

Scilab Manual for
Control Systems
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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

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

```

    2 * zeta * Wn = z(1,2)
12 zeta=z(1,2)/(2*Wn)           // zeta = d a m
    p i n g f a c t o r
13 Wd=Wn*sqrt(1-zeta^2)
14 Tp=%pi/Wd                   // Tp= p
    e a k t i m e
15 Mp=100*exp((-%pi*zeta)/sqrt(1-zeta^2)) // Mp=p e
    a k o v e r s h o o t
16 Td=(1+0.7*zeta)/Wn         // Td= d e
    l a y t i m e
17 a=atan(sqrt(1-zeta^2)/zeta)
18 Tr=(%pi-a)/Wd              // T r = r
    i s e t i m e
19 Tset=4/(zeta*Wn)           // T s =
    s e t t l i n g t i m e
20
21 Peak_time = sprintf("Peak Time = %6.3f secs",Tp);
22 Peak_overshoot = sprintf("Peak Overshoot = %6.3f
    percent",Mp);
23 Delay_time = sprintf("Delay_time = %6.3f secs",Td);
24 Rise_time = sprintf("Rise_time = %6.3f secs",Tr);
25 Settling_time = sprintf("Settling_time = %6.3f secs"
    ,Tset);
26
27 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

```

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

```

```

4 cv=[1 2 3];
5 s=%s;
6 for n=1:3
7 num = 10^10;
8 den = s^2 + 2*zeta(n)*100000*s +10^10; //wn=100k
      rad/sec
9 P = syslin('c',num,den);
10 Ps=csim('step',t,P);
11 plot2d(t,Ps,style=cv(n));
12 end;
13 xgrid;
14 xtitle(['Step Responses of a II order system for
          zeta=0.1(underdamped), zeta=1(critically damped)
          & zeta=1.5(overdamped)'], 'Time', 'Amplitude' );
15 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 //  $G(s) = \frac{\omega_n^2}{s(s+2\zeta\omega_n)}$  ,  $H(s) = K$  ,  $T(s) = \frac{K\omega_n^2}{s(s+2\zeta\omega_n) + K\omega_n^2}$ 
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 def f1(zeta) = 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(2,2,1)
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' );

```
