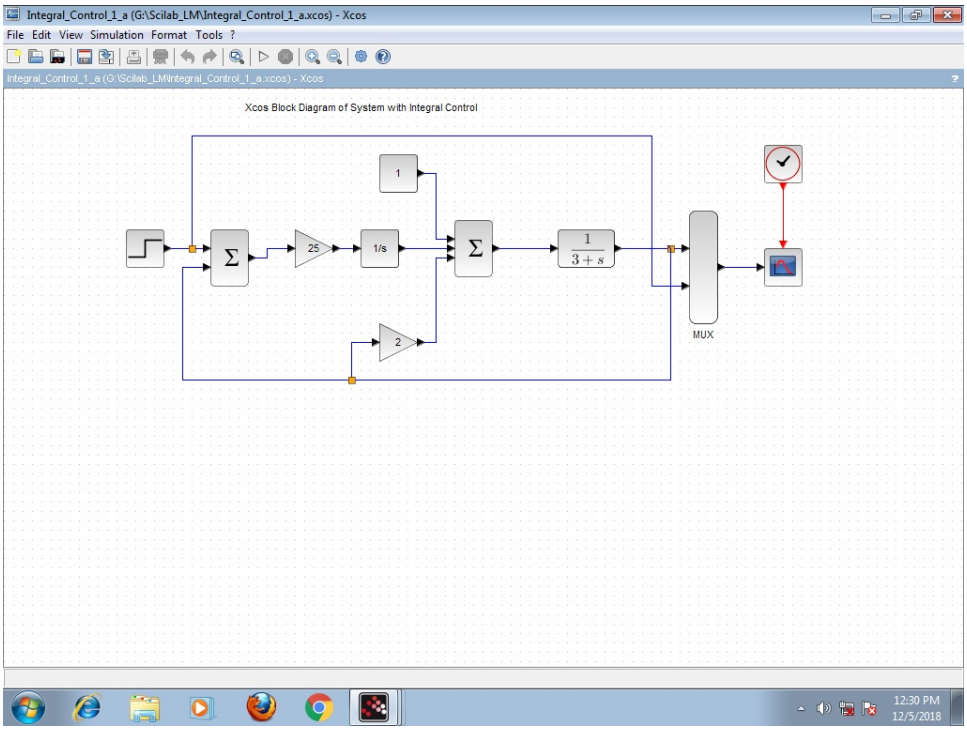


Figure 11.1: To apply integral control to servo problem to minimize the error

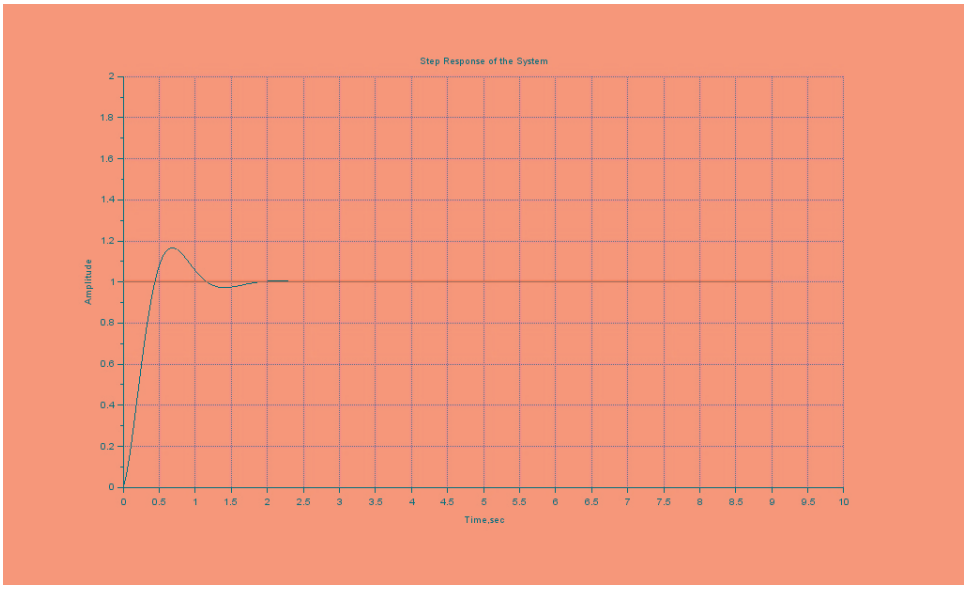


Figure 11.2: To apply integral control to servo problem to minimize the error