Scilab Manual for Control Systems by Mrs Supanna S Kumar Electrical Engineering KLE Dr M.S Sheshgiri College of Engg & Tech[1]

Solutions provided by
Mr. Supanna S Kumar
Electrical Engineering
KLE DR M.S Sheshgiri College of Engg&Tech, Belgaum

November 25, 2026

[1]Funded by a grant from the National Mission on Education through ICT, http://spoken-tutorial.org/NMEICT-Intro. This Scilab Manual and Scilab codes written in it can be downloaded from the "Migrated Labs" section at the website http://scilab.in

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Experiment: 1

Simulation of a typical second order system & determination of step response eval of time domain specifications

Scilab code Solution 1.1 Step Response and Time domain specifications

```
s=%s ;
T=syslin('c',25,25+4*s+s^2);
t=0:0.0005:5;
Ts=csim('step',t,T);
plot2d(t,Ts);
xgrid;
xtitle('Response of II order fn to unit-step input
   for T(s)=25/(s^2+6s+25)','Time(sec)',' C (t) ')
y=denom(T)                    // extracting the
   denominator of CL
z=coeff(y)       //extracting the coefficients of the
    denominator polynomial
                 //Wn^2= z(1,1), comparing the
                    coefficients
Wn=sqrt(z(1,1))             // Wn= natural frequency //
```

```
    2 * zeta * Wn = z(1,2)
zeta=z(1,2)/(2*Wn)                          // zeta = damping factor
Wd=Wn*sqrt(1-zeta^2)
Tp=%pi/Wd                                   // Tp= peak time
Mp=100*exp((-%pi*zeta)/sqrt(1-zeta^2))      // Mp=peak overshoot
Td=(1+0.7*zeta)/Wn                          // Td= delay time
a=atan(sqrt(1-zeta^2)/zeta)
Tr=(%pi-a)/Wd                               // Tr = rise time
Tset=4/(zeta*Wn)                            // Ts = settling time

Peak_time = sprintf("Peak Time = %6.3f secs",Tp);
Peak_overshoot = sprintf("Peak Overshoot = %6.3f percent",Mp);
Delay_time = sprintf("Delay_time = %6.3f secs",Td);
Rise_time = sprintf("Rise_time = %6.3f secs",Tr);
Settling_time = sprintf("Settling_time = %6.3f secs",Tset);

messagebox([Peak_overshoot,Peak_time,Delay_time,Rise_time,Settling_time],"Time response quantities");
```

Scilab code Solution 1.2 Step Responses for different Damping ratios

```
//Step Responses of a II order system for zeta=0.1(underdamped), zeta=1(critically damped) & zeta=1.5(overdamped)
t=0:0.0000001:0.0002;
zeta=[0.5 1 1.5];
```

```
cv=[1 2 3];
s=%s;
for n=1:3
num = 10^10;
den = s^2 + 2*zeta(n)*100000*s  +10^10; //wn=100k rad/sec
P = syslin('c',num,den);
Ps=csim('step',t,P);
plot2d(t,Ps,style=cv(n));
end;
xgrid;
xtitle(['Step Responses of a II order system for zeta=0.1(underdamped), zeta=1(critically damped) & zeta=1.5(overdamped)'],'Time', 'Amplitude' );
legends(['zeta=0.5';'zeta=1';'zeta=1.5'],[1,2,3],opt=4);
```

Experiment: 2

Evaluation of effect of additional poles & zeroes on Time response of second order system

Scilab code Solution 2.1 Addition of Poles to Open Loop transfer function

```
1 //Effect of Adding a Pole (1+Tp s)to OL tr fn G=wn
    ^2/(s(s+2zeta wn))on CL tr fn T=wn^2/(Tp s^3+(1+2
    zeta wn Tp)s^2+2zeta wn s+wn^2)of a II order
    system
2 s=%s;
3 t=0:0.1:30;
4 zeta=1;  wn=1;
5 Tp=[0 1 2 5];      //Poles added are s=-1/Tp i.e
    poles at -1/0, -1/1, -1/2, -1/5
6 line_style=[1 2 3 4];          // for dashed, dotted
    ,.... lines
7 for n=1:4
8    T=syslin('c',wn^2,(Tp(n)*s^3+(1+2*zeta *wn*Tp(n))
       *s^2+2*zeta *wn *s+wn^2));
```

```
9     Ts=csim('step',t,T);
10    xset("line style",line_style(n));
11    plot2d(t,Ts,style=1);  // style=1 for black line
12 end;
13 xgrid(3);                    //green grid
14 xtitle(['Effect of Adding a Pole (1+Tp s) to OL tr
      fn G = wn^2 / ( s (s + 2zeta wn))'],'Time(sec)',
      'c(t)' );
15 legends(['s = -1/0';'s = -1/1';'s = -1/2';'s = -1/5'
      ],[[1;1],[1;2],[1;3],[1;4]],opt=4);
```

Scilab code Solution 2.2 Adding Zeroes to Open Loop transfer function

```
1  //Effect of Adding a Zero,(1+Tz s)to OL tr fn G=wn
      ^2/(s(s+2zeta wn))on CL tr fn T=wn^2(1+Tz s)/(s
      ^2+(2zeta wn + wn^2 Tz)s + wn^2)of a II order
      system
2  s=%s;
3  t=0:0.001:20;
4  zeta=0.1;  wn=1;
5  Tz=[0 0.5 2 5];            //Zeroes added are s=-1/Tz
      i.e zeroes at -1/0, -1/0.5, -1/2, -1/5
6  line_style=[1 2 3 4];          // for dashed, dotted
      ,.... lines
7  for n=1:4
8     T=syslin('c',wn^2*(1+Tz(n)*s),(s^2+(2*zeta*wn+ Tz
         (n)*wn^2)*s+wn^2));
9     Ts=csim('step',t,T);
10    xset("line style",line_style(n));
11    plot2d(t,Ts,style=1);  // style=1 for black line
12 end;
13 xgrid(3);                    //green grid
14 xtitle(['Effect of Adding a Zero (1+Tz s) to OL tr
      fn G = wn^2 / ( s ( s + 2zeta wn))'],'Time(sec)',
       'c(t)' );
```

```
15 legends(['s = -1/0';'s = -1/0.5';'s = -1/2';'s =
     -1/5'],[[1;1],[1;2],[1;3],[1;4]],opt=4);
```

Scilab code Solution 2.3 Adding Poles to LClosed Loop transfer function

```
1  // Effect of addition of poles to CL tr fn T(s)
     =100/(s^2+4s+100) on its Time response
2  s=%s;
3  a=[15 4];
4
5  for n=1:3
6  if n==1 then
7     num=100
8     den=(s^2 +4*s + 100)
9  else
10    num=100*a(n-1)
11    den=(s^2 +4*s + 100)*(s+a(n-1));
12 end
13
14 T=syslin('c',num,den);
15 t=0:0.005:5;
16 Ts=csim('step',t,T);
17 xset("line style",n)
18 plot2d(t,Ts);
19 xgrid(3);                          // 3 - light shade (
     green) grid
20 end
21 xtitle('Effect of addition of poles to CL tr fn T(s)
     =100/(s^2+4s+100) on its Time response ','t(sec)'
     ,' C (t)');
22 legends(['Original tr.fn.','Added pole at s = - 15',
     'Added pole at s = - 4'],[[1;1],[1;2],[1;3]],opt
     =4);
```

Scilab code Solution 2.4 Adding Zeroes to Closed Loop transfer function

```
1  // Effect of Addition of Zeroes to CL tr fn T(s)
      =100/(s^2+4s+100) on its Time response
2  s=%s;
3  a=[8 2];
4  den=(s^2 +2*s + 9);
5
6  for n=1:3
7      if n==1 then
8      num=9
9      else
10     num=9*(s+a(n-1))/a(n-1);
11 end
12
13 T=syslin('c',num,den);
14
15 t=0:0.005:5;
16 Ts=csim('step',t,T);
17 xset("line style",n)
18 plot2d(t,Ts);
19 xgrid(3);                          // 3 - light shade (
      green) grid
20 end
21 xtitle('Effect of Addition of Zeroes to CL tr fn T(s
      )=100/(s^2+4s+100) on its Time response','t(sec)'
      ,'C (t)');
22 legends(['Original tr.fn.','Added zero at -8','Added
       zero at -2'],[[1;1],[1;2],[1;3]],opt=4);
```

Experiment: 3

Evaluation of effect of pole location on stability

Scilab code Solution 3.3 Effect of Pole Location on Stability

```
1 //Evaluation of effect of Pole location on stability
    of II order system
2 s=%s;
3 t=0:0.001:20;
4 wn=1;
5
6 //Poles on -ve real axis(zeta>1)
7 zeta=2 ;
8 R=roots(s^2 + 2*zeta*wn*s + wn^2)  // R(1) = -
    3.7320508 , R(2) = - 0.2679492
9 T=syslin('c',wn^2,(s-R(1))*(s-R(2)))//T=syslin('c',
    wn^2,s^2 + 2*zeta*wn*s + wn^2);
10 Ts1=csim('step',t,T);
11 subplot(231)
12 xtitle("Poles on -ve Real axis (zeta>1)")
13 plot(t,Ts1);
14 xgrid;
15
16 //Equal Poles on -ve Real axis (zeta=1)
```

```
17 zeta=1 ;
18 R=roots(s^2 + 2*zeta*wn*s + wn^2)  // R(1) = R(2) =
     -1
19 T=syslin('c',wn^2,(s-R(1))*(s-R(2)))//T=syslin('c',
     wn^2,s^2 + 2*zeta*wn*s + wn^2);
20 Ts1=csim('step',t,T);
21 subplot(232)
22 xtitle("Equal Poles on -ve Real axis (zeta=1)")
23 plot(t,Ts1);
24 xgrid;
25
26 //Complex conjugate Poles with -ve Real part (0<zeta
     <1)
27 zeta=0.5 ;
28 R=roots(s^2 + 2*zeta*wn*s + wn^2) // R(1)= -0.5
     +0.8660254i, R(2)= -0.5 -0.8660254i
29 T=syslin('c',wn^2,(s-R(1))*(s-R(2)))//T=syslin('c',
     wn^2,s^2 + 2*zeta*wn*s + wn^2);
30 Ts1=csim('step',t,T);
31 subplot(233)
32 xtitle("Complex conj Poles with -ve Real part (0<
     zeta<1)")
33 plot(t,Ts1);
34 xgrid;
35
36 //Complex conj Poles on Imag axis (zeta=0)
37 zeta=0 ;
38 R=roots(s^2 + 2*zeta*wn*s + wn^2)  // R(1)= i, R(2)
     = -i
39 T=syslin('c',wn^2,(s-R(1))*(s-R(2)))//T=syslin('c',
     wn^2,s^2 + 2*zeta*wn*s + wn^2);
40 Ts1=csim('step',t,T);
41 subplot(234)
42 xtitle("Complex conj Poles on Imag axis (zeta=0)")
43 plot(t,Ts1);
44 xgrid;
45
46 //Complex conj Poles with +ve Real part (0>zeta>-1)
```

```
47 zeta=-0.5 ;
48 R=roots(s^2 + 2*zeta*wn*s + wn^2)  // R(1)= 0.5 +
     0.8660254i, R(2) = 0.5 - 0.8660254i
49 T=syslin('c',wn^2,(s-R(1))*(s-R(2)))//T=syslin('c',
     wn^2,s^2 + 2*zeta*wn*s + wn^2);
50 Ts1=csim('step',t,T);
51 subplot(235)
52 xtitle("Complex conj Poles with +ve Real part (0>
     zeta>-1)")
53 plot(t,Ts1);
54 xgrid;
55
56 //Poles on +ve Real axis (zeta<-1)
57 zeta=-1.2 ;
58 R=roots(s^2 + 2*zeta*wn*s + wn^2)  // R(1)=
     5.8284271, R(2) = 0.1715729
59 T=syslin('c',wn^2,(s-R(1))*(s-R(2)))//T=syslin('c',
     wn^2,s^2 + 2*zeta*wn*s + wn^2);
60 Ts1=csim('step',t,T);
61 subplot(236)
62 xtitle("Poles on +ve Real axis (zeta<-1)")
63 plot(t,Ts1);
64 xgrid;
```

Experiment: 4

Effect of loop gain of a negative feedback system on stability

Scilab code Solution 4.1 Effect of Loop Gain on stability

```
1  // Effect of Loop Gain K of a Negative feedback
       system on Stability.
2  // G(s) = wn^2 / s(s+2zeta wn) , H(s) = K , T(s) = K
       wn^2 / ( s(s+2zeta wn) + K wn^2 )
3  s=%s;
4  t=0:0.01:10;
5  wn=1;zeta=1;
6  K=[1,2,5,10]
7  for n=1:4
8      T=syslin('c', K(n)*wn^2 , s*(s + 2*zeta*wn) + K(
           n)*wn^2 );
9      Ts=csim('step',t,T);
10     xset("line style",n);
11     plot2d(t,Ts);
12     xgrid(3);
13 end
14 xtitle('Effect of Loop Gain K of a - ve feedback
       system on Stability.','Time(sec)','C(t)');
15 legends(['K=1';'K=2';'K=5';'K=10'
```

```
;],[[1;1],[1;2],[1;3],[1;4]], opt=4);
```

Experiment: 5

To examine the relationships between open-loop frequency response and stability, open loop frequency and C.L transient response

Scilab code Solution 5.1 Relation between Open Loop Frequency Response and Closed Loop Transient Response

```
1 //OpenLoop Frequency Response & ClosedLoop Transient
      Response
2
3 // 1) Correlation b/w ub(Normalized bandwidth) &
     zeta(Damping factor) for a II order system
4 deff("[wbbywn]=f1(zeta)","wbbywn=sqrt(1-2*zeta^2+
     sqrt(2-4*zeta^2+4*zeta^4))")
5 zeta=[0:0.01:0.9];// don't end with 1 bec, division
     by 0 error
6 subplot(221)
7 fplot2d(zeta,f1,[1])
8 xgrid(3)
```

```
9  xtitle(['Correlation b/w ub(Normalized bandwidth) &
       zeta for a II order system'],'zeta (Damping ratio
       )', 'wb / wn' );
10
11 // 2) Correlation b/w Mp(Peak overshoot) & Mr(
       Resonance Peak) for a II order system
12 deff("[Mp]=f2(zeta)","Mp=exp((-%pi*zeta)/sqrt(1-zeta
       ^2))")
13 deff("[Mr]=f3(zeta)","Mr=1/(2*zeta*sqrt(1-zeta^2))")
14 zeta=[0.05:0.01:0.9];  //don't start from 0 & end
       with 0 because, division by 0 error
15 subplot(222)
16 xset("line style",4);
17 fplot2d(zeta,f2,[1])
18 xset("line style",1);
19 fplot2d(zeta,f3,[1])
20 xgrid(3)
21 xtitle(['Correlation between Mp & Mr for a II order
       system'],'zeta (Damping ratio)', 'Mp, Mr' );
22 legends(['Mp (Peak Gain)';'Mr (Gain at Resonance)'
       ],[[1;4],[1;1]],opt=1);
23
24 // 3) Correlation between wr(Resonant frequency) &
       wd(Damped frequency) for a II order system
25 deff("[wrbywd]=f4(zeta)","wrbywd=sqrt(1-2*zeta^2)/
       sqrt(1-zeta^2)")
26 zeta=[0:0.01:0.9];// don't end with 1 bec, division
       by 0 error
27 subplot(223)
28 fplot2d(zeta,f4,[1])
29 xgrid(3)
30 xtitle(['Correlation between wr & wd for a II order
       system'],'zeta (Damping ratio)', 'wr / wd' );
```