

Scilab Textbook Companion for
Design With Operational Amplifiers And
Analog Integrated Circuits
by S. Franco¹

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Book Description

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Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

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Chapter 1

Operational Amplifier Fundamentals

Scilab code Exa 1.1.a Amplifier Fundamentals

```
1 //Example 1.1(a)
2
3 clear;
4
5 clc;
6
7 Ri=100*10^3; //Input Resistance
8
9 Aoc=100; //Open Circuit Gain
10
11 Ro=1; //Output Resistance
12
13 Rs=25*10^3; //Source Resistance
14
15 RL=3; //Load Resistance
16
17 Av=(Ri/(Rs+Ri))*Aoc*(RL/(Ro+RL)); //Overall Gain
18
19 Vredin=(Ri/(Ri+Rs))*100; //Percentage Reduction in
```

```

    Source Voltage due to Input Loading
20
21 Vredo=(RL/(Ro+RL))*100;//Percentage Reduction in
    Output Voltage due to output loading
22
23 printf(" Overall Gain (Av)=%.2 f V/V" ,Av);
24
25 printf("\nPercentage Input Loading=%.2 f" ,Vredin);
26
27 printf("\nPercentage Output Loading=%.2 f" ,Vredo);

```

Scilab code Exa 1.1.b Amplifier Fundamentals

```

1 //Example 1.1(b)
2
3 clear;
4
5 clc;
6
7 Ri=100*10^3;//Input Resistance
8
9 Aoc=100;//Open Circuit Gain
10
11 Ro=1;//Output Resistance
12
13 Rs=50*10^3;//Source Resistance
14
15 RL=4;//Load Resistance
16
17 Av=(Ri/(Rs+Ri))*Aoc*(RL/(Ro+RL));//Overall Gain
18
19 Vredin=(Ri/(Ri+Rs))*100;//Percentage Reduction in
    Source Voltage due to Input Loading
20
21 Vredo=(RL/(Ro+RL))*100;//Percentage Reduction in

```



```

    Output Voltage due to output loading
22
23 printf(" Overall Gain (Av)=%.2 f V/V" ,Av);
24
25 printf("\nPercentage Input Loading=%.2 f (Not
    mentioned in book)",Vredin);
26
27 printf("\nPercentage Output Loading=%.2 f (Not
    mentioned in book)",Vredo);

```

Scilab code Exa 1.2.a Gain of a Noninverting OP AMP

```

1 //Example 1.2(a)
2
3 clear;
4
5 clc;
6
7 Vi=1; //Input Voltage
8
9 R1=2*10^3;
10
11 R2=18*10^3;
12
13 a=10^2; //Open Loop Gain
14
15 A=(1+(R2/R1))*(1+(1+(R2/R1))/a)^(-1); //Overall Gain
16
17 Vo=Vi*A; //Output Voltage
18
19 printf("Output Voltage (Vo)=%.3 f V" ,Vo);

```

Scilab code Exa 1.2.b Gain of a Noninverting OP AMP

```

1 //Example 1.2(b)
2
3 clear;
4
5 clc;
6
7 Vi=1; //Input Voltage
8
9 R1=2*10^3;
10
11 R2=18*10^3;
12
13 a=10^4; //Open Loop Gain
14
15 A=(1+(R2/R1))*(1+(1+(R2/R1))/a)^(-1); //Overall Gain
16
17 Vo=Vi*A; //Output Voltage
18
19 printf("Output Voltage (Vo)=%.3f V",Vo);

```

Scilab code Exa 1.2.c Gain of a Noninverting OP AMP

```

1 //Example 1.2(c)
2
3 clear;
4
5 clc;
6
7 Vi=1; //Input Voltage
8
9 R1=2*10^3;
10
11 R2=18*10^3;
12
13 a=10^6; //Open Loop Gain

```

```

14
15 A=(1+(R2/R1))*(1+(1+(R2/R1))/a)^(-1); // Overall Gain
16
17 Vo=Vi*A; //Output Voltage
18
19 printf("Output Voltage (Vo)=%.4f V",Vo);

```

Scilab code Exa 1.3 Inverting Amplifier Ideal Closed Loop Characteristics

```

1 //Example 1.3
2
3 clear;
4
5 clc;
6
7 R1=10*10^3;
8
9 R2=100*10^3;
10
11 Ri=R1; //Input Resistance
12
13 Ro=0; //Output Resistance
14
15 A=-(R2/R1); // Ideal Overall Gain
16
17 printf("Ri=%.2f kohms", (Ri/1000));
18
19 printf("\nRo=%.f ohms", Ro);
20
21 printf("\nA=%.2f V/V", A);

```

Scilab code Exa 1.4 Designing Summing Amplifiers

```

1 //Example 1.4
2
3 clear;
4
5 clc;
6
7 Rf=120*10^3; //Assuming feedback resistance Rf
      =120*10^3
8 //Imposing in equation  $V_o=-((R_f/R_1)V_1+(R_f/R_2)V_2+(R_f/R_3)V_3)$ 
9
10 R1=Rf/6; //From coefficient of V1
11
12 R2=Rf/8; //From coefficient of V2
13
14 R3=Rf/4; //From coefficient of V3
15
16 printf("Designed Summing Amplifier :");
17
18 printf("\n R1=%0.2 f kohms", (R1/1000));
19
20 printf("\n R2=%0.2 f kohms", (R2/1000));
21
22 printf("\n R3=%0.2 f kohms", (R3/1000));
23
24 printf("\n Rf=%0.2 f kohms", (Rf/1000));

```

Scilab code Exa 1.5 Designing Function Generators

```

1 //Example 1.5
2
3 clear;
4
5 clc;
6

```

```

7 Rf=100*10^3; //Assuming Feedback Resistance Rf
8
9 Vee=-15;
10
11 //Imposing  $V_o = -(R_f/R_1)V_i - (R_f/R_2)(-15) = -10V_i + 5$ 
12
13 R1=Rf/10;
14
15 R2=(Rf*15)/5;
16
17 printf("Designed Function Generator :");
18
19 printf("\n R1=%0.2 f kohms", (R1/1000));
20
21 printf("\n R2=%0.2 f kohms", (R2/1000));
22
23 printf("\n Rf=%0.2 f kohms", (Rf/1000));

```

Scilab code Exa 1.6 Designing Difference Amplifier

```

1 //Example 1.6
2
3 clear;
4
5 clc;
6
7 Ri1=100*10^3;
8
9 Ri2=100*10^3;
10
11 //Using standard equation for difference amplifier
12 //vo=(R2/R1) (((1+(R1/R2)))/(1+(R3/R4))) v2-v1 =v2-3v1
13 //Ri1=R1, Ri2=R3+R4, Ro=0
14
15 R1=Ri1;

```

```

16
17 R2=3*R1;
18
19 //Solving the equations  $R3+R4=Ri2=100\text{kohms}$  and
     $3[(1+(1/3))/(1+(R3/R4))]=1$ 
20 //  $3[4/3((R3+R4)/R4)]=1$ 
21 //As  $R3+R4=100 \rightarrow 4/(100/R4)=1 \rightarrow (4R4)/100=1 \rightarrow R4$ 
     $/25=1 \rightarrow R4=25\text{kohms}$ 
22
23 R4=25*10^3; //By solving the equations mentioned
    above
24
25 R3=Ri2-R4; //From standard equations
26
27 printf("Designed Difference Amplifier :");
28
29 printf("\nR1=%0.2 f kohms", (R1/1000));
30
31 printf("\nR2=%0.2 f kohms", (R2/1000));
32
33 printf("\nR3=%0.2 f kohms", (R3/1000));
34
35 printf("\nR4=%0.2 f kohms", (R4/1000));

```

Scilab code Exa 1.7.a Application of Negative Feedback

```

1 //Example 1.7(a)
2
3 clear;
4
5 clc;
6
7 //1.7(a)
8 Gerrormax=0.1; // Maximum Gain Error Percentage
9

```

```

10 //But Gerror100/T ->Gerrormax=100/Tmin -> Tmin=100/
    Gerrormax
11
12 Tmin=100/Gerrormax;
13
14 printf("Loop Gain (T)>=%0.2 f",Tmin);

```

Scilab code Exa 1.7.b Application of Negative Feedback

```

1 //Example 1.7(b)
2
3 clear;
4
5 clc;
6
7 Gerrormax=0.1; // Maximum Gain Error Percentage
8
9 //But Gerror100/T ->Gerrormax=100/Tmin -> Tmin=100/
    Gerrormax
10
11 Tmin=100/Gerrormax;
12
13 Aideal=100;
14
15 b=1/Aideal; //Feedback Factor
16
17 amin=Tmin/b; //Minimum Open Loop Gain
18
19 printf("\nOpen Loop Gain (a)>=%0.f",amin);

```

Scilab code Exa 1.7.c Application of Negative Feedback

```

1 //Example 1.7(c)

```

```

2
3 clear;
4
5 clc;
6
7 Gerrormax=0.1; // Maximum Gain Error Percentage
8
9 //But Gerror100/T ->Gerrormax=100/Tmin -> Tmin=100/
   Gerrormax
10
11 Tmin=100/Gerrormax;
12
13 Aideal=100;
14
15 b=1/Aideal; //Feedback Factor
16
17 amin=Tmin/b; //Minimum Open Loop Gain
18
19 //Imposing  $A=a/(1+ab)$ . We have  $a=10^5$  and  $Aideal=100$ 
   -> $100=10^5/(1+10^5b)$ 
20
21 y=poly(0, 'x');
22
23 z=(100*amin)*y+(100-amin); //Solving the equation
   mentioned in above comment.
24
25 b=roots(z);
26
27 printf("Feedback Factor (b) for A=100 is =%.5f",b);

```

Scilab code Exa 1.8.a Calculating Gain Desensitivity

```

1 //Example 1.8(a)
2
3 clear;

```



```

4
5 clc;
6
7 a=10^5; //Open Loop Gain
8
9 b=10^(-3); //Feedback Factor
10
11 T=a*b; //return ratio or loop gain
12
13 d=1+T; //Desensitivity Factor
14
15 A=a/d; //Overall Gain
16
17 anew=a+(10/100)*a; //Increasing gain by 10%
18
19 Tnew=anew*b; //New return ratio or loop gain
20
21 dnew=1+Tnew; //New Desensitivity Factor
22
23 Anew=anew/dnew; //Overall Gain
24
25 Achange=((Anew-A)/A)*100; //Percentage Change in
    Overall Gain
26
27 printf("Percentage change in A =%.1f percent",
    Achange);

```

Scilab code Exa 1.8.b Calculating Gain Desensitivity

```

1 //Example 1.8(b)
2
3 clear;
4
5 clc;
6

```

```

7 a=10^5; //Open Loop Gain
8
9 b=1; //Feedback Factor
10
11 T=a*b; //return ratio or loop gain
12
13 d=1+T; //Desensitivity Factor
14
15 aperchange=10; //Percentage Change in a
16
17 Achange=(1/(1+T))*aperchange; //Percentage Change in
    Overall Gain
18
19 printf("Percentage change in A =%.4f",Achange);

```

Scilab code Exa 1.9.a Noninverting Configuration Characteristics

```

1 //Example 1.9(a)
2
3 clear;
4
5 clc;
6
7 rd=2*10^6; //Input Resistance
8
9 ro=75; //Output Resistance
10
11 a=200*10^3; //Open loop Gain
12
13 R1=1*10^3;
14
15 R2=999*10^3;
16
17 b=R1/(R1+R2); //Feedback Factor
18

```

```

19 T=a*b;//return ratio or loop gain
20
21 Aapprox=(1+(R2/R1))*(1/(1+(1/T)))//Approximate Gain
22
23 Riapprox=rd*(1+T);//Approximate Input Resistance
24
25 Roapprox=ro/(1+T);
26
27 Anum=((1+(R2/R1))*a)+(ro/rd)//Numerator of exact
    Gain
28
29 Aden=1+a+(R2/R1)+((R2+ro)/rd)+(ro/R1);//Denominator
    of exact Gain
30
31 Aexact=Anum/Aden;//exact Gain
32
33 Ri1=rd*(1+(a/(1+((R2+ro)/R1)))));
34
35 Ri2=(R1*(R2+ro))/(R1+R2+ro);
36
37 Riexact=Ri1+Ri2;//Exact Input Resistance
38
39 Ronum=ro;
40
41 Roden=1+((a+(ro/R1)+(ro/rd))/(1+(R2/R1)+(R2/rd)))
42
43 Roexact=Ronum/Roden;//Exact Output Resistance
44
45 //Ideal Value of input resistance Ri1 is infinity
    and ideal value of output resistance Ro1 is 0.
46
47 printf("Exact Value of A is =%.2f V/V",Aexact);
48
49 printf("\nApproximate Value of A is =%.3f V/V",
    Aapprox);
50
51 printf("\nIdeal Value of A is =%.3f V/V",1000);
52

```

```

53 printf("\nExact Value of Ri is =%.3f Mohms",Riexact
    /10^6);
54
55 printf("\nApproximate Value of Ri is =%.3f Mohms",
    Riapprox/10^6);
56
57 printf("\nIdeal Value of Ri is infinity");
58
59 printf("\nExact Value of Ro is =%.3f mohms",Roexact
    *10^3);
60
61 printf("\nApproximate Value of Ro is =%.3f mohms",
    Roapprox*10^3);
62
63 printf("\nApproximate Value of Ro is =%.3f ohms",0);

```

Scilab code Exa 1.9.b Noninverting Configuration Characteristics

```

1 //Example 1.9(b)
2
3 clear;
4
5 clc;
6
7 rd=2*10^6;//Input Resistance
8
9 ro=75;//Output Resistance
10
11 a=200*10^3;//Open loop Gain
12
13 printf("Note (as mentioned in the book): Because of
    much larger value, we simply ignore the exact
    calculations and use only the approximations.");
14
15 //R12=infinity

```

```

16
17 R2=0;
18
19 //b2=R12/(R12+R22) (Feedback Factor) will be equal to
    1 as R12 tends to infinity and R22 is 0
20
21 b=1; //Feedback Factor
22
23 T=a*b; //return ratio or loop gain
24
25 //Aapprox=(1+(R22/R12))*(1/(1+(1/T2)))(Approximate
    Gain) but R22/R12=0
26
27 Trec=1/T;
28
29 Aden=(1+Trec);
30
31 Anum=1;
32
33 Aapprox=Anum/Aden; //Approximate Gain
34
35 Riapprox=rd*(1+T); //Approximate Input Resistance
36
37 Roapprox=ro/(1+T); //Approximate Output Resistance
38
39 //Ideal Value of input resistance Ri2 is infinity
    and ideal value of output resistance Ro2 is 0.
40
41 printf("\nApproximate Value of A is =%.f V/V",
    Aapprox);
42
43 printf("\nIdeal Value of A is =%.2f V/V",1);
44
45 printf("\nApproximate Value of Ri is =%.3f Gohms",
    Riapprox/10^9);
46
47 printf("\nIdeal Value of Ri is infinity");
48

```

```
49 printf("\nApproximate Value of Ro is =%.3f uohms",
        Roapprox*10^6);
50
51 printf("\nApproximate Value of Ro is =%.f ohms",0);
```

Scilab code Exa 1.10.a Inverting Configuration Characteristics

```
1 //Example 1.10(a)
2
3 clear;
4
5 clc;
6
7 R1=100*10^3;
8
9 R2=100*10^3;
10
11 ro=75; //Output Resistance
12
13 a=200*10^3; //Open Loop Gain for ic741
14
15 b=R1/(R1+R2); //Feedback Factor
16
17 T=a*b; //Loop Gain
18
19 Trec=1/T;
20
21 Atemp=1+Trec;
22
23 Atemp=1/Atemp;
24
25 A=(-R2/R1)*Atemp; //Gain
26
27 Rnum=R2+ro;
28
```

```

29 Rnden=1+a;
30
31 Rn=Rnum/Rnden; //Equivalent Resistance of the
    inverting input(Calculation Mistake in the book
    as a is taken as 10^5 rather than 2*10^5)
32
33 Ri=R1+Rn; //Equivalent Input Resistance
34
35 Ro=ro/(1+T); //Equivalent Output Resistance
36
37 printf("A=%0.5 f V/V" ,A);
38
39 printf("\nRn=%0.2 f ohms ",Rn); //answer in textbook is
    wrong
40
41 printf("\nRi=%0.2 f kohms" ,(Ri/1000));
42
43 printf("\nRo=%0.2 f mohms" ,(Ro*1000));

```

Scilab code Exa 1.10.b Inverting Configuration Characteristics

```

1 //Example 1.10(b)
2
3 clear;
4
5 clc;
6
7 R1=1*10^3;
8
9 R2=1*10^6;
10
11 ro=75; //Output Resistance
12
13 a=200*10^3; //Open Loop Gain for ic741
14

```

```

15 b=R1/(R1+R2); //Feedback Factor
16
17 T=a*b; //Loop Gain
18
19 Trec=1/T;
20
21 Atemp=1+Trec;
22
23 Atemp=1/Atemp;
24
25 A=(-R2/R1)*Atemp; //Gain
26
27 Rnum=R2+ro;
28
29 Rden=1+a;
30
31 Rn=Rnum/Rden; //Equivalent Resistance of the
    inverting input (Calculation Mistake in the book
    as a is taken as 10^5 rather than 2*10^5)
32
33 Ri=R1+Rn; //Equivalent Input Resistance
34
35 Ro=ro/(1+T); //Equivalent Output Resistance
36
37 printf("A=%0.5 f V/V",A);
38
39 printf("\nRn=%0.2 f ohms",Rn);
40
41 printf("\nRi=%0.3 f kohms", (Ri/1000));
42
43 printf("\nRo=%0.3 f ohms",Ro);

```

Scilab code Exa 1.11.a Finding the Loop Gain

```

1 //Example 1.11(a)

```



```

2
3 clear;
4
5 clc;
6
7 R1=1*10^6;
8
9 R2=1*10^6;
10
11 R3=100*10^3;
12
13 R4=1*10^3;
14
15 RL=2*10^3; //Load Resistance
16
17 A=-(R2/R1)*(1+(R3/R2)+(R3/R4)); //Ideal Gain
18
19 printf("Ideal Gain of of the op amp (A)=%.2 f V/V" ,A)
    ;

```

Scilab code Exa 1.11.b Finding the Loop Gain

```

1 //Example 1.11(b)
2
3 clear;
4
5 clc;
6
7 R1=1*10^6;
8
9 R2=1*10^6;
10
11 R3=100*10^3;
12
13 R4=1*10^3;

```

```

14
15 RL=2*10^3; //Load Resistance R1=1*10^6;
16
17 R2=1*10^6;
18
19 R3=100*10^3;
20
21 R4=1*10^3;
22
23 RL=2*10^3; //Load Resistance
24
25 A=-(R2/R1)*(1+(R3/R2)+(R3/R4)); //Ideal Gain
26
27 rd=1*10^6; //Internal input resistance
28
29 a=10^5; //Open Loop Gain
30
31 ro=100;
32
33 RA=(R1*rd)/(R1+rd);
34
35 RB=RA+R2;
36
37 RC=(RB*R4)/(RB+R4);
38
39 RD=RC+R3;
40
41 RE=(RD*RL)/(RD+RL);
42
43 RF=RE+ro;
44
45 c1=-(RA/RB); //vD=c1*v1
46
47 c2=(RC/RD); //v1=c2*vo
48
49 c3=(RE/RF); //vo=c3*vT
50
51 c4=a*(c1*c2*c3); //vR=a*vD=a*(c1*v1)=a*(c1*c2*vo)=a*(

```

```

    c1*c2*c3)vT=c4*vT -> vR=c4*vT
52
53 T=-c4;//T=(-vR/vT)=-c4 (Loop Gain)
54
55 Trec=1/T;
56
57 Atemp=1+Trec;
58
59 Aactual=A/Atemp;//Actual Gain
60
61 Adev=((Aactual-A)/A)*100;//Deviation in Gain
62
63 printf("Actual Gain of op amp=%0.1f V/V",Aactual);
64
65 printf("\nPercentage Departure of Actual Gain from
    Ideal gain=%0.2f",Adev);

```

Scilab code Exa 1.12.a Feedback Factor for Negative Feedback

```

1 //Example 1.12(a)
2
3 clear;
4
5 clc;
6
7 rd=1*10^6;//Internal Input Resistance
8
9 a=10^4;//Open Loop Gain
10
11 ro=100;//Internal Output Resistance
12
13 R1=10*10^3;//shown in Fig. 1.34a
14
15 R2=20*10^3;//shown in Fig. 1.34a
16

```

```

17 R3=30*10^3; //shown in Fig. 1.34a
18
19 R4=300*10^3; //Feedback Resistance (shown in Fig.
    1.34a)
20
21 RL=2*10^3; //Load Resistance
22
23 RArec=((1/R1)+(1/R2)+(1/R3)+(1/rd)) // Reciprocal of
    RA(parallel combination of R1, R2, R3 and rd)
24
25 RA=1/RArec;
26
27 RB=RA+R4;
28
29 RC=(RB*RL)/(RB+RL);
30
31 RD=RC+ro;
32
33 c1=(RA/RB); //vN=c1*vo
34
35 c2=(RC/RD); //vo=c2*vT
36
37 b=c1*c2; //Feedback Factor b=vN/vT=c1*c2
38
39 T=a*b; //Loop Gain
40
41 printf("b=%0.3 f V/V" , b);
42
43 printf("\nT=%0.2 f" , T);

```

Scilab code Exa 1.12.b Feedback Factor for Negative Feedback

```

1 //Example 1.12(b)
2
3 clear;

```

```

4
5  clc;
6
7  rd=1*106; //Internal Input Resistance
8
9  a=104; //Open Loop Gain
10
11 ro=100; //Internal Output Resistance
12
13 R1=10*103; //shown in Fig. 1.34a
14
15 R2=20*103; //shown in Fig. 1.34a
16
17 R3=30*103; //shown in Fig. 1.34a
18
19 R4=300*103; //Feedback Resistance (shown in Fig.
      1.34a)
20
21 RL=2*103; //Load Resistance
22
23 RAreC=((1/R1)+(1/R2)+(1/R3)+(1/rd)) //Reciprocal of
      RA(parallel combination of R1, R2, R3 and rd)
24
25 RA=1/RAreC;
26
27 RB=RA+R4;
28
29 RC=(RB*RL)/(RB+RL);
30
31 RD=RC+ro;
32
33 c1=(RA/RB); //vN=c1*vo
34
35 c2=(RC/RD); //vo=c2*vT
36
37 b=c1*c2; //Feedback Factor b=vN/vT=c1*c2
38
39 T=a*b; //Loop Gain

```

```

40
41 // 1.12(b)
42
43 p1=-(R4/R1);
44
45 p2=-(R4/R2);
46
47 p3=-(R4/R3);
48
49 // vo(ideal)=p1*v1+p2*v2+p3*v3
50
51 Trec=1/T;
52
53 ctemp=1+Trec;
54
55 ctemp=1/ctemp;
56
57 p1act=-(R4/R1)*ctemp;
58
59 p2act=-(R4/R2)*ctemp;
60
61 p3act=-(R4/R3)*ctemp;
62
63 printf("Ideal Transfer Characterstic of the circuit
        vo=-(%.2 f*v1" ,-p1);
64
65 printf("+%.2 f*v2" ,-p2);
66
67 printf("+%.2 f*v3)" ,-p3);
68
69 printf("\nActual Transfer Characterstic of the
        circuit vo=-(%.2 f*v1" ,-p1act);
70
71 printf("+%.2 f*v2" ,-p2act);
72
73 printf("+%.2 f*v3)" ,-p3act);

```

Scilab code Exa 1.13 Feedback Factor for Combination of Negative and Positive Feed

```
1 //Example 1.13
2
3 clear;
4
5 clc;
6
7 R1=30*10^3;//From Fig. 1.13b
8
9 R3=20*10^3;//Feedback Resistance obtained from Fig.
   1.13b
10
11 R2=10*10^3;//Load Resistance obtained from Fig. 1.13
   b
12
13 rd=100*10^3;//Internal Input Resistance
14
15 ro=100;//Internal Output Resistance
16
17 bNnum=((R1*rd)/(R1+rd))+R3;
18
19 bNden=ro+R2+bNnum;
20
21 bN=bNnum/bNden;
22
23 bPnum=R3;
24
25 bPden=bNden;
26
27 bP=bPnum/bPden;
28
29 b=bN-bP;//Feedback Factor
30
```

```
31 printf("b=%0.3 f V/V" ,b);
```

Scilab code Exa 1.14.a Current Flow and Power Dissipation

```
1 //Example 1.14(a)
2
3 clear;
4
5 clc;
6
7 R1=10*10^3;
8
9 R2=20*10^3;
10
11 RL=2*10^3; ///Load Resistance
12
13 vI=3; //Input Voltage
14
15 IQ=0.5*10^(-3);
16
17 v0=-(R2/R1)*vI; //Output Voltage
18
19 iL=-v0/RL; //Current through RL
20
21 i1=vI/R1; //Cuurent through R1
22
23 i2=i1; //Current through R2 (as current sunk by the
    op amp is 0)
24
25 i0=i2+iL; //Output Current
26
27 iCC=IQ;
28
29 iEE=iCC+i0;
30
```



```

31 printf("iCC=%0.2 f mA" ,(iCC*1000));
32
33 printf("\niEE=%0.2 f mA" ,(iEE*1000));
34
35 printf("\niO=%0.2 f mA" ,(iO*1000));

```

Scilab code Exa 1.14.b Current Flow and Power Dissipation

```

1 //Example 1.14(b)
2
3 clear;
4
5 clc;
6
7 R1=10*10^3;
8
9 R2=20*10^3;
10
11 RL=2*10^3; ///Load Resistance
12
13 vI=3; ///Input Voltage
14
15 IQ=0.5*10^(-3);
16
17 v0=-(R2/R1)*vI; ///Output Voltage
18
19 iL=-v0/RL; ///Current through RL
20
21 i1=vI/R1; ///Cuurent through R1
22
23 i2=i1; ///Current through R2 (as current sunk by the
    op amp is 0)
24
25 i0=i2+iL; ///Output Current
26

```

```

27 iCC=IQ;
28
29 iEE=iCC+i0;
30
31 VCC=15;
32
33 VEE=-15;
34
35 IQ=0.5*10(-3);
36
37 p0A=(VCC-VEE)*IQ+(v0-VEE)*i0; //Power Dissipated in
    the Op Amp
38
39 printf("Power Dissipated inside the op amp=%0.2f mW"
    ,(p0A*1000));

```

Scilab code Exa 1.15.a Designing variable dc source

```

1 //Example 1.15(a)
2
3 clear;
4
5 clc;
6
7 Rp=100*103; //Potentiometer Resistance
8
9 VCC=15;
10
11 VEE=-15;
12
13 //We have to choose the resistances in such a way
    that we get VA=10V and VB=-10V, so that if we
    want the source to be in the range -10V<=vW<=10V,
    we need to only turn the wiper. Let RA and RB be
    the resistances corresponding to nodes A and B

```

respectively. If $R_A=R_B=25\text{kohm}$ then there would be a drop of 5V accross each component (R_A, R_B and potentiometer) which will make $V_A=10\text{V}$ and $V_B=-10\text{V}$. Hence R_A and R_B are selected as 25kohms. (Refer Fig. 1.38)

```

14
15 //vRA(voltage accross RA)=5=(15*RA)/(50+RA) (Using
    Voltade Divider Rule)where 50kohm is the
    potentiometer resistance on node A side and RA
    is in kohms. Hence by solving the equation RA=25
    kohm. Similarly solve for RB.
16
17 y=poly(0, 'x');
18
19 p=5*(y+50*(10^3))-(15*y);
20
21 RA=roots(p);
22
23 RB=RA;
24
25 printf("Designed Source :");
26
27 printf("\nRA=%0.2 f kohms", (RA/1000)); //mentioned in
    the diagram
28
29 printf("\nRB=%0.2 f kohms", (RB/1000)); //mentioned in
    the diagram
30
31 printf("\nRpot=%0.2 f kohms", (Rp/1000)); //mentioned in
    the diagram

```

Scilab code Exa 1.15.b Designing variable dc source

```

1 //Example 1.15(b)
2

```

```

3  clear;
4
5  clc;
6
7  Rp=100*10^3; //Potentiometer Resistance
8
9  VCC=15;
10
11 VEE=-15;
12
13 //We have to choose the resistances in such a way
    that we get  $V_A=10V$  and  $V_B=-10V$ , so that if we
    want the source to be in the range  $-10V \leq v_W \leq 10V$ ,
    we need to only turn the wiper. Let  $R_A$  and  $R_B$  be
    the resistances corresponding to nodes A and B
    respectively. If  $R_A=R_B=25k\Omega$  then there would be
    a drop of 5V across each component ( $R_A, R_B$  and
    potentiometer) which will make  $V_A=10V$  and  $V_B=-10V$ 
    . Hence  $R_A$  and  $R_B$  are selected as 25k $\Omega$ s. (Refer
    Fig. 1.38)
14
15 //vRA(voltage across  $R_A$ )= $5=(15*R_A)/(50+R_A)$  (Using
    Voltage Divider Rule) where 50k $\Omega$  is the
    potentiometer resistance on node A side and  $R_A$ 
    is in k $\Omega$ s. Hence by solving the equation  $R_A=25$ 
    k $\Omega$ . Similarly solve for  $R_B$ .
16
17 y=poly(0, 'x');
18
19 p=5*(y+50*(10^3))-(15*y);
20
21 RA=roots(p);
22
23 RB=RA;
24
25 RL=1*10^3; //Load Resistance
26
27 vS=10; //Source voltage

```

Inverting Amplifier driven into saturation waveforms

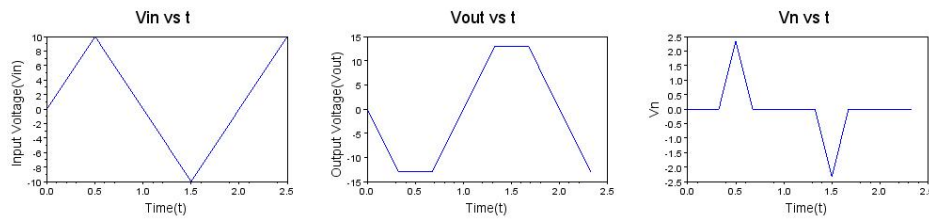


Figure 1.1: Inverting Amplifier driven into saturation

```
28
29 iL=vS/RL; // Current drawn by the load
30
31 a=200*10^3; // Open Loop Gain (defined for 741)
32
33 b=1; // Feedback Factor (Refer Fig. 1.38)
34
35 T=a*b; // Loop Gain
36
37 ro=75; // Internal Output Resistance (defined for 741)
38
39 Ro=ro/(1+T); // Output Resistance
40
41 vSchange=Ro*iL; // Change in Voltage
42
43 printf("Change in Vs=%0.3f uV", (vSchange*10^6));
```

Scilab code Exa 1.16 Inverting Amplifier driven into saturation

```
1 //Example 1.16
2
3 clear;
4
5 clc;
6
7 //Part(I)
8 //This part of the program includes the plotting of
   the input wave (triangular wave). To plot the
   wave we have divided the time period(assuming T
   =2) into 3 time intervals t1, t2, t3 and then
   create voltage equation for each using the given
   conditions.
9
10 VCC=13;
11
12 VEE=-13;
13
14 A=-2; //Gain
15
16 t1=[0:10-4:0.5];
17
18 t2=[0.5:10-4:1.5];
19
20 t3=[1.5:10-4:2.5];
21
22 vt1=20*t1;
23
24 vt2=20*(1-t2);
25
26 vt3=20*(t3-2);
27
```

```

28 subplot(131);
29
30 title("
        Inverting Amplifier driven into saturation
        waveforms ","fontsize",6);
31
32 subplot(334);
33
34 plot(t1,vt1);
35
36 plot(t2,vt2);
37
38 plot(t3,vt3);
39
40 xlabel("Time(t)","fontsize",3);
41
42 ylabel("Input Voltage(Vin)","fontsize",3);
43
44 title("Vin vs t","fontsize",4);
45
46 //Part(II)
47 //In this part we have plotted vo by using the
        conditions vo=-2vI for -6.5V<vI<6.5V, otherwise
        vo=-13. Again we have divided the time period into
        5 parts to1, to2, to3, to1i, to2i depending upon
        the response in each interval.
48
49 vIbor=VCC/2;
50
51 to1min=0;
52
53 to1max=6.5/20;
54
55 to2min=1-(6.5/20);
56
57 to2max=1+(6.5/20);
58

```

```

59 to3min=2-(6.5/20);
60
61 to3max=2+(6.5/20);
62
63 to1=[to1min:10^(-4):to1max];
64
65 to2=[to2min:10^(-4):to2max];
66
67 to3=[to3min:10^(-4):to3max];
68
69 to1imin=to1max;
70
71 to1imax=to2min;
72
73 to2imin=to2max;
74
75 to2imax=to3min;
76
77 to1i=[to1imin:10^(-4):to1imax];
78
79 to2i=[to2imin:10^(-4):to2imax];
80
81 vo1=-13*(to1-to1min)/(to1max-to1min);
82
83 vo1i=-13;
84
85 vo2=((13+13)/(to2max-to2min))*(to2-to2min)-13;
86
87 vo2i=13;
88
89 vo3=((13+13)/(to3min-to3max))*(to3-to3max)-13;
90
91 subplot(335);
92
93 plot(to1,vo1);
94
95 plot(to1i,vo1i*ones(1,length(to1i)));
96

```



```

97 plot(to2,vo2);
98
99 plot(to2i,vo2i*ones(1,length(to2i)));
100
101 plot(to3,vo3);
102
103 ylabel("Output Voltage(Vout)","fontsize",3);
104
105 xlabel("Time(t)","fontsize",3);
106
107 title("Vout vs t","fontsize",4);
108
109 //Part(III)
110 //In this part we will plot vN for which we have
    divided the time period into 7 time intervals
    tNi1, tNi2, tNi3, tN11, tN12, tN21, tN22
    depending upon the response in each cycle voltage
    equation is obtained and plotted.For  $-6.5 < vI < 6.5$ 
    vN=0 and when vI will peak at 10V vN will peak
    at 2.33 and for  $vI < -6.5$  and  $vI > 6.5$ , circuit
    behaviour is symmetric.
111
112 vIbor=VCC/2;
113
114 tNi1min=0;
115
116 tNi1max=6.5/20;
117
118 tNi2min=1-(6.5/20);
119
120 tNi2max=1+(6.5/20);
121
122 tNi3min=2-(6.5/20);
123
124 tNi3max=2+(6.5/20);
125
126 tNi1=[tNi1min:10^(-4):tNi1max];
127

```

```

128 tNi2=[tNi2min:10(-4):tNi2max];
129
130 tNi3=[tNi3min:10(-4):tNi3max];
131
132 tN11min=tNi1max;
133
134 tN11max=(tNi2min+tNi1max)/2;
135
136 tN12min=tN11max;
137
138 tN12max=tNi2min;
139
140 tN21min=tNi2max;
141
142 tN21max=(tNi2max+tNi3min)/2;
143
144 tN22min=tN21max;
145
146 tN22max=tNi3min;
147
148 tN11=[tN11min:10(-4):tN11max];
149
150 tN12=[tN12min:10(-4):tN12max];
151
152 tN21=[tN21min:10(-4):tN21max];
153
154 tN22=[tN22min:10(-4):tN22max];
155
156 vNi1=0;
157
158 vN11=(2.33/(tN11max-tN11min))*(tN11-tN11min);
159
160 vN12=-(2.33/(tN12max-tN12min))*(tN12-tN12max);
161
162 vNi2=0;
163
164 vN21=-(2.33/(tN21max-tN21min))*(tN21-tN21min);
165

```

```
166 vN22=(2.33/(tN22max-tN22min))*(tN22-tN22max);
167
168 vNi3=0;
169
170 subplot(336);
171
172 plot(tNi1,vNi1*ones(1,length(tNi1)));
173
174 plot(tN11,vN11);
175
176 plot(tN12,vN12);
177
178 plot(tNi2,vNi2*ones(1,length(tNi2)));
179
180 plot(tN21,vN21);
181
182 plot(tN22,vN22);
183
184 plot(tNi3,vNi3*ones(1,length(tNi3)));
185
186 xlabel("Time(t)","fontsize",3);
187
188 ylabel("Vn","fontsize",3);
189
190 title("Vn vs t","fontsize",4);
```

Chapter 2

Circuits with Resistive Feedback

Scilab code Exa 2.1 Closed Loop Parameters of Basic I V Converter

```
1 //Example 2.1
2
3 clear;
4
5 clc;
6
7 R=1*10^6;
8
9 a=200*10^3; //Open Loop Gain for ic741
10
11 rd=2*10^6; //defined for 741
12
13 ro=75; //internal output resistance defined for 741
14
15 Tnum=a*rd;
16
17 Tden=rd+R+ro;
18
19 T=Tnum/Tden; //Loop Gain
```

```

20
21 Anum=-R;
22
23 Aden=1+(1/T);
24
25 A=Anum/Aden; // Overall Gain
26
27 Rinumn=rd*(R+ro);
28
29 Rinumd=rd+R+ro;
30
31 Rinum=Rinumn/Rinumd;
32
33 Riden=1+T;
34
35 Ri=Rinum/Riden; // Input resistance
36
37 Ronum=ro;
38
39 Roden=1+T;
40
41 Ro=Ronum/Roden; // Output Resistance (Value obtained
    for Ro in the book is wrong)
42
43 printf("T=%0. f",T);
44
45 printf("\nA=%0.6 f V/uA",A*10^(-6));
46
47 printf("\nRi=%0.1 f ohms",Ri);
48
49 printf("\nRo=%0.3 f mohms", (Ro*(10^3))); // answer in
    textbook is wrong

```

Scilab code Exa 2.2 Designing High Sensitivity I V Converter

```

1 //Example 2.2
2
3 clear;
4
5 clc;
6
7 sen=0.1*10^9; //sensitivity in V/A
8
9 R=1*10^6; // Assumption
10
11 //sen=k*R ->k=sen/R
12
13 k=sen/R;
14
15 R1=1*10^3; // Assumption
16
17 //k=1+(R2/R1)+(R2/R) ->R2=(k-1)/((1/R1)+(1/R))
18
19 R2num=k-1;
20
21 R2den=((1/R1)+(1/R));
22
23 R2=R2num/R2den;
24
25 printf("Designed High Sensitivity I-V Converter :");
26
27 printf("\nR=%g f Mohms", (R*10^(-6)));
28
29 printf("\nR1=%g f kohms", R1*10^(-3));
30
31 printf("\nR2=%g f kohms", R2*10^(-3))

```

Scilab code Exa 2.3.a Characteristics of Floating Load V I Converters

```

1 //Example 2.3(a)

```

```

2
3 clear;
4
5 clc;
6
7 vI=5; //Input Voltage
8
9 R=10*10^3;
10
11 Vsat=13; //Saturation Voltage
12
13 iO=vI/R; //(from right to left for Fig.2.4(a) and
           from left to right for Fig.2.4(b))
14
15 printf("iO=%.1 f mA", iO*10^3);

```

Scilab code Exa 2.3.b Characteristics of Floating Load V I Converters

```

1 //Example 2.3(b)
2
3 clear;
4
5 clc;
6
7 vI=5; //Input Voltage
8
9 R=10*10^3;
10
11 Vsat=13; //Saturation Voltage
12
13 iO=vI/R; //iO for Circuit shown in Fig.2.4(a) (from
           right to left)
14
15 //For Circuit shown in Fig.2.4(a) VoL1<vL1<VoH1
16

```

```

17 VoL1=-Vsat-vI;
18
19 VoH1=Vsat-vI;
20
21 printf("For Circuit shown in Fig.2.4(a) %.1f V< vL <
    ",VoL1);
22
23 printf("%.1f V",VoH1);
24
25 //For Circuit shown in Fig.2.4(b) VoL2<vL2<VoH2
26
27 VoL2=-Vsat;
28
29 VoH2=Vsat;
30
31 printf("\nFor Circuit shown in Fig.2.4(b) %.1f V< vL
    <",VoL2);
32
33 printf("%.1f V",VoH2);

```

Scilab code Exa 2.3.c Characterstics of Floating Load V I Converters

```

1 //Example 2.3(c)
2
3 clear;
4
5 clc;
6
7 vI=5;//Input Voltage
8
9 R=10*10^3;
10
11 Vsat=13;//Saturation Voltage
12
13 i0=vI/R;//iO for Circuit shown in Fig.2.4(a) (from

```



```

    right to left)
14
15 //For Circuit shown in Fig.2.4(a)
16
17 VoL1=-Vsat-vI;
18
19 VoH1=Vsat-vI;
20
21 //For Circuit shown in Fig.2.4(b) VoL2<vL2<VoH2
22
23 VoL2=-Vsat;
24
25 VoH2=Vsat;
26
27 RLmax1=VoH1/i0;//Maximum Possible value of RL
28
29 //For Circuit shown in Fig.2.4(b)
30
31 RLmax2=VoH2/i0;//Maximum Possible Value of RL
32
33 printf("Max Value of RL for Circuit shown in Fig
    .2.4(a)= %.f kohms",RLmax1*10^(-3));
34
35 printf("\nMax Value of RL for Circuit shown in Fig
    .2.4(b)= %.f kohms",RLmax2*10^(-3));

```

Scilab code Exa 2.4 Designing Current Source using Grounded Load Converter

```

1 //Example 2.4
2
3 clear;
4
5 clc;
6
7 Vsat=15;//Saturation Voltage

```

```

8
9 vL=10;
10
11 iL=10^(-3); //Load Current
12
13 vI=Vsat; //Assuming Vsat as the input Voltage
14
15 R1=vI/iL; //( Tolerance -1%)
16
17 //vL<=(R1/(R1+R2))*Vsat , Vsat=15V ->10<=(R1/(R1+R2))
    *15 or 10=(R1/(R1+R2))*13 (approx)
18 //->R2=((13*R1)/vL)-R1
19
20 R2=((13*R1)/vL)-R1; //( Tolerance -1%)
21
22 R3=R1; //( Tolerance -1%)
23
24 R4=R2; //( Tolerance -1%)
25
26 printf("Designed Current Source using Grounded Load
    Converter :");
27
28 printf("\nR1=%0. f kohms" ,R1*10^(-3));
29
30 printf("\nR2=%0.1 f kohms" ,R2*10^(-3));
31
32 printf("\nR3=%0. f kohms" ,R3*10^(-3));
33
34 printf("\nR4=%0.1 f kohms" ,R4*10^(-3));

```

Scilab code Exa 2.5.a Effect of Resistance Mismatches in Grounded Load Converters

```

1 //Example 2.5(a)
2
3 clear;

```

```

4
5 clc;
6
7 R1=15*10^3; //From the result of Example 2.4
8
9 p=0.01; //For 1% tolerance p=t/100=1/100=0.01
10
11 emax=4*p; //imbalace factor
12
13 Romin=R1/emax;
14
15 printf("Ro can be anywhere in the range Ro>=%0.2 f
      kohms",Romin*10^(-3));

```

Scilab code Exa 2.5.b Effect of Resistance Mismatches in Grounded Load Converters

```

1 //Example 2.5(b)
2
3 clear;
4
5 clc;
6
7 R1=15*10^3; //From the result of Example 2.4
8
9 p=0.001; //For 1% tolerance p=t/100=1/100=0.01
10
11 emax=4*p; //imbalace factor
12
13 Romin=R1/emax;
14
15 printf("Ro can be anywhere in the range Ro>=%0.2 f
      Mohms",Romin*10^(-6));

```

Scilab code Exa 2.5.c Effect of Resistance Mismatches in Grounded Load Converters

```
1 //Example 2.5(c)
2
3 clear;
4
5 clc;
6
7 R1=15*10^3;//From the result of Example 2.4
8
9 Romin=50*10^6;
10
11 emax=R1/Romin;
12
13 p=emax/4;
14
15 pper=p*100;
16
17 printf("Resistance tolerance Required=%0.5f percent",
        pper);
```

Scilab code Exa 2.6 Howland Circuit Calibration

```
1 //Example 2.6
2
3 clear;
4
5 clc;
6
7 //From result of Example 2.4
8 R1=15*10^3;
9
10 R2=4.5*10^3;
11
12 R3=R1;
```

```

13
14 R4=R2;
15
16 p=0.01;
17
18 e=4*p*R1; // Resistance to be trimmed
19
20 R3redmax=R3-e; // R3red<=R3redmax
21
22 R3red=R3redmax-400; // Tolerance 1%
23
24 Rpot=2*(R3-R3red);
25
26 printf("Designed Current Source using Grounded Load
        Converter with trimmed R3 :");
27
28 printf("\nR1=%0.2 f kohms",R1*10^(-3));
29
30 printf("\nR2=%0.2 f kohms",R2*10^(-3));
31
32 printf("\nRs=%0.2 f kohms",R3red*10^(-3));
33
34 printf("\nRpot=%0.2 f kohms",Rpot*10^(-3));
35
36 printf("\nR4=%0.2 f kohms",R4*10^(-3));

```

Scilab code Exa 2.7 Effect of finite loop gain on Howland Circuit

```

1 //Example 2.7
2
3 clear;
4
5 clc;
6
7 R1=15*10^3;

```

```

8
9 R2=3*10^3;
10
11 R3=R1;
12
13 R4=R2;
14
15 a=200*10^3;
16
17 Ro1num=R1*R2;
18
19 Ro1den=R1+R2;
20
21 Ro1=Ro1num/Ro1den;
22
23 Ro2num=a;
24
25 Ro2den=(1+(R2/R1));
26
27 Ro2=Ro2num/Ro2den;
28
29 Ro=Ro1*(1+Ro2); //Output resistance
30
31 printf("Output Resistance (Ro)=%.f Mohms",Ro*10^(-6)
);

```

Scilab code Exa 2.8.a Output Voltage of a Difference Amplifier

```

1 //Example 2.8(a)
2
3 clear;
4
5 clc;
6
7 R1=10*10^3;

```

```

8
9 R3=R1;
10
11 R2=100*10^3;
12
13 R4=R2;
14
15 //For first pair of inputs (v1, v2)=(-0.1 V, +0.1V)
16 v11=-0.1;
17
18 v21=0.1;
19
20 vo1=(R2/R1)*(v21-v11);
21
22 vcm1=(v11+v21)/2;
23
24 //For Second pair of inputs (v1, v2)=(4.9 V, 5.1V)
25
26 v12=4.9;
27
28 v22=5.1;
29
30 vo2=(R2/R1)*(v22-v12);
31
32 vcm2=(v12+v22)/2;
33
34 //For Third pair of inputs (v1, v2)=(9.9 V, 10.1 V)
35
36 v13=9.9;
37
38 v23=10.1;
39
40 vo3=(R2/R1)*(v23-v13);
41
42 vcm3=(v13+v23)/2;
43
44 printf("vo for (-0.1 V,+0.1 V)=%.2 f V",vo1);
45

```

```
46 printf("\nvo for (4.9 V,5.1 V)=%.2 f V",vo2);
47
48 printf("\nvo for (9.9 V,10.1 V)=%.2 f V",vo3);
```

Scilab code Exa 2.8.b Output Voltage of a Difference Amplifier

```
1 //Example 2.8(b)
2
3 clear;
4
5 clc;
6
7 R1=10*10^3;
8
9 R2=98*10^3;
10
11 R3=9.9*10^3;
12
13 R4=103*10^3;
14
15 //For first pair of inputs (v1, v2)=(-0.1 V, +0.1V)
16 v11=-0.1;
17
18 v21=0.1;
19
20 vo1=(R2/R1)*(v21-v11);
21
22 vcm1=(v11+v21)/2;
23
24 //For Second pair of inputs (v1, v2)=(4.9 V, 5.1V)
25
26 v12=4.9;
27
28 v22=5.1;
29
```



```

30 vo2=(R2/R1)*(v22-v12);
31
32 vcm2=(v12+v22)/2;
33
34 //For Third pair of inputs (v1, v2)=(9.9 V, 10.1 V)
35
36 v13=9.9;
37
38 v23=10.1;
39
40 vo3=(R2/R1)*(v23-v13);
41
42 vcm3=(v13+v23)/2;
43
44 //vO=A2*v2-A1*v1
45
46 A2num=(1+(R2/R1));
47
48 A2den=(1+(R3/R4));
49
50 A2=A2num/A2den;
51
52 A1=R2/R1;
53
54 //For first pair of inputs (v1, v2)=(-0.1 V, +0.1V)
55
56 vo1m=A2*v21-A1*v11;
57
58 //For Second pair of inputs (v1, v2)=(4.9 V, 5.1V)
59
60 vo2m=A2*v22-A1*v12;
61
62 //For Third pair of inputs (v1, v2)=(9.9 V, 10.1 V)
63
64 vo3m=A2*v23-A1*v13;
65
66 printf("vo for (-0.1 V,+0.1 V)=%.3f V",vo1m);
67

```

```
68 printf("\nvo for (4.9 V,5.1 V)=%.3 f V",vo2m);
69
70 printf("\nvo for (9.9 V,10.1 V)=%.3 f V",vo3m);
```

Scilab code Exa 2.9 Common Mode Rejection Ratio for op amp

```
1 //Example 2.9
2
3 clear;
4
5 clc;
6
7 R1=10*103;
8
9 R3=R1;
10
11 R2=100*103;
12
13 R4=R2;
14
15 p=0.01;
16
17 emax=4*p;
18
19 Adm1=R2/R1;
20
21 Adm2n=emax*(R1+2*R2);
22
23 Adm2d=2*(R1+R2);
24
25 Adm2=1-(Adm2n/Adm2d);
26
27 Admin=Adm1*Adm2;
28
29 Acmax=(R2/(R1+R2))*emax;
```

```

30
31 cmrrm=20*log10(Admin/Acmax);
32
33 printf("(a) CMRR min=%0.1 f dB",cmrrm);
34
35 // 2.9(b)
36
37 vdm=0;
38
39 vcm=10;
40
41 v0=vcm*Acmax+vdm*Admin;
42
43 printf("\n(b) Output Error vO=%0.3 f V",v0);
44
45 // 2.9(c)
46
47 //CMRR=20*log((1+(R2/R1))/emax) -> 80=20*log((1+(R2/
    R1))/emax) -> 4=log((1+(R2/R1))/emax) ->10^4=(1+(
    R2/R1))/emax -> emax=10^4/(1+(R2/R1))
48
49 emax1=(1+(R2/R1))/(10^(4));
50
51 p=emax1/4;
52
53 pper=p*100;
54
55 printf("\n(c) Required Resistance Tolerance=%0.4 f
    percent",pper);

```

Scilab code Exa 2.10.a Designing Triple Op Amp Instrumentation Amplifier

```

1 //Example 2.10(a)
2
3 clear;

```

```

4
5 clc;
6
7 Amin=1;
8
9 Amax=103;
10
11 AI=0.5;
12
13 R1=100*103; //Tolerance (1%)
14
15 R2=AI*R1; //Tolerance (1%)
16
17 AImin=Amin/AI;
18
19 AImax=Amax/AI;
20
21 // AImin<=AI<=AImax
22 // AImin=1+((2*R3)/(R4+R1)) -> 1+((2*R3)/(R4+R1))-
    Amin=0 -> (1-AImin)*R4+2*R3+(1-AImin)*R1=0... (i)
    and AImax=1+((2*R3)/(R4+0)) ->(1-AImax)*R4+2*R3
    =0.... (ii)
23 //Solving these two equations will give R3 and R4
24
25 A=[2 (1-AImin);2 (1-AImax)];
26
27 B=[(1-AImin)*R1;0];
28
29 R=linsolve(A,B);
30
31 R3=R(1,1); //Tolerance (1%)
32
33 R4=R(2,1); //Tolerance (1%)
34
35 printf("Designed Instrumentation Amplifier :");
36
37 printf(" \nR1=%0.2 f kohms",R1*10(-3));
38

```

```

39 printf("\nR2=%0.2 f kohms",R2*10^(-3));
40
41 printf("\nR3=%0. f kohms",R3*10^(-3));
42
43 printf("\nR4=%0. f ohms",R4);

```

Scilab code Exa 2.10.b Designing Triple Op Amp Instrumentation Amplifier

```

1 //Example 2.10(b)
2
3 clear;
4
5 clc;
6
7 Amin=1;
8
9 Amax=10^3;
10
11 AI=0.5;
12
13 R1=100*10^3;//Tolerance (1%)
14
15 R2=AI*R1;//Tolerance (1%)
16
17 AImin=Amin/AI;
18
19 AImax=Amax/AI;
20
21 //AImin<=AI<=AImax
22 //AImin=1+((2*R3)/(R4+R1)) -> 1+((2*R3)/(R4+R1))-
    Amin=0 -> (1-AImin)*R4+2*R3+(1-AImin)*R1=0...( i )
    and AImax=1+((2*R3)/(R4+0)) ->(1-AImax)*R4+2*R3
    =0....( ii )
23 //Solving these two equations will give R3 and R4
24

```

```

25 A=[2 (1-AImin);2 (1-AImax)];
26
27 B=[(1-AImin)*R1;0];
28
29 R=linsolve(A,B);
30
31 R3=R(1,1); //Tolerance (1%)
32
33 R4=R(2,1); //Tolerance (1%)
34
35 p=0.01;
36
37 e=4*p*R2;
38
39 R5=100*10^3;
40
41 R2red=R2-e-500; //to be on the safer side 0.5 kohms
    more is reduced
42
43 Rpot=2*(R2-R2red); //Potentiometer Resistance
44
45 //Circuit is shown in Fig.2.21 in the book
46
47 printf("Designed Instrumentation Amplifier with
    trimmed resistances :");
48
49 printf("\nR1=%0.2 f kohms",R1*10^(-3));
50
51 printf("\nR2=%0.2 f kohms",R2*10^(-3));
52
53 printf("\nR3=%0. f kohms",R3*10^(-3));
54
55 printf("\nR4=%0. f ohms",R4);
56
57 printf("\nR5=%0. f kohms",R5*10^(-3));
58
59 printf("\nR6=%0.2 f kohms",R2red*10^(-3));
60

```

```
61 printf("\nR7=%0.2 f kohms",Rpot*10^(-3));
```

Scilab code Exa 2.10.c Designing Triple Op Amp Instrumentation Amplifier

```
1 //Example 2.10(c)
2
3 clear;
4
5 clc;
6
7 Amin=1;
8
9 Amax=10^3;
10
11 AI=0.5;
12
13 R1=100*10^3;//Tolerance (1%)
14
15 R2=AI*R1;//Tolerance (1%)
16
17 AImin=Amin/AI;
18
19 AImax=Amax/AI;
20
21 //AImin<=AI<=AImax
22 //AImin=1+((2*R3)/(R4+R1)) -> 1+((2*R3)/(R4+R1))-
    Amin=0 -> (1-AImin)*R4+2*R3+(1-AImin)*R1=0...( i )
    and AImax=1+((2*R3)/(R4+0)) ->(1-AImax)*R4+2*R3
    =0....( ii )
23 //Solving these two equations will give R3 and R4
24
25 A=[2 (1-AImin);2 (1-AImax)];
26
27 B=[(1-AImin)*R1;0];
28
```

```

29 R=linsolve(A,B);
30
31 R3=R(1,1); //Tolerance (1%)
32
33 R4=R(2,1); //Tolerance (1%)
34
35 //2.10(c)
36
37 Rpot1=100*10^3;
38
39 printf("To calibrate the circuit , tie the inputs
         together and set the Rpot1 pot for the maximum
         gain (wiper all the way up). Then, while
         switching the common inputs back and forth
         between -5V and +5V, adjust the Rpot2 pot for the
         minimum change at the output.");

```

Scilab code Exa 2.11.a Study of Resistance Temperature Detector

```

1 //Example 2.11(a)
2
3 clear;
4
5 clc;
6
7 R0=100;
8
9 alpha=0.00392;
10
11 //R(T)=R0*(1+alpha*T) -> R(T)=100*(1+0.00392*T)
12
13 printf("R(T)=%.2 f" ,R0);
14
15 printf("(1+%.5 f" ,alpha);
16

```



```
17 printf("T) ohms");
```

Scilab code Exa 2.11.b Study of Resistance Temperature Detector

```
1 //Example 2.11(b)
2
3 clear;
4
5 clc;
6
7 R0=100;
8
9 alpha=0.00392;
10
11 T1=25;
12
13 R1=R0*(1+alpha*T1);
14
15 printf("R(25 deg Celsius)=%0.2 f ohms",R1);
16
17 T2=100;
18
19 R2=R0*(1+alpha*T2);
20
21 printf("\nR(100 deg Celsius)=%0.2 f ohms",R2);
22
23 T3=-15;
24
25 R3=R0*(1+alpha*T3);
26
27 printf("\nR(-15 deg Celsius)=%0.2 f ohms",R3);
```

Scilab code Exa 2.11.c Study of Resistance Temperature Detector

```

1 //Example 2.11(c)
2
3 clear;
4
5 clc;
6
7 R0=100;
8
9 alpha=0.00392;
10
11 dT=10;
12
13 delta=alpha*dT;
14
15 deltaper=delta*100;
16
17 dR=R0*delta;
18
19 printf("Change in R=%0.2f ohms",dR);
20
21 printf("\nPercentage Deviation=%0.2f percent",
        deltaper);

```

Scilab code Exa 2.12.a Designing a Transducer Bridge with Instrumentation Amplifier

```

1 //Example 2.12(a)
2
3 clear;
4
5 clc;
6
7 R0=100;//Data taken from Example 2.11
8
9 alpha=0.00392;//Data taken from Example 2.11
10

```

```

11 Vref=15;
12
13 Prtd=0.2*10(-3);
14
15 i=(Prtd/R0)(0.5)-(0.41*10(-3));
16
17 R1=(Vref/i);
18
19 delta=alpha*1; //Fractional Deviation for 1 degree
    celsius change in temperature
20
21 s=0.1; //Output Voltage for 1 degree Celsius
    temperature change
22
23 A1=s*(2+(R1/R0)+(R0/R1));
24
25 A2=Vref*delta;
26
27 A=(A1/A2)+1.0555913;
28
29 printf("R1=%f kohms",R1*10(-3));
30
31 printf("\nA=%f V/V",A);

```

Scilab code Exa 2.12.b Designing a Transducer Bridge with Instrumentation Amplifier

```

1 //Example 2.12(b)
2
3 clear;
4
5 clc;
6
7 R0=100; //Data taken from Example 2.11
8
9 alpha=0.00392; //Data taken from Example 2.11

```

```

10
11 Vref=15;
12
13 Prtd=0.2*10(-3);
14
15 i=(Prtd/R0)(0.5)-(0.41*10(-3));
16
17 R1=(Vref/i);
18
19 delta=alpha*1; //Fractional Deviation for 1 degree
    celsius change in temperature
20
21 s=0.1; //Output Voltage for 1 degree Celsius
    temperature change
22
23 A1=s*(2+(R1/R0)+(R0/R1));
24
25 A2=Vref*delta;
26
27 A=A1/A2;
28
29 dT=100;
30
31 d2=alpha*dT;
32
33 v01num=A*Vref*d2;
34
35 v01den=1+(R1/R0)+((1+(R0/R1))*(1+d2));
36
37 v01=v01num/v01den;
38
39 v02num=A*Vref*d2;
40
41 v02den=(2+(R1/R0)+(R0/R1));
42
43 v02=v02num/v02den;
44
45 v0change=v02-v01;

```

```

46
47 printf("vO(100 deg Celsius)=%.3 f V",v01);
48
49 Tchange=v0change/s;
50
51 printf("\nEquivalent Temperature Error=%.2 f deg
    Celsius",Tchange);

```

Scilab code Exa 2.13.a Transducer Bridge Calibration

```

1 //Example 2.13(a)
2
3 clear;
4
5 clc;
6
7 R0=100;//Data taken from Example 2.11
8
9 alpha=0.00392;//Data taken from Example 2.11
10
11 Vref=15;
12
13 P=0.2*10^(-3);
14
15 i=(P/R0)^(0.5)-(0.41*10^(-3));
16
17 pV=0.05;
18
19 Vrefc=pV*Vref+0.25;
20
21 Vrefr=Vref-Vrefc;
22
23 R3=2/(2*i);
24
25 //R0+R1+(R2/2)=Vrefr/i;

```

```

26
27 Rtot=Vrefr/i;
28
29 p=0.01;
30
31 R2=(2*p*Rtot)+221.1748472;//220 ohms are added to be
    on the safe side
32
33 R1=(Rtot-(R2/2)-R0)+108.15494;//Tolerance 1%
34
35 v0=9.97;//Data from Example 2.12
36
37 R1u=R1+(R2/2);
38
39 dT=1;//obtained from Example 2.12
40
41 d2=alpha*dT;
42
43 v0=0.1;//Sensitivity (Refer Example 2.12)
44
45 Anum=v0*(2+(R1u/R0)+(R0/R1u));
46
47 Aden=Vrefr*d2;
48
49 A=Anum/Aden;//Overall Gain by using Eq.2.47
50
51 printf("Designed Circuit for Calibration :");
52
53 printf("\nR1=%0.1 f kohms",R1*10^(-3));
54
55 printf("\nR2=%0. f ohms",R2);
56
57 printf("\nR3=%0. f kohms",R3*10^(-3));
58
59 printf("\nA=%0.1 f V/V",A);

```

Scilab code Exa 2.13.b Transducer Bridge Calibration

```
1 //Example 2.13(a)
2
3 clear;
4
5 clc;
6
7 R0=100; //Data taken from Example 2.11
8
9 alpha=0.00392; //Data taken from Example 2.11
10
11 Vref=15;
12
13 P=0.2*10^(-3);
14
15 i=(P/R0)^(0.5)-(0.41*10^(-3));
16
17 pV=0.05;
18
19 Vrefc=pV*Vref+0.25;
20
21 Vrefr=Vref-Vrefc;
22
23 R3=2/(2*i);
24
25 //R0+R1+(R2/2)=Vrefr/i;
26
27 Rtot=Vrefr/i;
28
29 p=0.01;
30
31 R2=(2*p*Rtot)+220; //220 ohms are added to be on the
    safe side
```

```

32
33 R1=Rtot-(R2/2)-R0; // Tolerance 1%
34
35 v0=9.97; //Data from Example 2.12
36
37 R1u=R1+(R2/2);
38
39 dT=1; //obtained from Example 2.12
40
41 d2=alpha*dT;
42
43 v0=0.1; //Sensitivity (Refer Example 2.12)
44
45 Anum=v0*(2+(R1u/R0)+(R0/R1u));
46
47 Aden=Vrefr*d2;
48
49 A=Anum/Aden; //Overall Gain by using Eq.2.47
50
51 printf("To calibrate , first set T=0 degree Celsius
        and adjust R2 for vO=0 V. Then set T=100 degree
        Celsius and adjust R3 for vO=10.0 V.");

```

Scilab code Exa 2.14 Designing Strain Gauge Bridge with Instrumentation Amplifier

```

1 //Example 2.14
2
3 clear;
4
5 clc;
6
7 //2.14(a)
8
9 Rs=120;
10

```



```

11 Vref=15;
12
13 imax=20*10(-3);
14
15 Vb=2*Rs*imax;
16
17 Vtap=Vb/2;
18
19 Vtapch=0.01*Vtap;
20
21 v1=Vtap+Vtapch;
22
23 v2=Vtap-Vtapch;
24
25 v1ch=v1-v2;
26
27 i=v1ch/((Rs*Rs)/(Rs+Rs));
28
29 R1=(Vtap/i)-630;
30
31 R2=1000;
32
33 i3=2*imax+(4.8/R2);
34
35 R3=(2/i3)+6-0.642857 ;
36
37 R4=((Vref-(R3/2)*i3-Vb)/i3)-3;
38
39 printf("(a) R1=%0.2 f kohms",R1*10(-3));
40
41 printf("\n R2=%0. f kohms",R2*10(-3));
42
43 printf("\n R3=%0. f ohms",R3);
44
45 printf("\n R4=%0. f ohms",R4);
46
47 // 2.14(b)
48

```

```
49 printf("\n\n(b) To calibrate , first adjust R2 so
    that with no strain we get  $v_O=0$  V. Then supply a
    known strain , preferably near the full scale , and
    adjust R3 for the desired value of  $v_O$ .”);
```

Chapter 3

Active Filters Part I

Scilab code Exa 3.1 Pole Zero Response of Transfer Function

```
1 //Example 3.1
2
3 clear;
4
5 clc;
6
7 R=10;
8
9 C=40*10(-6);
10
11 L=5*10(-3);
12
13 Hsnum=(R/L)*%s;
14
15 Hsden=((%s(2))+(R/L)*%s+(1/(L*C)));
16
17 Hs=Hsnum/Hsden; //Transfer Function
18
19 h=syslin('c',Hs);
```

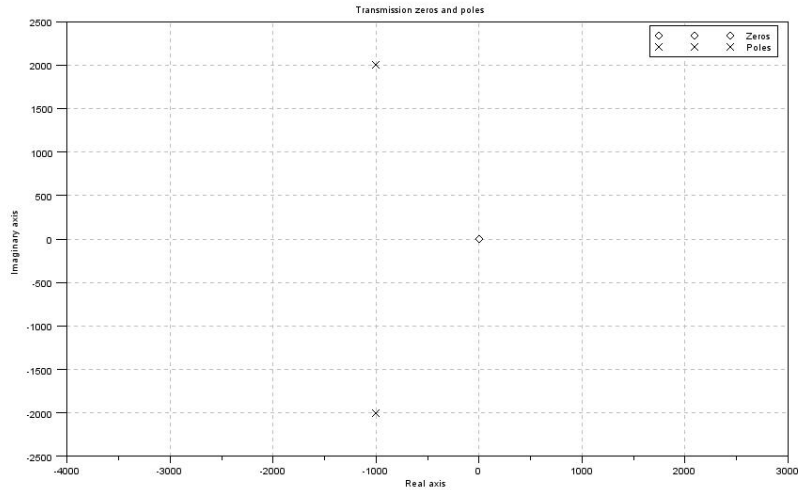


Figure 3.1: Pole Zero Response of Transfer Function

```

20
21 plzr(h);
22
23 zeroes=roots(Hsnum);
24
25 poles=roots(Hsden);

```

Scilab code Exa 3.2 Finding Impulse Response of a given circuit

```

1 //Example 3.2
2
3 clear;
4
5 clc;
6
7 printf("\nThe problem requires to find Laplace
  Transform which is not possible in scilab. Hence

```

```

        standard procedure");
8
9 printf("\nfor finding the Integral Transforms has
        been used")
10
11 syms s t;
12
13 R=10;
14
15 C=40*10^(-6);
16
17 L=5*10^(-3);
18
19 Hsnum=(R/L)*s;
20
21 Hsden=((s^(2))+(R/L)*s+(1/(L*C)));
22
23 Hs=Hsnum/Hsden; //Transfer Function
24
25 vot=ilaplace(Hs); //Impulse Response of Circuit

```

Scilab code Exa 3.3 Steady State Response of a Circuit

```

1 //Example 3.3
2
3 clear;
4
5 clc;
6
7 R=10;
8
9 C=40*10^(-6);
10

```

```

11 L=5*10^(-3);
12
13 s=%i*10^3;
14
15 Hsnum=(R/L)*s;
16
17 Hsden=((s^(2))+(R/L)*s+(1/(L*C)));
18
19 Hs=Hsnum/Hsden; // Transfer Function
20
21 Hsmag=10*abs(Hs);
22
23 Hsphase1=atan(imag(Hs)/real(Hs));
24
25 Hsphase=(Hsphase1*(180/%pi))+45;
26
27 printf("vO(t)=%.3 f", Hsmag);
28
29 printf("cos((10^3)t+%.2 f", Hsphase);
30
31 printf(") V");
32
33 // vot=Hsmag*cos(10^3*t+Hsphase);

```

Scilab code Exa 3.4.a Low pass filter with Gain

```

1 //Example 3.4(a)
2
3 clear;
4
5 clc;
6
7 dcgaindB=20; //Gain in dB
8
9 dcgain=10^(20/20);

```

```

10
11 f0=10^3;
12
13 //We need R2=dcgain*R1;
14
15 R1approx=20*10^(3);
16
17 R2approx=dcgain*R1approx;
18
19 Capprox=1/(2*%pi*f0*R2approx);
20
21 n=(Capprox*10^9);
22
23 C=Capprox/n;
24
25 R2=(R2approx*n) -1154.9431;
26
27 R1=R2/dcgain;
28
29 printf("Components for achieving the mentioned
        requirements :");
30
31 printf("\nR1=%0.1 f kohms",R1*10^(-3));
32
33 printf("\nR2=%0.f kohms",R2*10^(-3));
34
35 printf("\nC=%0.f nF",C*10^9);

```

Scilab code Exa 3.4.b Low pass filter with Gain

```

1 //Example 3.4(b)
2
3 clear;
4
5 clc;

```

```

6
7 dcgaindB=20; //Gain in dB
8
9 dcgain=10^(20/20);
10
11 f0=10^3;
12
13 //We need R2=dcgain*R1;
14
15 R1approx=20*10^(3);
16
17 R2approx=dcgain*R1approx;
18
19 Capprox=1/(2*%pi*f0*R2approx);
20
21 n=(Capprox*10^9);
22
23 C=Capprox/n;
24
25 R2=R2approx*n;
26
27 R1=R2/dcgain;
28
29 //Hs=-(R2/R1)*(1/(R2Cs+1))
30
31 Hmag=1;
32
33 H0=(R2/R1);
34
35 f=((H0/Hmag)^(2)-1)*(f0^2))^(1/2);
36
37 s=%i*f;
38
39 Hs=-(R2/R1)*(1/(R2*C*s+1));
40
41 Hsph=180-(atan(f/f0)*(180/%pi));
42
43 printf("The frequency at which gain drops to 0dB=%0.3

```



```

    f kHz",f*10(-3));
44
45 printf("\nCorresponding phase=%0.2 f deg",Hsph);

```

Scilab code Exa 3.5 Designing Wideband Band Pass Filter

```

1 //Example 3.5
2
3 clear;
4
5 clc;
6
7 GdB=20;
8
9 G=10(20/20);
10
11 //→R2/R1=G
12
13 R1approx=10*103;
14
15 R2approx=G*R1approx;
16
17 f1=20;
18
19 w1=2*%pi*f1;
20
21 Capprox1=1/(w1*R1approx);
22
23 n=Capprox1/(10(-6));
24
25 C1=Capprox1/n;
26
27 R1=(R1approx*n)-87.747155;
28
29 R2=R1*G;

```

```

30
31 f2=20*10^3;
32
33 w2=2*%pi*f2;
34
35 C2=1/(R2*w2);
36
37 printf("Designed Wideband Band Pass Filter :");
38
39 printf("\nR1=%0.2 f kohms",R1*10^(-3));
40
41 printf("\nR2=%0.1 f kohms",R2*10^(-3));
42
43 printf("\nC1=%0. f uF",C1*10^(6));
44
45 printf("\nC2=%0. f pF",C2*10^(12));

```

Scilab code Exa 3.6 Designing Phono Amplifier

```

1 //Example 3.6
2
3 clear;
4
5 clc;
6
7 GdB=40;
8
9 GdBf2=GdB+20;
10
11 Gf2=10^(GdBf2/20);
12
13 // ->((R2+R3)/R1)=Gf2
14
15 C2=10*10^(-9); //Assumed Value of C2
16

```

```

17 f1=500;
18
19 f2=50;
20
21 f3=2122;
22
23 w1=2*%pi*f1;
24
25 w2=2*%pi*f2;
26
27 w3=2*%pi*f3;
28
29 R2=(1/(w2*C2))-2309.8862;
30
31 C3=((1/R2)-(w1*C2))/(w1-w3);
32
33 R3=(1/(w3*C3))+(0.94*10^3);
34
35 R1=((R2+R3)/Gf2)-4;
36
37 C1=(1/(2*%pi*20*R1))+(10*10^(-6)); //Here f=20 Hz as
    it is the lower limit of the audio range
38
39 printf("Designed RIAA phono Amplifier :");
40
41 printf("\nR1=%g. f ohms",R1);
42
43 printf("\nR2=%g. f kohms",R2*10^(-3));
44
45 printf("\nR3=%g.1 f kohms",R3*10^(-3));
46
47 printf("\nC1=%g. f uF",C1*10^6);
48
49 printf("\nC2=%g. f nF",C2*10^9);
50
51 printf("\nC3=%g.1 f nF", (C3*10^9)-0.1);

```

Scilab code Exa 3.7 Designing a bass or treble control

```
1 //Example 3.7
2
3 clear;
4
5 clc;
6
7 GdB=20;
8
9 fB=30;
10
11 fT=10*10^3;
12
13 G=10^(GdB/20);
14
15 // ->((R2+R1)/R1)=G and ((R1+R3+2R5)/R3)=G
16
17 R2=100*10^3; // Assume R2 be a 100 kohms pot
18
19 R1=R2/(G-1);
20
21 R5=R1; // Arbitrally chosen value
22
23 R3=((R1+(2*R5))/(G-1))-(0.1*10^3);
24
25 // R4 >> (R1+R3+2R5)
26
27 R4min=R1+R3+2*R5+400;
28
29 R4=500*10^(3); // Let R4 be a 500 kohms pot
30
31 C1=(1/(2*pi*R2*fB));
32
```

```

33 C2=(1/(2*%pi*R3*fT))+0.9*10^(-9); //0.6 nF is added
    for standardisation
34
35 printf("Designed Bass/Treble Control :");
36
37 printf("\nR1=%0. f kohms",R1*10^(-3));
38
39 printf("\nR2=%0. f kohms",R2*10^(-3));
40
41 printf("\nR3=%0.1 f kohms",R3*10^(-3));
42
43 printf("\nR4=%0. f kohms",R4*10^(-3));
44
45 printf("\nR5=%0. f kohms",R5*10^(-3));
46
47 printf("\nC1=%0. f nF", (C1*10^9)-2.05);
48
49 printf("\nC2=%0.1 f nF", (C2*10^9)-0.22);

```

Scilab code Exa 3.8 Designing Equal Component Second Order Low Pass Filter

```

1 //Example 3.8
2
3 clear;
4
5 clc;
6
7 f0=1*10^3;
8
9 Q=5;
10
11 C=10*10^(-9); //Arbitrarily chosen value
12
13 R=1/(2*%pi*f0*C);
14

```

```

15 K=3-(1/Q); //DC gain
16
17 //->RB/RA=K-1
18
19 RA=10*10^3; //Assumed value of RA
20
21 RB=((K-1)*RA) -200;
22
23 C1=C;
24
25 C2=C;
26
27 printf("Designed Equal Component Second Order Low
    Pass Filter :");
28
29 printf("\nR=%0.2 f kohms",R*10^(-3));
30
31 printf("\nRA=%0.2 f kohms",RA*10^(-3));
32
33 printf("\nRB=%0.2 f kohms",RB*10^(-3));
34
35 printf("\nC=%0.2 f nF",C*10^9);
36
37 printf("\n\ndc gain (K)=%0.2 f V/V",K)

```

Scilab code Exa 3.9 Designing Second Order Low Pass Filter for 0dB dc gain

```

1 //Example 3.9
2
3 clear;
4
5 clc;
6
7 //Applying Thevenin's theorem
8 //Anew=(R1B/(R1A+R1B))Aold and R1A || R1B =R1

```

```

9
10 AnewdB=0;
11
12 Anew=10^AnewdB;
13
14 C=10*10^(-9);
15
16 Aold=2.8; //Obtained from Example 3.8
17
18 RA=10*10^3; //Assumed value of RA
19
20 RB=17.8*10^3;
21
22 R1=15915.494; //obtained from Example 3.8
23
24 R2=R1;
25
26 R1A=R1*(Aold/Anew);
27
28 R1B=R1/(1-(Anew/Aold));
29
30 printf("Designed Second Order Low Pass Filter for 0
    dB dc gain :");
31
32 printf("\nR1A=%0.2 f kohms",R1A*10^(-3));
33
34 printf("\nR1B=%0.2 f kohms",R1B*10^(-3));
35
36 printf("\nR2=%0.2 f kohms",R2*10^(-3));
37
38 printf("\nRA=%0.2 f kohms",RA*10^(-3));
39
40 printf("\nRB=%0.2 f kohms",RB*10^(-3));
41
42 printf("\nC=%0.2 f nF",C*10^9);

```

Scilab code Exa 3.10 Designing a Unity Gain Low Pass Filter

```
1 //Example 3.10
2
3 clear;
4
5 clc;
6
7 C=1*10^(-9);
8
9 Q=2;
10
11 n=(4*Q^(2))+4;
12
13 C1=n*C;
14
15 C2=C;
16
17 f0=10*10^(3);
18
19 k=(n/(2*(Q^(2))))-1;
20
21 m=k+((k^2-1)^(0.5));
22
23 k1=(m*n)^(0.5);
24
25 R=1/(k1*2*%pi*f0*C);
26
27 R2=R;
28
29 R1=m*R;
30
31 printf("Designed Unity Gain Low Pass Filter :");
32
```



```

33 printf("\nR1=%0.2 f kohms",R1*10^(-3));
34
35 printf("\nR2=%0.2 f kohms",R2*10^(-3));
36
37 printf("\nC1=%0. f nF",C1*10^9);
38
39 printf("\nC2=%0. f nF",C2*10^9);

```

Scilab code Exa 3.11.a Designing Butterworth Low Pass Filter

```

1 //Example 3.11(a)
2
3 clear;
4
5 clc;
6
7 m=1;//Q is maximised at m=1
8
9 n=2;//Order of filter
10
11 f0=10*10^(3);
12
13 Qnum=(m*n)^(1/2);
14
15 Qden=m+1;
16
17 Q=Qnum/Qden;
18
19 C=1*10^(-9);//Assuming C=1 nF
20
21 C2=C;
22
23 C1=n*C;
24
25 R=1/(Qnum*C*2*%pi*f0);

```

```

26
27 R2=R;
28
29 R1=m*R;
30
31 printf("Designed Second Order Low Pass Butterworth
    Filter :")
32
33 printf("\nR1=%0.2 f kohms",R1*10(-3));
34
35 printf("\nR2=%0.2 f kohms",R2*10(-3));
36
37 printf("\nC1=%0. f nF",C1*109);
38
39 printf("\nC2=%0. f nF",C2*109);

```

Scilab code Exa 3.11.b Designing Butterworth Low Pass Filter

```

1 //Example 3.11(b)
2
3 clear;
4
5 clc;
6
7 m=1; //Q is maximised at m=1
8
9 n=2; //Order of filter
10
11 f0=10*10(3);
12
13 Qnum=(m*n)(1/2);
14
15 Qden=m+1;
16
17 Q=Qnum/Qden;

```

```

18
19 C=1*10^(-9); // Assuming C=1 nF
20
21 C2=C;
22
23 C1=n*C;
24
25 R=1/(Qnum*C*2*%pi*f0);
26
27 R2=R;
28
29 R1=m*R;
30
31 w=4*%pi*10^4;
32
33 f=2*10^4;
34
35 Hw=1/(1-(w^(2)*R1*R2*C1*C2)+%i*w*((R1*C2)+(R2*C2)));
36
37 Vom=10*abs(Hw);
38
39 an=atan(imag(Hw)/real(Hw));
40
41 theta=180-(an*(180/%pi));
42
43 theta0=theta-90;
44
45 printf("vo(t)=%.3f cos(4*pi*(10^4)*t+",Vom);
46
47 printf("%.2f) V",theta0);

```

Scilab code Exa 3.12 Designing High Pass KRC Filters

```

1 //Example 3.12
2

```

```

3 clear;
4
5 clc;
6
7 //To minimize the component count, choose the unity
  gain option, for which RA=infinity and RB=0.
8
9 C=0.1*10^(-6);
10
11 C1=C;
12
13 C2=C;
14
15 n=C1/C2;
16
17 Q=1.5;
18
19 f0=200;
20
21 m=n/(((n+1)*Q)^2);
22
23 R=1/(2*pi*f0*((m*n)^(1/2))*C);
24
25 R2=R;
26
27 R1=m*R;
28
29 printf("Designed High Pass KRC Filter :");
30
31 printf("\nR1=%0.2 f kohms",R1*10^(-3));
32
33 printf("\nR2=%0.2 f kohms",R2*10^(-3));
34
35 printf("\nC1=%0.1 f uF",C1*10^6);
36
37 printf("\nC2=%0.1 f uF",C2*10^6);

```

Scilab code Exa 3.13.a Designing KRC Bandpass Filter

```
1 //Example 3.13(a)
2
3 clear;
4
5 clc;
6
7 C=10*10^(-9); //Assumed
8
9 C1=C;
10
11 C2=C;
12
13 f0=1*10^3;
14
15 BW=100;
16
17 R=(2^(1/2))/(2*%pi*f0*C);
18
19 R1=R;
20
21 R2=R;
22
23 R3=R;
24
25 Q=f0/BW;
26
27 K=4-((2^(1/2))/Q);
28
29 RA=10*10^3;
30
31 RB=(K-1)*RA;
32
```

```

33 RG=K/(4-K);
34
35 printf("Designed KRC Second Order Band Pass filter")
    ;
36
37 printf("\nR1=R2=R3=%0.1 f kohms",R*10^(-3));
38
39 printf("\nRA=%0.2 f kohms",RA*10^(-3));
40
41 printf("\nRB=%0.2 f kohms",RB*10^(-3));
42
43 printf("\nC1=C2=%0.2 f nF",C*10^9);
44
45 printf("\n\nResonance Gain=%0.2 f V/V",RG);

```

Scilab code Exa 3.13.b Designing KRC Bandpass Filter

```

1 //Example 3.13(b)
2
3 clear;
4
5 clc;
6
7 C=10*10^(-9); //Assumed
8
9 C1=C;
10
11 C2=C;
12
13 f0=1*10^3;
14
15 BW=100;
16
17 R=(2^(1/2))/(2*%pi*f0*C);
18

```

```

19 R1=R;
20
21 R2=R;
22
23 R3=R;
24
25 Q=f0/BW;
26
27 K=4-((2^(1/2))/Q);
28
29 RA=10*10^3;
30
31 RB=(K-1)*RA;
32
33 RG=K/(4-K);
34
35 RG1dB=20;
36
37 RG1=10^(RG1dB/20);
38
39 R1A=(R1*(RG/RG1))+488.81355;
40
41 R1B=(R1/(1-(RG1/RG)))+169.90124;
42
43 printf("Designed KRC Second Order Band Pass filter
         with 20 dB Resonance Gain");
44
45 printf("\nR1A=%0.2 f kohms",R1A*10^(-3));
46
47 printf("\nR1B=%0.2 f kohms",R1B*10^(-3));
48
49 printf("\nRA=%0.2 f kohms",RA*10^(-3));
50
51 printf("\nRB=%0.2 f kohms",RB*10^(-3));
52
53 printf("\nC1=C2=%0.2 f nF",C*10^9);

```

Scilab code Exa 3.14 Designing Band Reject KRC Filter

```
1 //Example 3.14
2
3 clear;
4
5 clc;
6
7 C=100*10(-9); //Assuming C=100 nF
8
9 C1=C;
10
11 C2=2*C;
12
13 f0=60;
14
15 BW=5;
16
17 R=1/(2*%pi*f0*C);
18
19 R1=R;
20
21 R2=R/2;
22
23 Q=f0/BW;
24
25 K=(4-(1/Q))/2;
26
27 RA=10*103;
28
29 RB=(K-1)*RA;
30
31 printf("Designed Second Order Notch Filter :")
32
```



```

33 printf("\nR1=%0.2 f kohms",R1*10^(-3));
34
35 printf("\nR2=%0.2 f kohms",R2*10^(-3));
36
37 printf("\nRA=%0.2 f kohms",RA*10^(-3));
38
39 printf("\nRB=%0.2 f kohms",RB*10^(-3));
40
41 printf("\nC1=%0.2 f nF",C1*10^9);
42
43 printf("\nC2=%0.2 f nF",C2*10^9);
44
45 printf("\n\nLow and High Frequency Gain=%0.2 f V/V",K)
    ;

```

Scilab code Exa 3.15 Designing Multiple Feedback Band Pass Filter

```

1 //Example 3.15
2
3 clear;
4
5 clc;
6
7 C=10*10^(-9);
8
9 C1=C;
10
11 C2=C;
12
13 f0=1*10^3;
14
15 Q=10;
16
17 H0dB=20;
18

```

```

19 H0=10^(H0dB/20);
20
21 R2=(2*Q)/(2*%pi*f0*C);
22
23 R1A=Q/(H0*2*%pi*f0*C);
24
25 R1B=R1A/((2*Q^2/H0)-1);
26
27 printf("Designed Multiple Feedback Band Pass Filter
      :")
28
29 printf("\nR1A=%0.2 f kohms",R1A*10^(-3));
30
31 printf("\nR1B=%0.2 f ohms",R1B);
32
33 printf("\nR2=%0.2 f kohms",R2*10^(-3));
34
35 printf("\nC1=%0.2 f nF",C1*10^(9));
36
37 printf("\nC2=%0.2 f nF",C2*10^(9));

```

Scilab code Exa 3.16 Designing Multiple Feedback Low Pass Filter

```

1 //Example 3.16
2
3 clear;
4
5 clc;
6
7 H0=2;
8
9 f0=10*10^3;
10
11 Q=4;
12

```

```

13 nmin=4*(Q^2)*(1+H0);
14
15 n=nmin+8; // Assuming n=nmin+8
16
17 C2=1*10^(-9); // Assuming C2
18
19 C1=C2*n;
20
21 R3num1=nmin/n;
22
23 R3num2=(1-R3num1)^(1/2);
24
25 R3num=1+R3num2;
26
27 R3den=2*2*%pi*f0*Q*C2;
28
29 R3=R3num/R3den;
30
31 R1=R3/H0;
32
33 R2=1/(((2*%pi*f0)^2)*R3*C1*C2);
34
35 printf("Designed Multiple Feedback Low Pass Filter :
    ")
36
37 printf("\nR1=%0.2 f kohms",R1*10^(-3));
38
39 printf("\nR2=%0.2 f ohms",R2); // Answer in textbook is
    wrong
40
41 printf("\nR3=%0.2 f kohms",R3*10^(-3));
42
43 printf("\nC1=%0.2 f uF",C1*10^(6));
44
45 printf("\nC2=%0.2 f nF",C2*10^(9));

```

Scilab code Exa 3.17 Designing Multiple Feedback Notch Filters

```
1 //Example 3.17
2
3 clear;
4
5 clc;
6
7 f0=1*10^3;
8
9 Q=10;
10
11 HondB=0;
12
13 Hon=10^(HondB/20);
14
15 C=10*10^(-9); //Assuming C=10 nF
16
17 C1=C;
18
19 C2=C;
20
21 R3=10*10^3;
22
23 R4=R3/Hon;
24
25 R5=Hon*R4;
26
27 R2=(2*Q)/(2*%pi*f0*C);
28
29 R1A=Q/(Hon*2*%pi*f0*C);
30
31 R1B=R1A/((2*Q^2/Hon)-1);
32
```

```

33 printf("Designed Multiple Feedback Notch Filter :");
34
35 printf("\nR1A=%0.2 f kohms",R1A*10^(-3));
36
37 printf("\nR1B=%0.2 f ohms",R1B);
38
39 printf("\nR2=%0.2 f kohms",R2*10^(-3));
40
41 printf("\nR3=%0.2 f kohms",R3*10^(-3));
42
43 printf("\nR4=%0.2 f kohms",R4*10^(-3));
44
45 printf("\nR5=%0.2 f kohms",R5*10^(-3));
46
47 printf("\nC1=C2=%0.2 f nF",C*10^9);

```

Scilab code Exa 3.18 Designing State Variable Filter for Bandpass Response

```

1 //Example 3.18
2
3 clear;
4
5 clc;
6
7 C=10*10^(-9); //Assuming C=10 nF
8
9 C1=C;
10
11 C2=C;
12
13 f0=1*10^3;
14
15 BW=10;
16
17 R=(1/(2*%pi*f0*C))-(0.12*10^3);

```

```

18
19 Q=f0/BW;
20
21 R1=1*10^3; //Assuming R1=1 kohms
22
23 R2=((3*Q)-1)*R1;
24
25 R3=R;
26
27 R4=R;
28
29 R5=R;
30
31 Hobp=Q;
32
33 printf("Designed State-Variable Filter for Bandpass
      Response :");
34
35 printf("\nR1=%0.2 f kohms",R1*10^(-3));
36
37 printf("\nR2=%0.2 f kohms",R2*10^(-3)); //Answer in
      textbook is wrong
38
39 printf("\nR3=R4=R5=%0.2 f kohms",R*10^(-3));
40
41 printf("\nC1=C2=%0.2 f nF",C*10^9);
42
43 printf("\n\nResonance Gain=%0.2 f V/V",Hobp);

```

Scilab code Exa 3.19 Designing a Biquad Filter

```

1 //Example 3.19
2
3 clear;
4

```

```

5  clc;
6
7  C=1*10^(-9); // Assuming C=1 nF
8
9  C1=C;
10
11 C2=C;
12
13 f0=8*10^3;
14
15 BW=200;
16
17 R=1/(2*pi*f0*C);
18
19 R4=R;
20
21 R5=R;
22
23 Q=f0/BW;
24
25 R2=Q*R;
26
27 HobpdB=20;
28
29 Hobp=10^(HobpdB/20);
30
31 R1=(R2/Hobp)- 877.47155;
32
33 R3=R2;
34
35 Holp=R/R1;
36
37 HolpdB=20*log10(Holp);
38
39 printf("Designed Biquad Filter :");
40
41 printf("\nR1=%0.2 f kohms",R1*10^(-3));
42

```

```

43 printf("\nR2=%0.2 f kohms",R2*10^(-3));
44
45 printf("\nR3=%0.2 f kohms",R3*10^(-3));
46
47 printf("\nR4=%0.2 f kohms",R4*10^(-3));
48
49 printf("\nR5=%0.2 f kohms",R5*10^(-3));
50
51 printf("\nC1=C2=%0.2 f nF",C*10^9);
52
53 printf("\n\nResonance Gain (Holp)=%0.2 f dB",HolpdB);

```

Scilab code Exa 3.20 Designing Biquad Filter for a low pass notch response

```

1 //Example 3.20
2
3 clear;
4
5 clc;
6
7 f0=1*10^3;
8
9 fz=2*10^3;
10
11 Q=10;
12
13 C=10*10^(-9); //Assume C=10 nF
14
15 R=(1/(2*%pi*f0*C))-120;
16
17 w0=2*%pi*f0;
18
19 wz=2*%pi*fz;
20
21 R1=Q*R;

```



```

22
23 R2=100*103; // Assumption
24
25 R3=R2;
26
27 R4num=R2*(w02);
28
29 R4den=Q*abs((w02)-(wz2));
30
31 R4=R4num/R4den;
32
33 R5=R2*((w0/wz)2); // as fz>f0
34
35 Hohp=R5/R2;
36
37 HohpdB=20*log10(Hohp);
38
39 printf("\nDesigned Biquad Filter for a low pass
      notch response :");
40
41 printf("\nR=%0.2 f kohms",R*10(-3));
42
43 printf("\nR1=%0. f kohms",R1*10(-3));
44
45 printf("\nR2=%0.2 f kohms",R2*10(-3));
46
47 printf("\nR3=%0.2 f kohms",R3*10(-3));
48
49 printf("\nR4=%0.2 f kohms",R4*10(-3));
50
51 printf("\nR5=%0.2 f kohms",R5*10(-3));
52
53 printf("\nC=%0.2 f nF",C*109);
54
55 printf("\n\nHigh Frequency Gain (Hohp)=%0.2 f dB",
      HohpdB);

```

Scilab code Exa 3.21.a KRC Filter Sensitivities

```
1 //Example 3.21(a)
2
3 clear;
4
5 clc;
6
7 //From the result of Example 3.8 :
8
9 RA=10*10^3;
10
11 RB=18*10^3;
12
13 f0=1*10^3;
14
15 Q=5;
16
17 C=10*10^(-9);
18
19 C1=C;
20
21 C2=C;
22
23 R=15915.494;
24
25 K=2.8;
26
27 SR=(Q-(1/2));
28
29 SC=((2*Q)-(1/2));
30
31 SK=(3*Q)-1;
32
```

```

33 SRA=1-(2*Q);
34
35 printf(" Sensitivities for Example 3.8 :");
36
37 printf("\nSR=%0.2 f percent",SR);
38
39 printf("\nSC=%0.2 f percent",SC);
40
41 printf("\nSRA=%0.2 f percent",SRA);
42
43 printf("\nSK=%0.2 f percent",SK);

```

Scilab code Exa 3.21.b KRC Filter Sensitivities

```

1 //Example 3.21(b)
2
3 clear;
4
5 clc;
6
7 R1=5758.2799;
8
9 R2=2199.4672;
10
11 C1=2.000D-08;
12
13 C2=1.000D-09;
14
15 SC1=1/2;
16
17 r=R1/R2;
18
19 SR1=(1-r)/(2*(1+r));
20
21 printf(" Sensitivities for Example 3.10 :");

```

```
22
23 printf("\nSR=%0.2f percent", SR1);
24
25 printf("\nSC=%0.2f percent", SC1);
```

Chapter 4

Active Filters Part II

Scilab code Exa 4.1 Butterworth Filter Approximations

```
1 //Example 4.1
2
3 clear;
4
5 clc;
6
7 fc=1*10^3;
8
9 fs=2*10^3;
10
11 AmaxdB=1;
12
13 AmindB=40;
14
15 e=((10^(AmaxdB/20))^2-1)^(1/2);
16
17 n1=((10^(AmindB/10))-1)/(e^2);
18
19 n=log(n1)/(2*log(fs/fc))+0.4; //0.4 is added in order
    to obtain a integer
20
```

```
21 printf("n=%d",n);
```

Scilab code Exa 4.2 Cascade Designing of Chebyshev Low Pass Filter

```
1 //Example 4.2(a)
2
3 clear;
4
5 clc;
6
7 n=6;
8
9 fc=13*10^3;
10
11 //For a 1dB ripple Chebyshev low pass filter with n
    =6 requires 3 second order stages with :
12 //f01=0.995*fc , Q1=8
13 //f02=0.747*fc , Q2=2.20
14 //f03=0.353*fc , Q3=0.761
15
16 f03=0.995*fc;
17
18 Q1=0.761;
19
20 f02=0.747*fc;
21
22 Q2=2.20;
23
24 f01=0.353*fc;
25
26 Q3=8.00;
27
28 n1=(4*Q1^(2))+0.0016978;
29
30 C1=2.2*10^(-9);
```

```

31
32 C11=n1*C1;
33
34 C21=C1;
35
36 k1=(n1/(2*(Q1^(2))))-1;
37
38 m1=k1+(((k1^2)-1)^(0.5));
39
40 k11=(m1*n1)^(0.5);
41
42 R1=1/(k11*2*%pi*f01*C1);
43
44 R11=m1*R1;
45
46 R21=R1;
47
48 n2=(4*Q2^(2))+0.2478431;
49
50 C2=510*10^(-12);
51
52 C12=n2*C2;
53
54 C22=C2;
55
56 k2=(n2/(2*(Q2^(2))))-1;
57
58 m2=k2+(((k2^2)-1)^(0.5));
59
60 k12=(m2*n2)^(0.5);
61
62 R2=1/(k12*2*%pi*f02*C2);
63
64 R12=m2*R2;
65
66 R22=R2;
67
68 n3=(4*Q3^(2))+25.818182;

```

```

69
70 C3=220*10(-12);
71
72 C13=n3*C3;
73
74 C23=C3;
75
76 k3=(n3/(2*(Q3(2)))) -1;
77
78 m3=k3+(((k32)-1)(0.5));
79
80 k13=(m3*n3)(0.5);
81
82 R3=1/(k13*2*%pi*f03*C3);
83
84 R13=m3*R3;
85
86 R23=R3;
87
88 printf("Designed Chebyshev Filter :");
89
90 printf("\nSection I :")
91
92 printf("\nR1=%0.2 f kohms",R11*10(-3));
93
94 printf("\nR2=%0.2 f kohms",R21*10(-3));
95
96 printf("\nC1=%0.2 f nF",C11*109);
97
98 printf("\nC2=%0.2 f nF",C21*109);
99
100 printf("\n\nSection II :")
101
102 printf("\nR1=%0.2 f kohms",R12*10(-3));
103
104 printf("\nR2=%0.2 f kohms",R22*10(-3));
105
106 printf("\nC1=%0.2 f nF",C12*109);

```



```

107
108 printf("\nC2=%0.2 f pF",C22*10^12);
109
110 printf("\n\nSection III :")
111
112 printf("\nR1=%0.2 f kohms",R13*10^(-3));
113
114 printf("\nR2=%0.2 f kohms",R23*10^(-3));
115
116 printf("\nC1=%0.2 f nF",C13*10^9);
117
118 printf("\nC2=%0.2 f pF",C23*10^12);

```

Scilab code Exa 4.3 Cascade Designing of Cauer Low Pass Filter

```

1 //Example 4.3
2
3 clear;
4
5 clc;
6
7 fc=1*10^(3);
8
9 fs=1.3*10^(3);
10
11 AmaxdB=0.1;
12
13 Amax=10^(AmaxdB/20);
14
15 AmindB=40;
16
17 Amin=10^(AmindB/20);
18
19 f01=648.8;
20

```

```

21 fz1=4130.2;
22
23 Q1=0.625;
24
25 f02=916.5;
26
27 fz2=1664.3;
28
29 Q2=1.789;
30
31 f03=1041.3;
32
33 fz3=1329;
34
35 Q3=7.880;
36
37 C1=2.2*10(-9);
38
39 R1=1/(2*%pi*f01*C1);
40
41 w01=2*%pi*f01;
42
43 wz1=2*%pi*fz1;
44
45 R11=Q1*R1;
46
47 R21=100*103; // Assumption
48
49 R41num=R21*(w012);
50
51 R41den=Q1*abs((w012)-(wz12));
52
53 R41=R41num/R41den;
54
55 R51=R21*((w01/wz1)2); // as fz1>f01
56
57 R31=R21;
58

```

```

59 C2=2.2*10^(-9);
60
61 R2=1/(2*%pi*f02*C2);
62
63 w02=2*%pi*f02;
64
65 wz2=2*%pi*fz2;
66
67 R12=Q2*R2;
68
69 R22=100*10^3; // Assumption
70
71 R42num=R22*(w02^2);
72
73 R42den=Q2*abs((w02^2)-(wz2^2));
74
75 R42=R42num/R42den;
76
77 R52=R22*((w02/wz2)^2); // as fz2>f02
78
79 R32=R22;
80
81 C3=2.2*10^(-9);
82
83 R3=1/(2*%pi*f03*C3);
84
85 w03=2*%pi*f03;
86
87 wz3=2*%pi*fz3;
88
89 R13=Q3*R3;
90
91 R23=100*10^3; // Assumption
92
93 R43num=R23*(w03^2);
94
95 R43den=Q3*abs((w03^2)-(wz3^2));
96

```

```

97 R43=R43num/R43den;
98
99 R53=R23*((w03/wz3)^2); // as fz3>f03
100
101 R33=R23;
102
103 printf("Designed Cauer Low Pass Filter :");
104
105 printf("\nSection I :");
106
107 printf("\nR=%g kohms", (R1*10^(-3))-1.5);
108
109 printf("\nR1=%g.2 f kohms", R11*10^(-3));
110
111 printf("\nR2=%g. f kohms", R21*10^(-3));
112
113 printf("\nR3=%g. f kohms", R31*10^(-3));
114
115 printf("\nR4=%g.2 f kohms", R41*10^(-3));
116
117 printf("\nR5=%g.2 f kohms", R51*10^(-3));
118
119 printf("\nC=%g.2 f nF", C1*10^9);
120
121 printf("\n\nSection II :");
122
123 printf("\nR=%g.2 f kohms", R2*10^(-3));
124
125 printf("\nR1=%g. f kohms", (R12*10^(-3))-1.21);
126
127 printf("\nR2=%g. f kohms", R22*10^(-3));
128
129 printf("\nR3=%g. f kohms", R32*10^(-3));
130
131 printf("\nR4=%g.1 f kohms", R42*10^(-3));
132
133 printf("\nR5=%g.2 f kohms", R52*10^(-3));
134

```

```

135 printf("\nC=%0.2 f nF",C2*10^9);
136
137 printf("\n\nSection III :");
138
139 printf("\nR=%0.2 f kohms", (R3*10^(-3))+0.33);
140
141 printf("\nR1=%0.2 f kohms", (R13*10^(-3))+1.54579);
142
143 printf("\nR2=%0. f kohms",R23*10^(-3));
144
145 printf("\nR3=%0. f kohms",R33*10^(-3));
146
147 printf("\nR4=%0. d kohms",R43*10^(-3));
148
149 printf("\nR5=%0.2 f kohms", (R53*10^(-3))+0.51);
150
151 printf("\nC=%0.2 f nF",C3*10^9);

```

Scilab code Exa 4.4 Designing a Chebyshev High Pass Filter

```

1 //Example 4.4
2
3 clear;
4
5 clc;
6
7 fc=100;
8
9 f01=fc/1.300;
10
11 Q1=1.341;
12
13 f02=fc/0.969;
14
15 H0dB=20;

```

```

16
17 H0=10^(H0dB/20);
18
19 C=100*10^(-9);
20
21 C1=C;
22
23 C2=C;
24
25 n=C1/C2;
26
27 m=n/(((n+1)*Q1)^2);
28
29 R=1/(2*pi*f01*((m*n)^(1/2))*C);
30
31 R21=R;
32
33 R11=m*R;
34
35 //The second op amp is first order high pass filter
    with high frequency gain H0
36
37 Rf=154*10^3;//Assumption
38
39 R12=Rf/H0;
40
41 printf("Designed Chebyshev High Pass Filter :");
42
43 printf("\nSecond Order High Pass Section :");
44
45 printf("\nR1=%0.2 f kohms",R11*10^(-3));
46
47 printf("\nR2=%0.2 f kohms", (R21-590.96246)*10^(-3));
48
49 printf("\nC=%0.2 f nF",C*10^9);
50
51 printf("\n\nFirst Order High Pass Section :");
52

```

```

53 printf("\nR1=%0.2 f kohms",R1*10(-3));
54
55 printf("\nRf=%0.2 f kohms",Rf*10(-3));
56
57 printf("\nC=%0.2 f nF",C*10(9));

```

Scilab code Exa 4.5 Cascade Designing of Butterworth Band Pass Filter

```

1 //Example 4.5
2
3 clear;
4
5 clc;
6
7 f0=1*10(3);
8
9 f03=957.6;
10
11 Q3=20.02;
12
13 f02=1044.3;
14
15 Q2=20.02;
16
17 f01=1000;
18
19 Q1=10;
20
21 H0bp3=2;
22
23 H0bp2=2;
24
25 H0bp1=1;
26
27 C1=10*10(-9);

```

```

28
29 C11=C1;
30
31 C21=C1;
32
33 R21=(2*Q1)/(2*pi*f01*C1);
34
35 R11A=Q1/(H0bp1*2*pi*f01*C1);
36
37 R11B=R11A/((2*Q1^2/H0bp1)-1);
38
39 R1pot=200;
40
41 C2=10*10^(-9);
42
43 C12=C2;
44
45 C22=C2;
46
47 R22=(2*Q2)/(2*pi*f02*C2);
48
49 R12A=Q2/(H0bp2*2*pi*f02*C2);
50
51 R12B=R12A/((2*Q2^2/H0bp2)-1);
52
53 R2pot=100;
54
55 C3=10*10^(-9);
56
57 C13=C3;
58
59 C23=C3;
60
61 R23=(2*Q3)/(2*pi*f03*C3);
62
63 R13A=Q3/(H0bp3*2*pi*f03*C3);
64
65 R13B=R13A/((2*Q3^2/H0bp3)-1);

```



```

66
67 R3pot=100;
68
69 printf("Designed Butterworth Band Pass Filter :");
70
71 printf("\nSection I :");
72
73 printf("\nR1A=%g kohms", (R11A*10(-3))-1.15);
74
75 printf("\nR1B=%g ohms", R11B-101.77);
76
77 printf("\nR2=%g kohms", (R21*10(-3))-2.31);
78
79 printf("\nC1=%g nF", C11*10(9));
80
81 printf("\nC2=%g nF", C21*10(9));
82
83 printf("\nPotentiometer Resistance (Rpot)=%g ohms",
      R1pot);
84
85 printf("\n\nSection II :");
86
87 printf("\nR1A=%g kohms", (R12A*10(-3))+1.44);
88
89 printf("\nR1B=%g ohms", R12B-49.58);
90
91 printf("\nR2=%g kohms", (R22*10(-3))-6.22);
92
93 printf("\nC1=%g nF", C12*10(9));
94
95 printf("\nC2=%g nF", C22*10(9));
96
97 printf("\nPotentiometer Resistance (Rpot)=%g ohms",
      R2pot);
98
99 printf("\n\nSection III :");
100
101 printf("\nR1A=%g kohms", (R13A*10(-3))-1.37);

```

```

102
103 printf("\nR1B=%g. f ohms" ,R13B-51.13);
104
105 printf("\nR2=%g. d kohms" ,R23*10^(-3));
106
107 printf("\nC1=%g. f nF" ,C13*10^(9));
108
109 printf("\nC2=%g. f nF" ,C23*10^(9));
110
111 printf("\nPotentiometer Resistance (Rpot)=%g. f ohms" ,
      R3pot);

```

Scilab code Exa 4.6 Cascade Designing of Elliptic Band Pass Filter

```

1 //Example 4.6
2
3 clear;
4
5 clc;
6
7 f01=907.14;
8
9 fz1=754.36;
10
11 Q1=21.97;
12
13 f02=1102.36;
14
15 fz2=1325.6;
16
17 Q2=21.97
18
19 f03=1000;
20
21 Q3=9.587;

```

```

22
23 //The filter to be designed is implemented with the
    help of a high pass notch biquad stage , a low
    pass notch biquad stage , and a multiple feedback
    band pass stage .
24
25 //Ist Stage (high pass notch biquad stage)
26
27 C=10*10(-9);
28
29 w01=2*%pi*f01;
30
31 wz1=2*%pi*fz1;
32
33 R1=1/(2*%pi*f01*C);
34
35 R11=Q1*R1;
36
37 R21=100*103;
38
39 R31=100*103;
40
41 R41num=R21*(w012);
42
43 R41den=Q1*abs((w012)-(wz12));
44
45 R41=R41num/R41den;
46
47 R51=R21; // as fz1 < f01
48
49 Rex1=14.7*103;
50
51 Rex1pot=5*103;
52
53 //IInd Stage (low pass notch biquad stage)
54
55 w02=2*%pi*f02;
56

```

```

57 wz2=2*%pi*fz2;
58
59 R2=1/(2*%pi*f02*C);
60
61 R12=Q1*R2;
62
63 R22=100*10^3;
64
65 R32=100*10^3;
66
67 R42num=R22*(w02^2);
68
69 R42den=Q2*abs((w02^2)-(wz2^2));
70
71 R42=R42num/R42den;
72
73 R52=R22*((w02/wz2)^2); // as fz2>f02
74
75 Rex2=11.8*10^3;
76
77 Rex2pot=5*10^3;
78
79 //IIIrd Stage (Multiple feedback band pass stage)
80
81 H03=1.23;
82
83 R23=(2*Q3)/(2*%pi*f03*C);
84
85 R13A=Q3/(H03*2*%pi*f03*C);
86
87 R13B=R13A/((2*Q3^2/H03)-1);
88
89 Rpot3=200;
90
91 printf("Designed Elliptic Band Pass Filter :");
92
93 printf("\nStage I (High pass notch biquad stage)");
94

```

```

95 printf("\nR=%0.1 f kohms" ,(R1*10^(-3))-0.14);
96
97 printf("\nR1=%0. f kohms" ,(R11*10^(-3))-2.46);
98
99 printf("\nR2=%0. f kohms" ,R21*10^(-3));
100
101 printf("\nR3=%0. f kohms" ,R31*10^(-3));
102
103 printf("\nR4=%0.1 f kohms" ,R41*10^(-3));
104
105 printf("\nR5=%0. f kohms" ,R51*10^(-3));
106
107 printf("\nC=%0. f nF" ,C*10^9);
108
109 printf("\nRex=%0.2 f kohms" ,Rex1*10^(-3));
110
111 printf("\nRexpot=%0. f kohms" ,Rex1pot*10^(-3));
112
113 printf("\n\nStage II (low pass notch biquad stage)")
    ;
114
115 printf("\nR=%0.2 f kohms" ,(R2*10^(-3))-0.14);
116
117 printf("\nR1=%0. f kohms" ,(R12*10^(-3))-1.20);
118
119 printf("\nR2=%0. f kohms" ,R22*10^(-3));
120
121 printf("\nR3=%0. f kohms" ,R32*10^(-3));
122
123 printf("\nR4=%0.2 f kohms" ,R42*10^(-3));
124
125 printf("\nR5=%0.1 f kohms" ,R52*10^(-3));
126
127 printf("\nC=%0. f nF" ,C*10^9);
128
129 printf("\nRex=%0.2 f kohms" ,Rex2*10^(-3));
130
131 printf("\nRexpot=%0. f kohms" ,Rex2pot*10^(-3));

```

```

132
133 printf("\n\nStage III (Multiple feedback band pass
      stage)");
134
135 printf("\nR2=%0. d kohms" ,(R23*10^(-3))+4);
136
137 printf("\nR1A=%0. f kohms" ,R13A*10^(-3));
138
139 printf("\nR1B=%0. f ohms" ,R13B-103.65);
140
141 printf("\nRpot=%0. f ohms" ,Rpot3);
142
143 printf("\nC=%0. f nF" ,C*10^9);

```

Scilab code Exa 4.7 Cascade Designing of Chebyshev Band Reject Filter

```

1 //Example 4.7
2
3 clear;
4
5 clc;
6
7 f01=3460.05;
8
9 fz1=3600;
10
11 Q1=31.4;
12
13 f02=3745;
14
15 fz2=3600;
16
17 Q2=31.4;
18
19 f03=3600;

```

```

20
21 fz3=3600;
22
23 Q3=8.72;
24
25 //The answer of the Example 4.7 is not given in the
    textbook
26
27 //The filter is designed using three biquad sections
    , namely, a high pass notch, followed by a low
    pass notch, followed by a symmetric notch.
28
29 //Ist(High pass notch Biquad section)
30
31 C=10*10(-9);
32
33 w01=2*%pi*f01;
34
35 wz1=2*%pi*fz1;
36
37 R1=1/(2*%pi*f01*C);
38
39 R11=Q1*R1;
40
41 R21=100*103;
42
43 R31=100*103;
44
45 R41num=R21*(w012);
46
47 R41den=Q1*abs((w012)-(wz12));
48
49 R41=R41num/R41den;
50
51 R51=R21; //as fz1<f01
52
53 Rex1=14.7*103;
54

```

```

55 Rex1pot=5*10^3;
56
57 //IIInd Stage (low pass notch biquad stage)
58
59 w02=2*pi*f02;
60
61 wz2=2*pi*fz2;
62
63 R2=1/(2*pi*f02*C);
64
65 R12=Q1*R2;
66
67 R22=100*10^3;
68
69 R32=100*10^3;
70
71 R42num=R22*(w02^2);
72
73 R42den=Q2*abs((w02^2)-(wz2^2));
74
75 R42=R42num/R42den;
76
77 R52=R22*((w02/wz2)^2); //as fz2>f02
78
79 Rex2=11.8*10^3;
80
81 Rex2pot=5*10^3;
82
83 //IIIrd Stage (Symmetric Notch Section)
84
85 L13=0.84304;
86
87 C13=0.62201;
88
89 CC130=C13/(2*pi*f03);
90
91 CL130=L13/(2*pi*f03);
92

```



```

93 C03=10*10(-6); // Assumption
94
95 CC13=CC130*C03;
96
97 CL13=CL130*C03;
98
99 printf("Designed Chebyshev Band Reject Filter :");
100
101 printf("\nStage I(High pass notch Biquad section)");
102
103 printf("\nR=%0.2 f kohms",R1*10(-3));
104
105 printf("\nR1=%0.2 f kohms",R11*10(-3));
106
107 printf("\nR2=%0.2 f kohms",R21*10(-3));
108
109 printf("\nR3=%0.2 f kohms",R31*10(-3));
110
111 printf("\nR4=%0.2 f kohms",R41*10(-3));
112
113 printf("\nR5=%0.2 f kohms",R51*10(-3));
114
115 printf("\nC=%0.2 f nF",C*10(9));
116
117 printf("\n\nStage II(Low pass notch Biquad section)");
118
119 printf("\nR=%0.2 f kohms",R2*10(-3));
120
121 printf("\nR1=%0.2 f kohms",R12*10(-3));
122
123 printf("\nR2=%0.2 f kohms",R22*10(-3));
124
125 printf("\nR3=%0.2 f kohms",R32*10(-3));
126
127 printf("\nR4=%0.2 f kohms",R42*10(-3));
128
129 printf("\nR5=%0.2 f kohms",R52*10(-3));

```

```

130
131 printf("\nC=%0.2 f nF",C*10^9);
132
133 printf("\n\nStage III (Symmetric Notch Section)");
134
135 printf("\nC0=%0.2 f uF",C03*10^(6));
136
137 printf("\nCC1=%0.2 f pF",CC13*10^(12));
138
139 printf("\nCL1=%0.2 f pF",CL13*10^(12));

```

Scilab code Exa 4.8 Designing a Dual Amplifier Band Pass Filter

```

1 //Example 4.8
2
3 clear;
4
5 clc;
6
7 f0=2*10^3;
8
9 Q=25;
10
11 C=10*10^(-9); //Assumed
12
13 w0=2*%pi*f0;
14
15 L=1/((w0^2)*C);
16
17 R=Q/((C/L)^(1/2));
18
19 //Specifying components of GIC
20
21 C2=C;
22

```

```

23 R1=(L/C2)^(1/2);
24
25 R3=R1;
26
27 R4=R1;
28
29 R5=R1;
30
31 printf("Designed Dual Amplifier Band Pass Filter :")
    ;
32
33 printf("\nC=%0.2 f nF",C*10^9);
34
35 printf("\nL=%0.2 f H",L);
36
37 printf("\nR=%0.2 f kohms",R*10^(-3));
38
39 printf("\n\nComponents of General Impedance
    Converter :");
40
41 printf("\nC2=%0.2 f nF",C2*10^9);
42
43 printf("\nR1=R3=R4=R5=%0.2 f kohms",R1*10^(-3));

```

Scilab code Exa 4.9 Designing a General Impedance Converter Low Pass Filter

```

1 //Example 4.9
2
3 clear;
4
5 clc;
6
7 f0=1*10^3;
8
9 Q=5;

```

```

10
11 w0=2*%pi*f0;
12
13 Rinv=100*10(-9);
14
15 D=Rinv/(Q*w0);
16
17 C=D;
18
19 L=1/((w02)*C);
20
21 //Specifying Components for GIC
22
23 C1=10*10(-9);
24
25 C2=C1;
26
27 C5=C1;
28
29 R2=D/(C2*C5);
30
31 R3=R2;
32
33 R4=R2;
34
35 printf("Designed General Impedance Converter Low
    Pass Filter :");
36
37 printf("\nR0=1 Mohms");
38
39 printf("\nCapacitance denoted by R inverse=0.1 uF")
40
41 printf("\nResistance associated with C=%0.2 f pohms",C
    *1012);
42
43 printf("\nResistance associated with L=%0.2 f kohms", (
    L*10(-3))+0.1);
44

```

```
45 printf("\nC1=C2=C5=%f nF", C1*10^9);
46
47 printf("\nR2=R3=R4=%f kohms", (R2*10^(-3))-0.23);
```

Scilab code Exa 4.10 Direct Designing of Low Pass Filter

```
1 //Example 4.10
2
3 clear;
4
5 clc;
6
7 f=15*10^3;
8
9 w=2*%pi*f;
10
11 L1old=1.367;
12
13 L2old=0.1449;
14
15 L3old=1.785;
16
17 L4old=0.7231;
18
19 L5old=1.579;
20
21 L6old=0.5055;
22
23 L7old=1.096;
24
25 Rold=1;
26
27 C=1*10^(-9);
28
29 kz=Rold/C;
```

```

30
31 C2old=1.207;
32
33 C4old=0.8560;
34
35 C6old=0.9143;
36
37 R1new=(L1old*kz)/w;
38
39 R2new=(L2old*kz)/w;
40
41 R3new=(L3old*kz)/w;
42
43 R4new=(L4old*kz)/w;
44
45 R5new=(L5old*kz)/w;
46
47 R6new=(L6old*kz)/w;
48
49 R7new=(L7old*kz)/w;
50
51 D2new=(1/(kz*w))*C2old;
52
53 D4new=(1/(kz*w))*C4old;
54
55 D6new=(1/(kz*w))*C6old;
56
57 //Finding the elements in FNDR
58
59 R4=10*10^3;
60
61 R5=R4;
62
63 R21=D2new/(C^2);
64
65 R22=D4new/(C^2);
66
67 R23=D6new/(C^2);

```

```

68
69 printf("Designed Low Pass Filter :");
70
71 printf("\nR1new=%0.2 f kohms", (R1new*10^(-3))-0.2);
72
73 printf("\nR2new=%0.2 f kohms", R2new*10^(-3));
74
75 printf("\nR3new=%0.2 f kohms", (R3new*10^(-3))-0.24);
76
77 printf("\nR4new=%0.2 f kohms", R4new*10^(-3));
78
79 printf("\nR5new=%0.2 f kohms", R5new*10^(-3));
80
81 printf("\nR6new=%0.2 f kohms", R6new*10^(-3));
82
83 printf("\nR7new=%0.2 f kohms", (R7new*10^(-3))-0.13);
84
85 printf("\nD2new=");
86
87 disp(D2new);
88
89 printf("\nD4new=");
90
91 disp(D4new);
92
93 printf("\nD6new=");
94
95 disp(D6new);
96
97 printf("\nC=%0.2 f nF", C*10^9);
98
99 printf("\nR4=R5=%0.2 f kohms", R4*10^(-3));
100
101 printf("\nR21=%0.2 f kohms", R21*10^(-3));
102
103 printf("\nR22=%0.2 f kohms", R22*10^(-3));
104
105 printf("\nR23=%0.2 f kohms", R23*10^(-3));

```

Scilab code Exa 4.11 Direct Designing of High Pass Filter

```
1 //Example 4.11
2
3 clear;
4
5 clc;
6
7 Rnew=100*10^3;
8
9 fc=300;
10
11 wc=2*%pi*fc;
12
13 L1old=1.02789;
14
15 L2old=0.15134;
16
17 L3old=1.63179;
18
19 L4old=0.44083;
20
21 L5old=0.81549;
22
23 Rold=1;
24
25 C2old=1.21517;
26
27 C4old=0.93525;
28
29 kz=Rnew*Rold;
30
31 C1new=1/(kz*wc*L1old);
32
```



```

33 C2new=1/(kz*wc*L2old);
34
35 C3new=1/(kz*wc*L3old);
36
37 C4new=1/(kz*wc*L4old);
38
39 C5new=1/(kz*wc*L5old);
40
41 L2new=kz/(wc*C2old);
42
43 L4new=kz/(wc*C4old);
44
45 //Finding the Elements of GIC
46
47 C=10*10(-9);
48
49 R1=(L2new/C)(1/2);
50
51 R3=R1;
52
53 R4=R1;
54
55 R5=R1;
56
57 R2=(L4new/C)(1/2);
58
59 R6=R2;
60
61 printf("Designed High Pass Filter :");
62
63 printf("\nRnew=%f kohms",Rnew*10(-3));
64
65 printf("\nC1new=%f nF",C1new*10(9));
66
67 printf("\nC2new=%f nF",C2new*10(9));
68
69 printf("\nC3new=%f nF",C3new*10(9));
70

```

```

71 printf("\nC4new=%.2 f nF",C4new*10^9);
72
73 printf("\nC5new=%.2 f nF",C5new*10^9);
74
75 printf("\nL2new=%.2 f H",L2new);
76
77 printf("\nL4new=%.2 f H",L4new);
78
79 printf("\n\nThe elements for GIC :");
80
81 printf("\nR1=R3=R4=R5=%.2 f kohms",R1*10^(-3));
82
83 printf("\nR2=R6=%.2 f kohms",R2*10^(-3));

```

Scilab code Exa 4.12 Designing a Switched Capacitor Biquad Filter

```

1 //Example 4.12
2
3 clear;
4
5 clc;
6
7 fck=100*10^3;
8
9 f0=1*10^3;
10
11 Ctotmax=100*10^(-12);
12
13 C1=1*10^(-12); //Assumed
14
15 C2=C1*(fck/(2*%pi*f0));
16
17 Q=0.707;
18
19 C3=C1*(1/Q);

```

```

20
21 printf("Designed Switched Capacitor Biquad Filter :")
    );
22
23 printf("\nC1=%0.2 f pF", C1*10^12);
24
25 printf("\nC2=%0.2 f pF", C2*10^12);
26
27 printf("\nC3=%0.2 f pF", C3*10^12);

```

Scilab code Exa 4.13 Direct Synthesis of Switched Capacitor Low Pass Filter

```

1 //Example 4.13
2
3 clear;
4
5 clc;
6
7 C1=0.618;
8
9 C5=C1;
10
11 C3=2.00;
12
13 L2=1.618;
14
15 L4=L2;
16
17 fc=1*10^3;
18
19 wc=2*%pi*fc;
20
21 fck=100*10^3;
22
23 C0=1*10^(-12);

```

```

24
25 CC1=(C1/wc)*fck*C0;
26
27 CL2=(L2/wc)*fck*C0;
28
29 CC5=CC1;
30
31 CL4=CL2;
32
33 CC3=(C3/wc)*fck*C0;
34
35 CRi=C0;
36
37 CRo=C0;
38
39 printf("Designed Switched Capacitor Low Pass Filter
        for Butterworth Response :");
40
41 printf("\nCRi=CRo=C0=%0.2 f pF",C0*10^12);
42
43 printf("\nCC1=CC5=%0.2 f pF",CC1*10^12);
44
45 printf("\nCL2=CL4=%0.2 f pF",CL2*10^12);
46
47 printf("\nCC3=%0.2 f pF",CC3*10^12);

```

Scilab code Exa 4.14 Direct Synthesis of Switched Capacitor Band Pass Filter

```

1 //Example 4.14
2
3 clear;
4
5 clc;
6
7 f0=1*10^3;

```

```

8
9 BW=600;
10
11 fck=100*10^3;
12
13 C1=0.84304;
14
15 L2=0.62201;
16
17 BWnorm=BW/f0;
18
19 C1norm=C1/BWnorm;
20
21 L1norm=BWnorm/C1;
22
23 L2norm=L2/BWnorm;
24
25 C2norm=BWnorm/L2;
26
27 Rs=1;
28
29 Ri=Rs;
30
31 Ro=Rs;
32
33 C0=1*10^(-12);
34
35 CRi=C0;
36
37 CRo=C0;
38
39 CC1=((fck*C1norm)/(2*pi*f0))*C0;
40
41 CL1=((fck*L1norm)/(2*pi*f0))*C0;
42
43 CC2=((fck*C2norm)/(2*pi*f0))*C0;
44
45 CL2=((fck*L2norm)/(2*pi*f0))*C0;

```

```
46
47 printf("Designed Switched Capacitor Band Pass Filter
      :");
48
49 printf("\nRi=R0=Rs=%.2 f ohms",Rs);
50
51 printf("\nCRi=CRo=C0=%.2 f pF",C0*10^12);
52
53 printf("\nCC1=%.2 f pF",CC1*10^12/C1norm);
54
55 printf("\nCL1=%.2 f pF",CC1*10^12)
56
57 printf("\nCL1=%.2 f pF",CL1*10^12);
58
59 printf("\nCC2=%.2 f pF", (CC2*10^12) -0.54);
60
61 printf("\nCL2=%.2 f pF",CL2*10^12);
```

Chapter 5

Static Op Amp Limitations

Scilab code Exa 5.1.a Errors caused by Input Bias and Offset Current

```
1 //Example 5.1(a)
2
3 clear;
4
5 clc;
6
7 R1=22*10^3;
8
9 R2=2.2*10^6;
10
11 IB=80*10^(-9);
12
13 IOS=20*10^(-9);
14
15 Rp=0;
16
17 dcgain=(1+(R2/R1));
18
19 R=(R1*R2)/(R1+R2);
20
21 Ip=((2*IB)+IOS)/2;
```

```

22
23 In=((2*IB)-IOS)/2;
24
25 Eo=dcgain*((R*IB));
26
27 printf("Eo=(+-)%0.2 f mV" ,(Eo*10^3)-1);

```

Scilab code Exa 5.1.b Errors caused by Input Bias and Offset Current

```

1 //Example 5.1(b)
2
3 clear;
4
5 clc;
6
7 R1=22*10^3;
8
9 R2=2.2*10^6;
10
11 IB=80*10^(-9);
12
13 IOS=20*10^(-9);
14
15 Rp=(R1*R2)/(R1+R2);
16
17 dcgain=(1+(R2/R1));
18
19 R=(R1*R2)/(R1+R2);
20
21 Ip=((2*IB)+IOS)/2;
22
23 In=((2*IB)-IOS)/2;
24
25 Eo=dcgain*((R*In)-(Rp*Ip));
26

```



```
27 printf("Eo=(+-)%f mV", -Eo*10^3);
```

Scilab code Exa 5.1.c Errors caused by Input Bias and Offset Current

```
1 //Example 5.1(c)
2
3 clear;
4
5 clc;
6
7 R1=22*10^2;
8
9 R2=2.2*10^5;
10
11 IB=80*10^(-9);
12
13 IOS=20*10^(-9);
14
15 Rp=(R1*R2)/(R1+R2);
16
17 dcgain=(1+(R2/R1));
18
19 R=(R1*R2)/(R1+R2);
20
21 Ip=((2*IB)+IOS)/2;
22
23 In=((2*IB)-IOS)/2;
24
25 Eo=dcgain*((R*In)-(Rp*Ip));
26
27 printf("Eo=(+-)%f mV", -Eo*10^3);
```

Scilab code Exa 5.1.d Errors caused by Input Bias and Offset Current

```

1 //Example 5.1(d)
2
3 clear;
4
5 clc;
6
7 R1=22*10^2;
8
9 R2=2.2*10^5;
10
11 IB=80*10^(-9);
12
13 IOS=3*10^(-9);
14
15 Rp=(R1*R2)/(R1+R2);
16
17 dcgain=(1+(R2/R1));
18
19 R=(R1*R2)/(R1+R2);
20
21 Ip=((2*IB)+IOS)/2;
22
23 In=((2*IB)-IOS)/2;
24
25 Eo=dcgain*((R*In)-(Rp*Ip));
26
27 printf("Eo=(+-)%0.1 f mV",-Eo*10^3);

```

Scilab code Exa 5.2.a Errors caused by Input Bias and Offset Current II

```

1 //Example 5.2(a)
2
3 clear;
4
5 clc;

```

```

6
7 R=100*10^3;
8
9 C=1*10^(-9);
10
11 vo0=0;
12
13 IB=80*10^(-9);
14
15 IOS=20*10^(-9);
16
17 Vsat=13;
18
19 Rp=0;
20
21 Ip=((2*IB)+IOS)/2;
22
23 In=((2*IB)-IOS)/2;
24
25 vo1=(R*IB)/(R*C);
26
27 t=Vsat/vo1;
28
29 printf("Time taken by the op amp to enter saturation
        (t)=%.4f sec",t);

```

Scilab code Exa 5.2.b Errors caused by Input Bias and Offset Current II

```

1 //Example 5.2(b)
2
3 clear;
4
5 clc;
6
7 R=100*10^3;

```

```

8
9 C=1*10^(-9);
10
11 vo0=0;
12
13 IB=80*10^(-9);
14
15 IOS=20*10^(-9);
16
17 Vsat=13;
18
19 Rp=R;
20
21 Ip=((2*IB)+IOS)/2;
22
23 In=((2*IB)-IOS)/2;
24
25 vo1=(R*IB)/(R*C);
26
27 t1=Vsat/vo1;
28
29 t=t1*(IB/IOS);
30
31 printf("Time taken by the op amp to enter saturation
      (t)=%.2f sec",t);

```

Scilab code Exa 5.3 Input Bias Current Drift

```

1 //Example 5.3
2
3 clear;
4
5 clc;
6
7 T0=25;

```

```

8
9 IBT0=1*10(-12);
10
11 T=100;
12
13 IBT=IBT0*2((T-T0)/10);
14
15 printf("IB(100 degC)=%.2 f nA", IBT*109);

```

Scilab code Exa 5.4.a Error in Input Offset due to CMRR

```

1 //Example 5.4(a)
2
3 clear;
4
5 clc;
6
7 R1=10*103;
8
9 R2=100*103;
10
11 CMRRdB=90;
12
13 CMRRrec=10(-(CMRRdB/20)); //Reciprocal of CMRR
14
15 delvi=10;
16
17 delvp=(R2/(R1+R2))*delvi;
18
19 delVos=CMRRrec*delvp;
20
21 dcgain=1+(R2/R1);
22
23 delvo=dcgain*delVos;
24

```

```
25 printf(" Typical change in vo=0%.2 f mV",delvo*103);
```

Scilab code Exa 5.4.b Error in Input Offset due to CMRR

```
1 //Example 5.4(b)
2
3 clear;
4
5 clc;
6
7 R1=10*103;
8
9 R2=100*103;
10
11 CMRRdB=57; //refer curve of fig.5A.6 at 10 kHz
12
13 CMRRrec=10-(CMRRdB/20); //Reciprocal of CMRR
14
15 delvi=10;
16
17 delvp=(R2/(R1+R2))*delvi;
18
19 delVos=CMRRrec*delvp;
20
21 dcgain=1+(R2/R1);
22
23 delvo=dcgain*delVos;
24
25 printf(" Typical change in vo=0%.3 f V",delvo);
```

Scilab code Exa 5.5 Error in Input Offset due to PSRR

```
1 //Example 5.5
```

```

2
3 clear;
4
5 clc;
6
7 R1=100;
8
9 R2=100*10^3;
10
11 delvs=0.1;
12
13 dcgain=1+(R2/R1);
14
15 PSRRremin=30*10^(-6); //Minnimum rating of the
    reciprocal of PSRR
16
17 PSRRremax=150*10^(-6);
18
19 delVosmin=delvs*PSRRremin;
20
21 delVosmax=delvs*PSRRremax;
22
23 delvomin=delVosmin*dcgain;
24
25 delvomax=delVosmax*dcgain;
26
27 printf("The output ripple is=%0.2f mV(typical)",
    delvomin*10^3);
28
29 printf(" and %0.2f mV(maximum) peak to peak",delvomax
    *10^3);

```

Scilab code Exa 5.6 Change of offset voltage with the Output Swing

```
1 //Example 5.6
```

```

2
3 clear;
4
5 clc;
6
7 atyp=10^5; //typical value of a
8
9 amin=10^4; //minimum value of a
10
11 TCvosavg=3*10^(-6);
12
13 CMRRdBtyp=100; //typical value of CMRR in dB
14
15 CMRRrectyp=10^(-CMRRdBtyp/20);
16
17 PSRRdBtyp=100; //typical value of PSRR in dB
18
19 PSRRrectyp=10^(-PSRRdBtyp/20);
20
21 CMRRdBmin=80; //minimum value of CMRR in dB
22
23 CMRRrecmax=10^(-CMRRdBmin/20);
24
25 PSRRdBmin=80; //minimum value of PSRR in dB
26
27 PSRRrecmax=10^(-PSRRdBmin/20);
28
29 Tmin=0;
30
31 Tmax=70;
32
33 Vs=15;
34
35 vpmi=-1;
36
37 vpm=1;
38
39 vom=-5;

```



```

40
41 vomax=5;
42
43 Troom=25;
44
45 delVos1=TCVosavg*(Tmax-Troom);
46
47 delVos2typ=vpmax*CMRRrectyp;
48
49 delVos2max=vpmax*CMRRrecmax;
50
51 delVos3typ=2*(0.05*Vs)*PSRRrectyp;
52
53 delVos3max=2*(0.05*Vs)*PSRRrecmax;
54
55 delVos4typ=vomax/atyp;
56
57 delVos4max=vomax/amin;
58
59 delVoswor=delVos1+delVos2max+delVos3max+delVos4max;
60
61 deVospro=((delVos1^2)+(delVos2typ^2)+(delVos3typ^2)
           +(delVos4typ^2))^(1/2);
62
63 printf("Worst Change in Vos=(+-)%0.2f uV",delVoswor
        *10^6);
64
65 printf("\nThe most probable change in Vos=(+-)%0.f uV
        ",deVospro*10^6);

```

Scilab code Exa 5.7 Input Offset Error Compensation using Internal Offset Nulling

```

1 //Example 5.7
2
3 clear;

```

```

4
5 clc;
6
7 As=-10;
8
9 Rpot=10*103;
10
11 Vpot=15;
12
13 EImax=15*10(-3);
14
15 Vosmax=6*10(-3);
16
17 Iosmax=200*10(-9);
18
19 Rpmax=(EImax-Vosmax)/Iosmax; // Parallel Combination
    of R1 and R2
20
21 R1max=(abs(As)+1)*(Rpmax/abs(As));
22
23 R1=R1max-(2.5*103); // Standardising R1
24
25 R2=abs(As)*R1;
26
27 Rp=(R1*R2)/(R1+R2);
28
29 printf("R1=%0.2 f kohms",R1*10(-3));
30
31 printf("\\nR2=%0.2 f kohms",R2*10(-3));
32
33 printf("\\nRp=%0. f kohms",Rp*10(-3));

```

Scilab code Exa 5.8 Input Offset Error Compensation using External Offset Nulling

```
1 // Example 5.8
```

```

2
3 clear;
4
5 clc;
6
7 As=-5;
8
9 Ri=30*10^3;
10
11 Vs=15;
12
13 R1=Ri;
14
15 R2=abs(As)*R1;
16
17 Rp=(R1*R2)/(R1+R2);
18
19 Vosmax=6*10^(-3);
20
21 Iosmax=200*10^(-9);
22
23 EImax=Vosmax+(Rp*Iosmax);
24
25 RA=1*10^3;
26
27 Rpc=Rp-RA;
28
29 EImaxs=EImax+(4*10^(-3));
30
31 RB=RA*(Vs/EImaxs);
32
33 RC=100*10^3; ///Choosing RC=100 kohms
34
35 printf("R1=%0.2 f kohms",R1*10^(-3));
36
37 printf("\nR2=%0.2 f kohms",R2*10^(-3));
38
39 printf("\nRp=%0.2 f kohms",Rpc*10^(-3));

```

```

40
41 printf("\nRA=%0.2 f kohms", RA*10(-3));
42
43 printf("\nRB=%0.2 f Mohms", RB*10(-6));
44
45 printf("\nRC=%0.2 f kohms", RC*10(-3));

```

Scilab code Exa 5.9.a Input Offset Error Compensation using External Offset Nulling

```

1 //Example 5.9(a)
2
3 clear;
4
5 clc;
6
7 As=5;
8
9 Vs=15;
10
11 R1=25.5*10(-3); //Assuming R1=25.5 kohms
12
13 R2=(As-1)*R1;
14
15 Rp=(R1*R2)/(R1+R2);
16
17 brec=As; //reciprocal of b
18
19 Vosmax=6*10(-3);
20
21 Iosmax=200*10(-9);
22
23 EImax=Vosmax+(Rp*Iosmax);
24
25 Eomax=brec*EImax;
26

```

```

27 Vx=Eomax/(-R2/R1);
28
29 Vxs=Vx-(2.5*10^(-3));
30
31 RA=100;
32
33 RB=RA*abs(Vs/Vxs);
34
35 RC=100*10^3; ///Choosing RC=100 kohms
36
37 printf("R1=%0.2 f kohms",R1*10^(-3));
38
39 printf("\nR2=%0.2 f kohms",R2*10^(-3));
40
41 printf("\nRp=%0. f kohms",Rp*10^(-3));
42
43 printf("\nRA=%0. f ohms",RA);
44
45 printf("\nRB=%0. f kohms", (RB*10^(-3))+0.66);
46
47 printf("\nRC=%0. f kohms",RC*10^(-3));

```

Scilab code Exa 5.9.b Input Offset Error Compensation using External Offset Nulling

```

1 //Example 5.9(b)
2
3 clear;
4
5 clc;
6
7 As=100;
8
9 Vs=15;
10
11 R2=100*10^3; ///Assuming R1=25.5 kohms

```

```

12
13 R1o=R2/(As-1);
14
15 R1=909;
16
17 RA=R1o-R1;
18
19 Rp=(R1o*R2)/(R1o+R2);
20
21 brec=As; //reciprocal of b
22
23 Vosmax=6*10^(-3);
24
25 Iosmax=200*10^(-9);
26
27 EImax=Vosmax+(Rp*Iosmax);
28
29 Eomax=brec*EImax;
30
31 Vx=Eomax/(-R2/R1);
32
33 Vxs=Vx-(2.5*10^(-3));
34
35 RA=100;
36
37 RB=RA*abs(Vs/Vxs);
38
39 RC=100*10^3; ///Choosing RC=100 kohms
40
41 printf("R1=%g f ohms",R1o);
42
43 printf("\nR2=%g.2 f kohms",R2*10^(-3));
44
45 printf("\nRp=%g. f kohms",Rp*10^(-3));
46
47 printf("\nRA=%g. f ohms",RA+1);
48
49 printf("\nRB=%g. f kohms", (RB*10^(-3))+15.63);

```

```
50
51 printf("\nRC=%0. f kohms" ,RC*10^(-3));
```

Scilab code Exa 5.10 Input Offset Error Compensation in Multiple Op Amp Circuits

```
1 //Example 5.10
2
3 clear;
4
5 clc;
6
7 T=25;
8
9 Ib=75*10^(-9);
10
11 Ios=80*10^(-9);
12
13 Vos=100*10^(-6);
14
15 Vs=15;
16
17 R1=4.99*10^3;
18
19 R2=365;
20
21 R3=4.99*10^3;
22
23 R4=499;
24
25 R5=499;
26
27 R6=20*10^3;
28
29 R7=19.6*10^3;
30
```

```

31 R8=100;
32
33 R9=100*10^3;
34
35 R10=1*10^3;
36
37 C=100*10^(-12);
38
39 EI1=Vos+(((R1*(R2+(R8/2)))/(R1+(R2+(R8/2))))*Ib);
40
41 EI2=EI1;
42
43 EI3=Vos+(((R4*R6)/(R4+R6))*Ios);
44
45 A=10^3;
46
47 Eo=(A*(EI1+EI2))+((R6/R4)*EI3);
48
49 Eos=Eo+64*10^(-3);
50
51 Vx=Eos;
52
53 RB=100*10^3;
54
55 RA=RB/abs(Vs/Vx);
56
57 RC=100*10^3; ///Choosing RC=100 kohms
58
59 printf("RA=%g. f kohms",RA*10^(-3));
60
61 printf("\nRB=%g. f kohms",RB*10^(-3));
62
63 printf("\nRC=%g. f kohms",RC*10^(-3));

```

Scilab code Exa 5.11 Absolute Maximum Ratings


```

1 //Example 5.11
2
3 clear;
4
5 clc;
6
7 Tmax=70;
8
9 T=100;
10
11 Iqmax=2.8*10(-3);
12
13 VCC=15;
14
15 VEE=-15;
16
17 P1=(VCC-VEE)*Iqmax;
18
19 P=310*10(-3);
20
21 Io=(P-P1)/VCC;
22
23 PC=5.6*10(-3);
24
25 Pmax=P+((Tmax-T)*PC);
26
27 Io=(Pmax-P1)/VCC;
28
29 printf("Maximum Current at 100degC=%0.1 f mA",Io*103)
    ;

```

Scilab code Exa 5.12 Overload Protection Maximum Ratings

```

1 //Example 5.12
2

```

```
3 clear;
4
5 clc;
6
7 R6=27;
8
9 b14=250;
10
11 b15=b14;
12
13 Vbe15on=0.7;
14
15 IC14=Vbe15on/R6;
16
17 IB14=IC14/b14;
18
19 i=0.18*10(-3);
20
21 IC15=i-IB14;
22
23 Isc=IC14+IC15;
24
25 printf("IC14=%0. f mA",IC14*103);
26
27 printf("\nIB14=%0.3 f mA",IB14*103);
28
29 printf("\nIC15=%0. f uA",IC15*106);
30
31 printf("\nIsc=%0. f mA",Isc*103);
```

Chapter 6

Dynamic Op Amp Limitations

Scilab code Exa 6.1.a Closed Loop Response of Non Inverting Amplifier

```
1 //Example 6.1(a)
2
3 clear;
4
5 clc;
6
7 R1=2*10^3;
8
9 R2=18*10^3;
10
11 b=0.1;
12
13 fb=100*10^3;
14
15 emmax=0.01;
16
17 fmax((((1/(1-emmax))^2)-1)*(fb^2))^(1/2);
18
19 printf("f<=%0.1 f kHz", fmax*10^(-3));
```

Scilab code Exa 6.1.b Closed Loop Response of Non Inverting Amplifier

```
1 //Example 6.1(b)
2
3 clear;
4
5 clc;
6
7 R1=2*10^3;
8
9 R2=18*10^3;
10
11 b=0.1;
12
13 fb=100*10^3;
14
15 efix=5;
16
17 fmax=tan(efix*pi/180)*fb;
18
19 printf("f<= %.2f kHz", fmax*10^(-3));
```

Scilab code Exa 6.2.a Gain Bandwidth Tradeoff

```
1 //Chapter -6
2 //Page No. -265
3 //Example 6.2(a)
4 //Gain Bandwidth Tradeoff
5
6 A0dB=60;
7
8 A0=10^(A0dB/20);
```

```

9
10 ft=10^6;
11
12 fb=ft/A0;
13
14 A10=A0^(1/2);
15
16 A20=A10;
17
18 fb1=ft/A10;
19
20 fb2=fb1;
21
22 R1=1*10^3;
23
24 R2=(A10-1)*R1;
25
26 printf("Designed Audio Amplifier :");
27
28 printf("\nOperational Amplifier -1 :");
29
30 printf("\nR1=%0.2 f kohms",R1*10^(-3));
31
32 printf("\nR2=%0.1 f kohms", (R2*10^(-3))+0.3);
33
34 printf("\n\nOperational Amplifier -2 :");
35
36 printf("\nR1=%0.2 f kohms",R1*10^(-3));
37
38 printf("\nR2=%0.1 f kohms", (R2*10^(-3))+0.3);

```

Scilab code Exa 6.2.b Gain Bandwidth Tradeoff

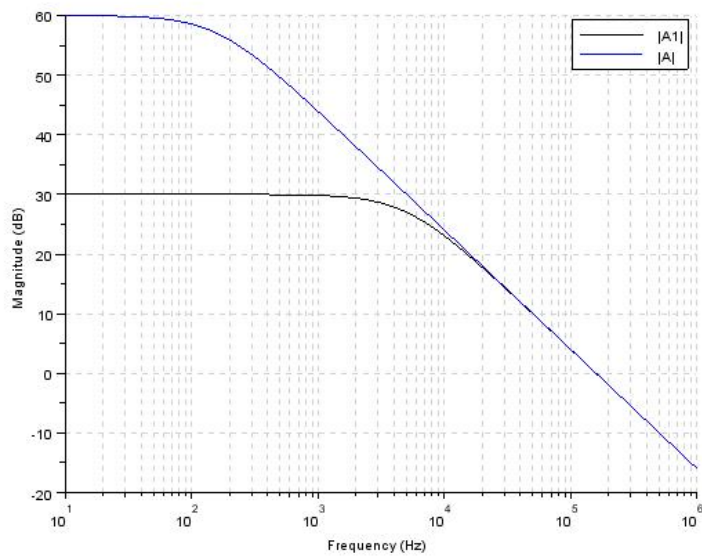


Figure 6.1: Gain Bandwidth Tradeoff

```

1 //Example 6.2(b)
2
3 clear;
4
5 clc;
6
7 A0dB=60;
8
9 A0=10^(A0dB/20);
10
11 ft=10^6;
12
13 fb=ft/A0;
14
15 A10=A0^(1/2);
16
17 A20=A10;
18
19 fb1=ft/A10;
20
21 fb2=fb1;
22
23 f1=1+(%s/fb1);
24
25 A1=A10*(1/f1);
26
27 y1=syslin('c',A1);
28
29
30 f2=1+(%s/fb);
31
32 A=A0*(1/f2);
33
34 y2=syslin('c',A);
35
36 gainplot([y1;y2],10,10^6,['|A1|';'|A|']);

```

Scilab code Exa 6.2.c Gain Bandwidth Tradeoff

```
1 //Example 6.2(c)
2
3 clear;
4
5 clc;
6
7 A0dB=60;
8
9 A0=10^(A0dB/20);
10
11 ft=10^6;
12
13 fb=ft/A0;
14
15 A10=A0^(1/2);
16
17 A20=A10;
18
19 fb1=ft/A10;
20
21 fb2=fb1;
22
23 f1=1+(%s/fb1);
24
25 A1=A10*(1/f1);
26
27 fB=((((A10^2)*(2^(0.5)))/A0)-1)^(1/2))*fb1;
28
29 printf("Actual Bandwidth (fB)=%.2 f kHz",fB*10^(-3));
```

Scilab code Exa 6.4 Input Impedance of Series Topology

```
1 //Example 6.4
2
3 clear;
4
5 clc;
6
7 rd=1*10^6;
8
9 rc=1*10^9;
10
11 a0=10^5;
12
13 ro=100;
14
15 ft=1*10^6;
16
17 R1=2*10^3;
18
19 R2=18*10^3;
20
21 b=R1/(R1+R2);
22
23 fB=b*ft;
24
25 Rs=rd;
26
27 Rd=rd*(1+(a0*b));
28
29 Rp=((2*rc)*Rd)/((2*rc)+Rd);
30
31 Ceq=1/(2*%pi*fB*rd);
32
33 f1=(Rs/Rp)*fB;
34
35 printf("Element Values in the Equivalent Circuit of
      Zi :");
```

```

36
37 printf("\nRs=%0.2 f Mohms" ,Rs*10^(-6));
38
39 printf("\nRp=%0.2 f Gohms" ,Rp*10^(-9));
40
41 printf("\nCeq=%0.2 f pF" ,Ceq*10^12);
42
43 printf("\n\nBreakpoint Frequencies of Magnitude Plot
      :");
44
45 printf("\nfB=%0.2 f kHz" ,fB*10^(-3));
46
47 printf("\nf1=%0.2 f Hz" ,f1);

```

Scilab code Exa 6.5 Output Impedance of Shunt Topology

```

1 //Example 6.5
2
3 clear;
4
5 clc;
6
7 rd=1*10^6;
8
9 rc=1*10^9;
10
11 a0=10^5;
12
13 ro=100;
14
15 ft=1*10^6;
16
17 R1=2*10^3;
18
19 R2=18*10^3;

```

```

20
21 b=R1/(R1+R2);
22
23 fb=ft/a0;
24
25 fB=b*ft;
26
27 Rp=ro;
28
29 Rs=ro/(1+(a0*b));
30
31 Leq=ro/(2*%pi*fB);
32
33 printf("Element Values in the Equivalent Circuit of
      Zo :");
34
35 printf("\nRs=%0. f mohms",Rs*10^(3));
36
37 printf("\nRp=%0.2 f ohms",Rp);
38
39 printf("\nLeq=%0. f uH",Leq*10^6);
40
41 printf("\n\nBreakpoint Frequencies of Magnitude Plot
      :");
42
43 printf("\nfb=%0.2 f Hz",fb);
44
45 printf("\nft=%0.2 f MHz",ft*10^(-6));

```

Scilab code Exa 6.6.a Finding Gain Zi and Zo for High Sensitivity I V Converter

```

1 //Example 6.6(a)
2
3 clear;
4

```

```

5  clc;
6
7  R=100*103;
8
9  R1=2*103;
10
11 R2=18*103;
12
13 b=R1/(R1+R2);
14
15 A0=- (1+(R2/R1))*R;
16
17 a0=2*105;
18
19 ft=1*106;
20
21 ro=100;
22
23 fB=b*ft;
24
25 Ri=[R+((R1*R2)/(R1+R2))]/(1+(a0*b));
26
27 Ro=ro/(1+(a0*b));
28
29 fb=ft/a0;
30
31 printf("A(jf)=(%d V/A)",A0);
32
33 printf("/(1+(jf/%.d))",fB);
34
35 printf("\\nZi(jf)=%.d",Ri);
36
37 printf("*(1+j(f/%.d))",fb);
38
39 printf("/(1+(jf/%.d)) ohms",fB);
40
41 printf("\\nZo(jf)=%.d",Ro*103);
42

```

Step Response of the Circuit

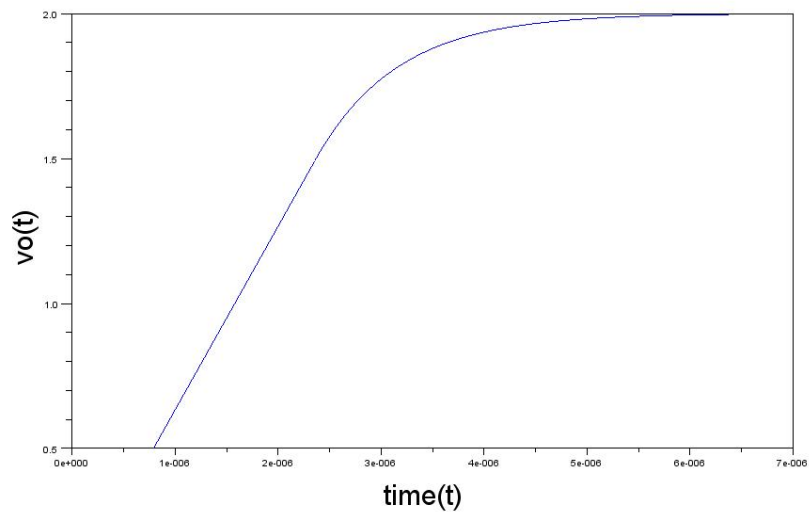


Figure 6.2: Effect of Slew Rate Limiting

```
43 printf("*(1+j(f/%.d))", fB);  
44  
45 printf("/(1+(jf/%.d)) mohms", fB);
```

Scilab code Exa 6.7.a Effect of Slew Rate Limiting

```
1 //Example 6.7(a)  
2  
3 clear;  
4  
5 clc;  
6  
7 IA=19.6*10^(-6);  
8  
9 Cc=30*10^(-12);
```

```

10
11 SR=0.633*10^6;
12
13 R1=3*10^3;
14
15 R2=12*10^3;
16
17 A0=-(R2/R1);
18
19 b=R1/(R1+R2);
20
21 a0=2*10^5;
22
23 ft=1*10^6;
24
25 ro=100;
26
27 Vim=-0.5;
28
29 tau=1/(2*pi*b*ft);
30
31 Vomcrit=SR*tau;
32
33 Voinf=A0*Vim;
34
35 V1=Voinf-Vomcrit;
36
37 t=[0:2*10^(-8):7*10^(-6)];
38
39 t1=V1/SR;
40
41 t12=[0:2*10^(-8):tau]
42
43 vo3=0*ones(1,length(t12));
44 plot(t12,vo3);
45
46 t11=[tau:2*10^(-8):t1+tau];
47

```

```

48 vo1=SR*(t11-tau);
49
50 t22=[t1+tau:2*10^(-8):7*10^(-6)];
51
52 vo2=Voinf+((V1-Voinf)*exp(-(t22-t1-tau)/tau));
53
54 plot(t11,vo1);
55
56 plot(t22,vo2);
57
58 xlabel("time(t)","fontsize",6);
59
60 ylabel("vo(t)","fontsize",6);
61
62 title("Step Response of the Circuit","fontsize",8);

```

Scilab code Exa 6.8.a Full Power Bandwidth

```

1 //Example 6.8(a)
2
3 clear;
4
5 clc;
6
7 Vs=15;
8
9 A=10;
10
11 Vim=0.5;
12
13 SR=0.5*10^6;
14
15 Vom=A*Vim;
16
17 fmax=SR/(2*pi*Vom);

```

```
18
19 printf("fmax=%0. f kHz",fmax*10(-3));
```

Scilab code Exa 6.8.b Full Power Bandwidth

```
1 //Example 6.8(b)
2
3 clear;
4
5 clc;
6
7 Vs=15;
8
9 A=10;
10
11 f=10*103;
12
13 SR=0.5*106;
14
15 Vommax=SR/(2*%pi*f);
16
17 Vimmax=Vommax/A;
18
19 printf("Maximum Value of Vim before the output
    distorts=%0.3 f V",Vimmax);
```

Scilab code Exa 6.8.c Full Power Bandwidth

```
1 //Example 6.8(c)
2
3 clear;
4
5 clc;
```



```

6
7 Vs=15;
8
9 A=10;
10
11 Vim=40*10(-3);
12
13 SR=0.5*106;
14
15 fmax=SR/(2*%pi*Vim*A);
16
17 ft=1*106;
18
19 fB=ft/A;
20
21 printf("Useful Frequency Range of Operation f<=0.2 f
      kHz" ,fB*10(-3));

```

Scilab code Exa 6.8.d Full Power Bandwidth

```

1 //Example 6.8(d)
2
3 clear;
4
5 clc;
6
7 Vs=13;
8
9 A=10;
10
11 ft=1*106;
12
13 SR=0.5*106;
14
15 f=2*103;

```

```

16
17 Vommax=SR/(2*%pi*f);
18
19 if Vommax>Vs then
20 Vimmax=Vs/A;
21
22 printf("Useful Input Amplitude Range is Vim<=%.2 f V"
        ,Vimmax);

```

Scilab code Exa 6.9 Effect of finite GBP on Integrator Circuits

```

1 //Example 6.9
2
3 clear;
4
5 clc;
6
7 f0=10*10^3;
8
9 Q=25;
10
11 HobpdB=0;
12
13 R1=10*10^3; // Assumption
14
15 R2=R1; // Assumption
16
17 R5=R1; // Assumption
18
19 R6=R1; // Assumption
20
21 R3=250*10^3; // Assumption
22
23 R4=R3; // Assumption
24

```

```

25 C1=1/(2*pi*f0*R5); // Assumption
26
27 C2=C1; // Assumption
28
29 f0reler=0.01; // as relative error defined for f0=1%
30
31 Qreler=0.01
32
33 ftf0=f0/f0reler;
34
35 ftQ=(4*Q*f0)/Qreler;
36
37 printf("Designed Biquad Filter :")
38
39 printf("\nR1=R2=R5=R6=%0.2 f kohms",R1*10^(-3));
40
41 printf("\nR3=R4=%0.2 f kohms",R4*10^(-3));
42
43 printf("\nC1=C2=%0.2 f nF",C1*10^9);
44
45 if ftf0>ftQ then
46     ft=ftf0;
47
48 else ft=ftQ
49
50 printf("\nGBP>=%0.2 f MHz",ft*10^(-6));

```

Scilab code Exa 6.10.b Biquad Filter with Phase Compensation

```

1 //Example 6.10(b)
2
3 clear;
4
5 clc;
6

```

```

7  f0=10*103;
8
9  Q=25;
10
11 HobpdB=0;
12
13 R1=10*103; // Assumption
14
15 R2=R1; // Assumption
16
17 R5=R1; // Assumption
18
19 R6=R1; // Assumption
20
21 R3=250*103; // Assumption
22
23 R4=R3; // Assumption
24
25 C1=1/(2*%pi*f0*R5); // Assumption
26
27 C2=C1; // Assumption
28
29 f0reler=0.01; //as relative error defined for f0=1%
30
31 Qreler=0.01
32
33 ftf0=f0/f0reler;
34
35 ftQ=(4*Q*f0)/Qreler;
36
37 ft=1*106;
38
39 //Changing the component values using Phase
    Compensation
40
41 ch=f0/ft;
42
43 C1new=C1-(C1*ch);

```

```

44
45 C2new=C1new;
46
47 printf("Designed Biquad Filter :")
48
49 printf("\nR1=R2=R5=R6=%0.2 f kohms",R1*10^(-3));
50
51 printf("\nR3=R4=%0.2 f kohms",R4*10^(-3));
52
53 printf("\nC1=C2=%0.3 f nF",C1new*10^9);

```

Scilab code Exa 6.11 Effect of finite GBP on first order filter

```

1 //Example 6.11
2
3 clear;
4
5 clc;
6
7 C=(5/%pi)*10^(-9);
8
9 R1=10*10^3;
10
11 R2=30*10^3;
12
13 GBP=1*10^6;
14
15 Hreler=0.01;//Departure of H from Hideal
16
17 ft=1*10^6;
18
19 fx=ft/(1+(R2/R1));
20
21 fmax=((1/((1-Hreler)^2)-1)^(1/2))*fx;
22

```

```

23 f0=1/(2*%pi*R1*C);
24
25 fmin3dB=(1/((1/(f0^2))-(1/(fx^2))-(1/((f0^2)*(fx^2))
    )))^(1/2); //f(-3dB)
26
27 f3dBer=((fmin3dB-f0)/fmin3dB)*100;
28
29 printf("Percentage Deviation of cut off frequency=%
    .2 f",f3dBer*2);

```

Scilab code Exa 6.12 Effect of finite GBP on second order filter

```

1 //Example 6.12
2
3 clear;
4
5 clc;
6
7 C=10*10^(-9);
8
9 H0bpdB=0;
10
11 f0=10*10^3;
12
13 Q=10;
14
15 H0bp=10^(H0bpdB/20);
16
17 R1=Q/(2*%pi*f0*C*H0bp);
18
19 R2=(R1/((2*(Q^2))/(H0bp)))-1;
20
21 R3=(2*Q)/(2*%pi*f0*C);
22
23 BW=f0/Q;

```

```

24
25 BWer=0.01; //BW deviation from its design value is 1%
26
27 GBPmin=(2*Q*f0)/BWer;
28
29 printf("Components for the mentioned circuit :");
30
31 printf("\nR1=%0.2 f kohms",R1*10^(-3));
32
33 printf("\nR2=%0.2 f ohms",R2);
34
35 printf("\nR3=%0.2 f kohms",R3*10^(-3));
36
37 printf("\nGBP>=%0.2 f MHz",GBPmin*10^(-6));

```

Scilab code Exa 6.14 Parameters for Current Feedback Amplifier

```

1 //Example 6.14
2
3 clear;
4
5 clc;
6
7 zo=0.71*10^6;
8
9 Req=zo;
10
11 fb=350*10^3;
12
13 Ceq=1/(2*pi*Req*fb);
14
15 vo=5;
16
17 iN=vo/Req;
18

```

```
19 printf("Ceq=%.2 f pF",Ceq*10^12);
20
21 printf("\niN=%.2 f uA",iN*10^6);
```

Scilab code Exa 6.15 Current Feedback Amplifier Dynamics

```
1 //Example 6.15
2
3 clear;
4
5 clc;
6
7 ft=100*10^6;
8
9 brec=1.5*10^3;
10
11 R2=1.5*10^3;
12
13 rn=50;
14
15 A01=1;
16
17 A02=10;
18
19 A03=100;
20
21 //R11=R2/(A01-1) ->R1=infinity
22
23 R12=R2/(A02-1);
24
25 R13=R2/(A03-1);
26
27 fB1=ft/(1+(A01/30));
28
29 fB2=ft/(1+(A02/30));
```



```

30
31 fB3=ft/(1+(A03/30));
32
33 tR1=2.2/(2*%pi*fB1);
34
35 tR2=2.2/(2*%pi*fB2);
36
37 tR3=2.2/(2*%pi*fB3);
38
39 printf("Values of R1, fB and tR for A0=1 :")
40
41 printf("\nR1=infinity");
42
43 printf("\nfB=%0.2 f MHz", fB1*10^(-6));
44
45 printf("\ntR=%0.2 f nS", tR1*10^9);
46
47 printf("\n\nValues of R1, fB and tR for A0=10 :")
48
49 printf("\nR1=%0.2 f ohms", R12);
50
51 printf("\nfB=%0.2 f MHz", fB2*10^(-6));
52
53 printf("\ntR=%0.2 f nS", tR2*10^9);
54
55 printf("\n\nValues of R1, fB and tR for A0=100 :")
56
57 printf("\nR1=%0.2 f ohms", R13);
58
59 printf("\nfB=%0.2 f MHz", fB3*10^(-6));
60
61 printf("\ntR=%0.2 f nS", tR3*10^9);

```

Scilab code Exa 6.16 Compensation of B W Reduction in Current Feedback Amplifier

```

1 //Example 6.16
2
3 clear;
4
5 clc;
6
7 A0=10;
8
9 fB=100*10^6;
10
11 brec=1.5*10^3;
12
13 rn=50;
14
15 R2=brec-(rn*A0);
16
17 R1=R2/(A0-1);
18
19 printf("(a) Redesigned Current Feedback Amplifier of
        Example 6.15 :");
20
21 printf("\n      R1=%0.f ohms",R1);
22
23 printf("\n      R2=%0.2 f kohms",R2*10^(-3));
24
25 z0=0.75*10^6;
26
27 T0=(1/brec)*z0;
28
29 epsilon=-100/T0;
30
31 printf("\n\n(b) Percentage dc gain error=%0.1f",
        epsilon);

```

Chapter 7

Noise

Scilab code Exa 7.1.a Noise Properties

```
1 //Example 7.1(a)
2
3 clear;
4
5 clc;
6
7 fL=0.1;
8
9 fH=100;
10
11 enw=20*10(-9);
12
13 fce=200;
14
15 En=enw*sqrt((fce*log(fH/fL))+fH-fL);
16
17 printf("Estimated RMS input voltage=%0.2f uV",En
    *106);
```

Scilab code Exa 7.1.b Noise Properties

```
1 //Example 7.1(b)
2
3 clear;
4
5 clc;
6
7 fL=20;
8
9 fH=20*10^3;
10
11 enw=20*10^(-9);
12
13 fce=200;
14
15 En=enw*sqrt((fce*log(fH/fL))+fH-fL);
16
17 printf("Estimated RMS input voltage=%.2f uV",En
    *10^6);
```

Scilab code Exa 7.1.c Noise Properties

```
1 //Example 7.1(c)
2
3 clear;
4
5 clc;
6
7 fL=0.1;
8
9 fH=1*10^6;
10
11 enw=20*10^(-9);
12
```

```

13 fce=200;
14
15 En=enw*sqrt((fce*log(fH/fL))+fH-fL);
16
17 printf("Estimated RMS input voltage=%0.1f uV",En
    *10^6);

```

Scilab code Exa 7.3 Graphical Representation of Noise Dynamics

```

1 //Example 7.3
2
3 clear;
4
5 clc;
6
7 fL1=1;
8
9 fH1=1*10^3;
10
11 fL2=fH1;
12
13 fH2=10*10^3;
14
15 fL3=fH2;
16
17 //fH3=infinity
18
19 enw=20*10^(-9);
20
21 fce=100;
22
23 Eno1=enw*sqrt((fce*log(fH1/fL1))+fH1-fL1);
24
25 eno=enw/fL2;
26

```

```

27 Eno2=sqrt(integrate("(eno*f)^2",'f',fL2,fH2));
28
29 f0=100*10^3;
30
31 enw3=200*10^(-9);
32
33 Eno3=enw3*sqrt((1.57*f0)-fL3);
34
35 Eno=sqrt((Eno1^2)+(Eno2^2)+(Eno3^2));
36
37 printf("Estimated rms noise voltage=%0.1f uV",Eno
    *10^6);

```

Scilab code Exa 7.4 Calculation of Thermal Noise

```

1 //Example 7.4
2
3 clear;
4
5 clc;
6
7 R=10*10^3;
8
9 k=1.38*10^(-23);
10
11 T=25+273;//Room Temperature in Kelvin
12
13 eR=sqrt(4*k*T*R);
14
15 printf("(a) Noise Voltage (eR)=%0.2f nV/sqrt(Hz)",eR
    *10^9);
16
17 iR=eR/R;
18
19 printf("\n(b) Noise Current (iR)=%0.2f pA/sqrt(Hz)",iR

```

```

    *10^12);
20
21 fH=20*10^3;
22
23 fL=20;
24
25 ER=eR*sqrt(fH-fL);
26
27 printf("\n(c) rms noise voltage over audio range=%0.2
    f uV",ER*10^6);

```

Scilab code Exa 7.5.a Calculation of Shot Noise

```

1 //Example 7.5(a)
2
3 clear;
4
5 clc;
6
7 ID=1*10^(-6);
8
9 fH=1*10^6;
10
11 q=1.602*10^(-19);
12
13 In=sqrt(2*q*ID*fH);
14
15 SNR=20*log10(ID/In);
16
17 printf("Signal to Noise Ratio=%0.1f dB",SNR);

```

Scilab code Exa 7.5.b Calculation of Shot Noise

```

1 //Example 7.5(b)
2
3 clear;
4
5 clc;
6
7 ID=1*10^(-9);
8
9 fH=1*10^6;
10
11 q=1.602*10^(-19);
12
13 In=sqrt(2*q*ID*fH);
14
15 SNR=20*log10(ID/In);
16
17 printf("Signal to Noise Ratio=%0.1f dB",SNR);

```

Scilab code Exa 7.7.a Total Output Noise in an Op Amp

```

1 //Example 7.7(a)
2
3 clear;
4
5 clc;
6
7 R1=100*10^3;
8
9 R2=200*10^3;
10
11 R3=68*10^3;
12
13 enw=20*10^(-9);
14
15 fce=200;

```



```

16
17 ft=1*10^6;
18
19 inw=0.5*10^(-12);
20
21 fci=2*10^3;
22
23 Rp=(R1*R2)/(R1+R2);
24
25 Ano=1+(R2/R1);
26
27 fB=ft/Ano;
28
29 fL=0.1;
30
31 Enoe=Ano*enw*sqrt([fci*log(fB/fL)]+[1.57*fB]-fL]);
32
33 Enoi=Ano*[(R3^2)+(Rp^2)]^(1/2)*inw*([(fci*log(fB/
    fL))+(1.57*fB)]^(1/2));
34
35 k=1.38*10^(-23);
36
37 T=25+273; //Room temperature in Kelvin
38
39 EnoR=Ano*[(4*k*T)*(R3+Rp)*1.57*fB]^(1/2)];
40
41 Eno=sqrt((Enoe^2)+(Enoi^2)+(EnoR^2));
42
43 printf("RMS Output Noise Voltage=%f uV",Eno*10^6);
44
45 printf("\nPeak to Peak Noise Voltage=%f mV",6.6*
    Eno*10^3);

```

Scilab code Exa 7.8 Improvement in the Circuit to find the Total Output Noise

```

1 //Example 7.8
2
3 clear;
4
5 clc;
6
7 R1=100*10^3;
8
9 R2=200*10^3;
10
11 R3=68*10^3;
12
13 enw=20*10^(-9);
14
15 fce=200;
16
17 ft=1*10^6;
18
19 inw=0.5*10^(-12);
20
21 fci=2*10^3;
22
23 Rp=(R1*R2)/(R1+R2);
24
25 Ano=1+(R2/R1);
26
27 fB=ft/Ano;
28
29 fL=0.1;
30
31 Enoeold=Ano*enw*sqrt([fce*log(fB/fL)]+{1.57*fB}-fL
    ]);
32
33 Enoiold=Ano*[{(R3^2)+(Rp^2)}^(1/2)]*inw*([(fci*log(
    fB/fL))+(1.57*fB)]^(1/2));
34
35 k=1.38*10^(-23);
36

```

```

37 T=25+273; //Room temperature in Kelvin
38
39 EnoRold=Ano*[{(4*k*T)*(R3+Rp)*1.57*fB}^(1/2)];
40
41 Enoold=sqrt((Enoeold^2)+(Enoiold^2)+(EnoRold^2));
42
43 Enonew=50*10^(-6); //New Value of Eno mentioned in
    problem
44
45 Enoisum=(Enonew^2)-(Enoeold^2); //sum of (Enoi^2) and
    (EnoR^2)
46
47 Enoinewsq=(Ano^2)*(inw^2)*[(fci*log(fB/fL))+(1.57*fB
    )]; //(Enoinew^2)/(R^2)
48
49 EnoRnewsq=(Ano^2)*((4*k*T)*1.57*fB);
50
51 r=poly(0, 'x');
52
53 p=(Enoinewsq*(r^2))+(EnoRnewsq*r)-Enoisum;
54
55 [r1]=roots(p);
56
57 R=r1(2,1)
58
59 R3new=R/2;
60
61 R1new=(3*R3new)/2;
62
63 R2new=2*R1new;
64
65 printf("Resistances after scaling are :");
66
67 printf("\nR1=%0.2 f kohms",R1new*10^(-3));
68
69 printf("\nR2=%0.1 f kohms",R2new*10^(-3));
70
71 printf("\nR3=%0.1 f kohms",R3new*10^(-3));

```

Scilab code Exa 7.9 Calculation of Signal to Noise Ratio

```
1 //Example 7.9
2
3 clear;
4
5 clc;
6
7 R1=100*10^3; //From Example 7.7(a)
8
9 R2=200*10^3; //From Example 7.7(a)
10
11 Aso=- (R2/R1);
12
13 Eno=154*10^(-6); //From Example 7.9
14
15 Eni=Eno/abs(Aso);
16
17 Vipa=0.5; //Peak amplitude of input ac signal
18
19 Virms=Vipa/sqrt(2);
20
21 SNR=20*log10(Virms/Eni);
22
23 printf("SNR of the circuit of Example 7.7=%0.1f dB",
        SNR);
```

Scilab code Exa 7.10 Calculation of Noise in Current Feedback Amplifier

```
1
2 //Example 7.10
```

```

3
4 clear;
5
6 clc;
7
8 z0=710*10^3;
9
10 fb=350*10^3;
11
12 rn=50;
13
14 enw=2.4*10^(-9);
15
16 fce=50*10^3;
17
18 inpw=3.8*10^(-12);
19
20 fcip=100*10^3;
21
22 innw=20*10^(-12);
23
24 fcin=100*10^3;
25
26 R1=166.7;
27
28 R2=1.5*10^3;
29
30 R3=100; //internal resistance
31
32 fL=0.1;
33
34 Rp=(R1*R2)/(R1+R2);
35
36 ft=(z0*fb)/R2;
37
38 fB=ft/[1+(rn/((R1*R2)/(R1+R2)))]);
39
40 Ano=1+(R2/R1);

```

```

41
42 Enoe=enw*sqrt([fce*log(fB/fL)]+{1.57*fB}-fL]);
43
44 Enoi=R3*inpw*sqrt(((fcip*log(fB/fL)))+(1.57*fB)-fL));
45
46 Enop=Rp*innw*sqrt({(fcin*log(fB/fL)))+(1.57*fB)-fL});
47
48 k=1.38*10^(-23);
49
50 T=25+273;//Room temperature in Kelvin
51
52 EnoR=[{(4*k*T)*(R3+Rp)*((1.57*fB)-fL)}^(1/2)];
53
54 Eno=Ano*sqrt((Enoe^2)+(Enoi^2)+(EnoR^2)+(Enop^2));
55
56 c=6.6*10^3;
57
58 Eno1=Eno*c;
59
60 printf("RMS Noise Voltage (Eno)=%.2f uV",Eno*10^6);
    //answer in textbook is wrong
61
62 printf("\nPeak to Peak Noise Voltage (Eno)=%.2f mV",
    Eno1);//answer in textbook is wrong

```

Scilab code Exa 7.11 Noise in Photodiode Amplifiers

```

1 //Example 7.11
2
3 clear;
4
5 clc;
6
7 ft=16*10^6;
8

```

```
9  enw=4.5*10(-9);
10
11  fce=100;
12
13  IB=1*10(-12);
14
15  fL=0.01;
16
17  R1=100*10(9);
18
19  C1=45*10(-12);
20
21  R2=10*106;
22
23  C2=0.5*10(-12);
24
25  b0rec=1;
26
27  binfrec=91;
28
29  fz=350;
30
31  fp=31.8*103;
32
33  fx=176*103;
34
35  k=1.38*10(-23);
36
37  T=25+273;
38
39  iR2=sqrt((4*k*T)/R2);
40
41  q=1.602*10(-19);
42
43  in=sqrt(2*q*IB);
44
45  Enoe=binfrec*enw*sqrt(((%pi/2)*fx)-fp);
46
```

```

47 EnoR=R2*iR2*sqrt((%pi/2)*fp);
48
49 Eno=sqrt((Enoe^2)+(EnoR^2));
50
51 printf("Total Output Noise=%f uV",Eno*10^6);

```

Scilab code Exa 7.12 Photodiode amplifier with Noise Filtering

```

1 //Example 7.12
2
3 clear;
4
5 clc;
6
7 ft=16*10^6;
8
9 enw=4.5*10^(-9);
10
11 fce=100;
12
13 IB=1*10^(-12);
14
15 fL=0.01;
16
17 R1=100*10^(9);
18
19 C1=45*10^(-12);
20
21 R2=10*10^6;
22
23 C2=0.5*10^(-12);
24
25 b0rec=1;
26
27 binfrec=91;

```



```

28
29 fz=350;
30
31 fp=31.8*10^3;
32
33 fx=176*10^3;
34
35 k=1.38*10^(-23);
36
37 T=25+273;
38
39 Cc=0.5*10^(-12); // Assumed
40
41 C2=Cc;
42
43 C3=10*10^(-9);
44
45 R3=(R2*Cc)/C3;
46
47 printf("Cc=C2=%0.1 f pF", Cc*10^(12));
48
49 printf("\nR3=%0. f ohms", R3);
50
51 printf("\nC3=%0. f nF", C3*10^(9));

```

Scilab code Exa 7.13 Designing T Feedback Photodiode Amplifiers

```

1 //Example 7.13
2
3 clear;
4
5 clc;
6
7 C1=2*10^(-9);
8

```

```

 9  binfrec=4000;
10
11  inw=0.566*10(-15);
12
13  T=1*10(9);
14
15  ft=16*106;
16
17  R1=100*10(9);
18
19  C2=0.5*10(-12);
20
21  fx=(1/binfrec)*ft;
22
23  enw=4.5*10(-9);
24
25  Enoe=binfrec*enw*sqrt((%pi*fx)/2);
26
27  EnoRmax=Enoe/3;
28
29  k=1.38*10(-23);
30
31  Temp=25+273;
32
33  ex=((EnoRmax2)*C2)/(k*Temp);
34
35  R2=T/ex;
36
37  R3=1*103; // Assumed
38
39  R4=(ex-1)*R3;
40
41  printf("(a) Designed T Network :");
42
43  printf("\n      R1=%0.2 f Gohms",R1*10(-9));
44
45  printf("\n      R2=%0.1 f Mohms",R2*10(-6));
46

```

```

47 printf("\n      R3=%0.2 f kohms" ,R3*10^(-3));
48
49 printf("\n      R4=%0.2 f kohms" ,R4*10^(-3));
50
51 printf("\n      C1=%0.2 f nF" ,C1*10^9);
52
53 printf("\n      C2=%0.2 f pF" ,C2*10^12);
54
55 fp=1/(2*%pi*ex*R2*C2);
56
57 fB=fp;
58
59 Rp=(R1*R2)/(R1+R2);
60
61 Enoi=((1.57*fB)^(1/2))*inw;
62
63 Eno=sqrt((Enoe^2)+(Enoi^2)+(EnoRmax^2));
64
65 printf("\n\n(b) Total rms Output Noise=%0.2 f mV" ,Eno
        *10^3);
66
67 printf("\n      Bandwidth(fB)=%0.d Hz" ,fB);

```

Chapter 8

Stability

Scilab code Exa 8.1 Gain Margin and Phase Margin of an op amp system

```
1 //Example 8.1
2
3 clear;
4
5 clc;
6
7 T0=10^4;
8
9 f1=100;
10
11 f2=10^6;
12
13 f3=10*10^6;
14
15 w1=2*pi*f1;
16
17 w2=2*pi*f2;
18
19 w3=2*pi*f3;
20
21 h=syslin('c',T0/[(1-(%s/w1))*(1-(%s/w2))*(1-(%s/w3))])
```

```

    ]);
22
23 gm=g_margin(h);
24
25 pm=p_margin(h);
26
27 printf("(a) Gain Margin(GM)=%.2 f dB",gm);
28
29 printf("\n(b) Phase Margin(PM)=%.1 f degrees",-pm);
30
31 f=512*10^3;
32
33 w=2*%pi*f;
34
35 T1=T0/[(1-((%i*w)/w1))*(1-((%i*w)/w2))*(1-((%i*w)/w3
    ))];
36
37 den=1/(abs(T1)/T0);
38
39 printf("\n(c) T0 for PM=60 degrees=%. f",den);

```

Scilab code Exa 8.2 Stability in Differentiator Circuits

```

1 //Example 8.2
2
3 clear;
4
5 clc;
6
7 R=159*10^3;
8
9 C=10*10^(-9);
10
11 f0=1/(2*%pi*R*C);
12

```

```

13 ft=10^6;
14
15 fx=sqrt(f0*ft);
16
17 Q=sqrt(ft/f0);
18
19 d=-90-((180/%pi)*atan(fx/f0));
20
21 pm=180+d;
22
23 printf("fx=%0.2 f kHz",fx*10^(-3));
24
25 printf("\nQ=%0. f",Q);
26
27 printf("\nPhase Margin (PM)=%0.1 f degrees",pm);

```

Scilab code Exa 8.3 Stray Input Capacitance Compensation for inverting configuration

```

1 //Example 8.3
2
3 clear;
4
5 clc;
6
7 R1=30*10^3;
8
9 R2=R1;
10
11 Cext=3*10^(-12);
12
13 GBP=20*10^6;
14
15 Cd=7*10^(-12);
16
17 Cc=12*10^(-12);

```

```

18
19 Cn=Cext+Cd+(Cc/2);
20
21 Rp=(R1*R2)/(R1+R2);
22
23 Cf1=0;
24
25 fz1=1/(2*pi*Rp*(Cn+Cf1));
26
27 ft=20*10^6;
28
29 Q=sqrt((ft)/(2*fz1));
30
31 pm=(180/pi)*acos((sqrt(1+(1/(4*Q^4))))-(1/(2*Q^2)))
    ;
32
33 Cf2=(R1/R2)*Cn;
34
35 fp=1/(2*pi*R2*Cf2);
36
37 x=poly(0, 'f');
38
39 A=-1/[(1+(i*(x/fp)))*(1+(i*(x/(0.5*ft))))];
40
41 printf("(a) Phase Margin with Cf absent=%0.1f degrees
    ",pm);
42
43 printf("\n(b) Cf for PM=90 degrees=%0.2f pF",Cf2
    *10^12);
44
45 printf("\n(c) A(jf)=");
46
47 disp(A);

```

Scilab code Exa 8.4 Stray Input Capacitance Compensation for non inverting configu

```

1 //Example 8.4
2
3 clear;
4
5 clc;
6
7 R1=30*10^3;
8
9 R2=R1;
10
11 ft=20*10^6;
12
13 Cext=3*10^(-12);
14
15 GBP=20*10^6;
16
17 Cd=7*10^(-12);
18
19 Cc=12*10^(-12);
20
21 Cf=(R1/R2)*((Cc/2)+Cext);
22
23 Cn=Cext+Cd+(Cc/2);
24
25 fx=ft/(1+(Cn/Cf));
26
27 x=poly(0, 'f');
28
29 A=(1+(R2/R1))/(1+(%i*(x/fx)));
30
31 printf("A(jf)=");
32
33 disp(A);
34
35 printf("V/V");

```

Scilab code Exa 8.5 Stabilizing a capacitively loaded op amp circuit

```
1 //Example 8.5
2
3 clear;
4
5 clc;
6
7 GBP=10*10^6;
8
9 ro=100;
10
11 A0=-2;
12
13 CL=5*10^(-9);
14
15 R1=10*10^3;
16
17 R2=20*10^3;
18
19 Rs=(R1/R2)*ro;
20
21 Cf=((1+(R1/R2))^2)*(ro/R2)*CL;
22
23 f3dB=1/(2*pi*R2*Cf);
24
25 b=1/3;
26
27 fx=b*GBP;
28
29 printf("(a) Rs=%g. f ohms",Rs);
30
31 printf("\n      Cf=%g. f pF",Cf*10^12);
32
```

```

33 x=poly(0, 'f');
34
35 A=A0/((1+(%i*(x/fx)))*(1+(%i*(x/f3dB))));
36
37 printf("\n\n(b) A(jf)=");
38
39 disp(A);
40
41 printf("V/V");

```

Scilab code Exa 8.6 Internal Frequency Compensation

```

1 //Example 8.6
2
3 clear;
4
5 clc;
6
7 a0=3600;
8
9 f1=1*10^6;
10
11 f2=4*10^6;
12
13 f3=40*10^6;
14
15 fmin135=4.78*10^6;
16
17 fmin180=14.3*10^6;
18
19 gbp1=abs(a0/[(1+(%i*(fmin135/f1)))*(1+(%i*(fmin135/
    f3)))*(1+(%i*(fmin135/f3)))])-256;
20
21 gbp2=abs(a0/[(1+(%i*(fmin180/f1)))*(1+(%i*(fmin180/
    f3)))*(1+(%i*(fmin180/f3)))])-158.97561;

```

```

22
23 printf(" |a(j*fmin135)|=%.d V/V" , gbp1);
24
25 printf("\n |a(j*fmin180)|=%.1 f V/V" , gbp2);

```

Scilab code Exa 8.7 Dominant Pole Compensation

```

1 //Example 8.7
2
3 clear;
4
5 clc;
6
7 PM=45;
8
9 anganewjfx=-180+PM;
10
11 a0=3600;
12
13 f1=1*10^6;
14
15 f2=4*10^6;
16
17 f3=40*10^6;
18
19 angajfx=anganewjfx+90;
20
21 fx=683*10^3;
22
23 ajf=a0/(((1+(%i*(fx/f1)))*(1+(%i*(fx/f2)))*(1+(%i*(fx
    /f3)))));
24
25 ang=(180/%pi)*atan(imag(ajf)/real(ajf));
26
27 mag=abs(ajf);

```

```
28
29 fd=sqrt((fx^2)/((mag^2)-1));
30
31 printf("fd=%f Hz",fd);
```

Scilab code Exa 8.8 Shunt Capacitance Compensation

```
1 //Example 8.8
2
3 clear;
4
5 clc;
6
7 rd=1*10^6;
8
9 g1=2*10^(-3);
10
11 R1=100*10^(3);
12
13 g2=10*10^(-3);
14
15 R2=50*10^3;
16
17 ro=100;
18
19 f1=100*10^3;
20
21 f2=1*10^6;
22
23 f3=10*10^3;
24
25 PM=45;
26
27 a0=g1*R1*g2*R2;
28
```

```

29 C1=1/(2*%pi*f1*R1);
30
31 b1=1;
32
33 f1new1=f2/(b1*a0);
34
35 Cc1=1/(2*%pi*R1*f1new1);
36
37 printf("(a) fd=%f Hz",f1new1);
38
39 printf("\n      Cc=%f nF",Cc1*10^9);
40
41 b2=0.5;
42
43 f1new2=f2/(b2*a0);
44
45 Cc2=1/(2*%pi*R1*f1new2);
46
47 printf("\n\n(b) fd=%f Hz",f1new2);
48
49 printf("\n      Cc=%f nF",Cc2*10^9);

```

Scilab code Exa 8.9 Miller Compensation

```

1 //Example 8.9
2
3 clear;
4
5 clc;
6
7 rd=1*10^6;
8
9 g1=2*10^(-3);
10
11 R1=100*10^(3);

```

```

12
13 g2=10*10^(-3);
14
15 R2=50*10^3;
16
17 ro=100;
18
19 f1=100*10^3;
20
21 f2=1*10^6;
22
23 f3=10*10^6;
24
25 PM=45;
26
27 a0=g1*R1*g2*R2;
28
29 C1=1/(2*%pi*f1*R1);
30
31 b1=1;
32
33 C21=1/(2*%pi*f2*R2);
34
35 f2newap1=g2/[2*%pi*(C1+C21)];
36
37 fx1=f3;
38
39 f1new1=f3/(b1*a0);
40
41 Cc1=1/(2*%pi*R1*g2*R2*f1new1);
42
43 f2new1=(g2*Cc1)/(2*%pi*((C1*C21)+(Cc1*C1)+(Cc1*C21))
    );
44
45 fz1=g2/(2*%pi*Cc1);
46
47 printf("(a) f1new=%0. f Hz", f1new1);
48

```

```

49 printf("\n      f2new=%g. f MHz", f2new1*10^(-6));
50
51 printf("\n      Cc=%g.1 f pF", Cc1*10^12);
52
53 b2=0.5;
54
55 C22=1/(2*pi*f2*R2);
56
57 f2newap2=g2/[2*pi*(C1+C22)];
58
59 fx2=f3;
60
61 f1new2=f3/(b2*a0);
62
63 Cc2=1/(2*pi*R1*g2*R2*f1new2);
64
65 f2new2=(g2*Cc2)/(2*pi*((C1*C22)+(Cc2*C1)+(Cc2*C22))
        );
66
67 fz2=g2/(2*pi*Cc2);
68
69 printf("\n\n(b) f1new=%g. f Hz", f1new2);
70
71 printf("\n      f2new=%g. f MHz", f2new2*10^(-6));
72
73 printf("\n      Cc=%g.1 f pF", Cc2*10^12);

```

Scilab code Exa 8.10 Pole Zero Compensation

```

1 //Example 8.10
2
3 clear;
4
5 clc;
6

```

```

7 PM=45;
8
9 b=1;
10
11 rd=1*10^6;
12
13 g1=2*10^(-3);
14
15 R1=100*10^(3);
16
17 g2=10*10^(-3);
18
19 R2=50*10^3;
20
21 ro=100;
22
23 f1=100*10^3;
24
25 f2=1*10^6;
26
27 f3=10*10^6;
28
29 a0=g1*R1*g2*R2;
30
31 C1=1/(2*%pi*f1*R1);
32
33 Cc=(b*a0)/(2*%pi*R1*f3);
34
35 Rc=1/(2*%pi*Cc*f2);
36
37 f4=1/(2*%pi*Rc*C1);
38
39 printf("Cc=%0.1 f nF",Cc*10^9);
40
41 printf("\nRc=%0. f ohms",Rc);
42
43 printf("\nR1=%0. f kohms",R1*10^(-3)); //The value of
    R1 is not provided in the textbook

```



```
44
45 printf("\nC1=%0.2 f pF",C1*10^12); //The value of R1 is
    not provided in the textbook
```

Scilab code Exa 8.11 Frequency Compensation via Loop Gain Reduction

```
1 //Example 8.11
2
3 clear;
4
5 clc;
6
7 a0=10^5;
8
9 f1=10*10^3;
10
11 f2=3*10^6;
12
13 f3=30*10^6;
14
15 R1=10*10^3;
16
17 R2=100*10^3;
18
19 PM=45;
20
21 ajf=a0/((1+(%i*(f2/f1)))*(1+(%i*(f2/f2)))*(1+(%i*(f2
    /f3))));
22
23 ajf2mag=abs(ajf);
24
25 Rc1=R2/(ajf2mag-(1+(R2/R1)));
26
27 printf("(a) Rc=%0.1 f ohms",Rc1);
28
```

```

29 Rc2=430;
30
31 brec=1+(R2/R1)+(R2/Rc2);
32
33 a0b=a0/brec;
34
35 dcge=-100/(a0b);
36
37 printf("\n\n(b) DC Gain Error=%0.2f percent",dcge);
38
39 EI=1*10^(-3);
40
41 E0=brec*EI;
42
43 printf("\n\n(c) DC Output Error=%0.f mV",E0*10^3);
44
45 fmin3dB=f2;
46
47 printf("\n\n(d) f-3dB=%0.f MHz",fmin3dB*10^(-6));

```

Scilab code Exa 8.12 Input Lag Compensation

```

1 //Example 8.12
2
3 clear;
4
5 clc;
6
7 a0=10^5;
8
9 f1=10*10^3;
10
11 f2=3*10^6;
12
13 f3=30*10^6;

```

```

14
15 R1=10*10^3;
16
17 R2=100*10^3;
18
19 PM=45;
20
21 Rc=447.4;
22
23 Cc=5/(%pi*Rc*f2);
24
25 printf("(a) Rc=%0.1f ohms",Rc);
26
27 printf("\n      Cc=%0.3f nF",Cc*10^9);
28
29 b0rec=1+(R2/R1);
30
31 a0b0=a0*(1/b0rec);
32
33 dcge=-100/(a0b0);
34
35 printf("\n\n(b) DC Gain Error=%0.3f percent",dcge);
36
37 EI=1*10^(-3);
38
39 E0=b0rec*EI;
40
41 printf("\n\n(c) DC Output Error=%0.f mV",E0*10^3);
42
43 fmin3dB=f2;
44
45 printf("\n\n(d) f-3dB=%0.f MHz",fmin3dB*10^(-6));
46
47 f=2.94*10^6;
48
49 T=(410*[1+(%i*(f/(0.1*f2)))])/[(1+((%i*f)/f1))*(1+((
      %i*f)/f2))*(1+((%i*f)/f3))*(%i*(f/(0.1*f2)))]];
50

```

```

51 Tang=- (180-(180/%pi)*atan(imag(T)/real(T)));
52
53 PM1=180+Tang;
54
55 printf("\n\n(e) Actual Phase Margin=%0.1f degrees",
        PM1);

```

Scilab code Exa 8.13 Feedback Lead Compensation

```

1 //Example 8.13
2
3 clear;
4
5 clc;
6
7 a0=10^5;
8
9 f1=1*10^3;
10
11 f2=100*10^3;
12
13 f3=5*10^6;
14
15 A0=20;
16
17 R1=1.05*10^3;
18
19 R2=20*10^3;
20
21 b0=1/(1+(R2/R1));
22
23 a0b0=a0*b0;
24
25 f=700*10^3;
26

```

```

27 T=a0b0/[(1+((%i*f)/f1))*(1+((%i*f)/f2))*(1+((%i*f)/
    f3))];
28
29 Tang=-((180-(180/%pi)*atan(imag(T)/real(T)));
30
31 PM=180+Tang;
32
33 printf("(a) PM=%0.1f degrees indicating a circuit in
    bad need of compensation.",PM);
34
35 amod=sqrt(20);
36
37 aang=-192.3;
38
39 fx=1.46*10^6;
40
41 Cf=sqrt(1+(R2/R1))/(2*pi*R2*fx);
42
43 PM1=180+aang-(90-(2*(180/%pi)*atan(sqrt(1+(R2/R1))))
    );
44
45 printf("\n\n(b) PM after compensation=%0.1f degrees",
    PM1);
46
47 f3dB=(1/(2*pi*R2*Cf))+1000;
48
49 printf("\n\n(c) f-3dB=%0. f kHz",f3dB*10^(-3));

```

Scilab code Exa 8.14 Configuring a Decompensated op amp as a Unity Gain Voltage Fo

```

1 //Example 8.14
2
3 clear;
4
5 clc;

```

```

6
7 A0=1;
8
9 brecmin=5;
10
11 Rc=3*10^3;
12
13 Rf=Rc*(brecmin-1);
14
15 GBP=20*10^6;
16
17 fx=(1/brecmin)*GBP;
18
19 Cc=brecmin/(%pi*Rc*fx);
20
21 printf("(a) Rc=%f kohms",Rc*10^(-3));
22
23 printf("\n      Rf=%f kohms",Rf*10^(-3));
24
25 printf("\n      Cc=%f pF",Cc*10^12);
26
27 printf("\n\n(b) A(jf)=1/[1+jf/(%f MHz)] V/V",fx
      *10^(-6));

```

Scilab code Exa 8.15 Input Stray Capacitance Compensation in CFA Circuits

```

1 //Example 8.15
2
3 clear;
4
5 clc;
6
7 zo=750*10^3;
8
9 fb=200*10^3;

```

```

10
11 rn=50;
12
13 R2=1.5*10^3;
14
15 Cn=100*10^(-12);
16
17 PM=45;
18
19 Cf=sqrt((rn*Cn)/(2*pi*R2*zo*fb));
20
21 printf(" Cf=%0.2 f pF" ,Cf*10^12);

```

Scilab code Exa 8.16 Feedback Lead Compensation for Composite Amplifier

```

1 //Example 8.16
2
3 clear;
4
5 clc;
6
7 R1=1*10^3;
8
9 R2=99*10^3;
10
11 PM=45;
12
13 ft1=1*10^6;
14
15 ft2=ft1;
16
17 Cf=sqrt((1+(R2/R1))/(ft1*ft2))/(2*pi*R2);
18
19 a0=2*10^5;
20

```

```

21 T0=(a0^2)/100;
22
23 fp=(1/(2*%pi*R2*Cf));
24
25 fB=fp;
26
27 PMs=PM*2;
28
29 T0s=a0/100;
30
31 fBs=ft1/100;
32
33 printf("(a) Composite Amplifier with feedback Lead
    Compensation Parameters :");
34
35 printf("\n    PM=%f degrees",PM);
36
37 printf("\n    T0=");
38
39 disp(T0);
40
41 printf("    fB=%f kHz",fB*10^(-3));
42
43 printf("\n\n    Single Op Amp Parameters :");
44
45 printf("\n    PM=%f degrees",PMs);
46
47 printf("\n    T0=");
48
49 disp(T0s);
50
51 printf("    fB=%f kHz",fBs*10^(-3));
52
53 Cf2=((1+(R2/R1))^(1/4))*Cf;
54
55 fp2=(1/(2*%pi*R2*Cf2));
56
57 fz2=(1+(R2/R1))*fp2;

```



```

58
59 fx2=sqrt(fp2*fz2);
60
61 PM2=180-180-[(180/%pi)*((atan(fx2/fz2))-atan(fx2/fp2
    ))];
62
63 printf("\n\n(b) Cf=%0.1f pF",Cf2*10^12);
64
65 printf("\n      fp=%0.2f kHz",fp2*10^(-3));
66
67 printf("\n      PM=%0.1f degrees",PM2);
68
69 printf("\n\n(c) Increasing Cf above %0.1f pF will
    reduce PM until eventually PM=0 degrees,",Cf2
    *10^12);
70
71 printf("\n      indicating the overcompensation is
    decremental.")

```

Scilab code Exa 8.17 Composite Amplifier with Compensation provided by op amp 2

```

1 //Example 8.17
2
3 clear;
4
5 clc;
6
7 dcgain=-100;
8
9 R1=1*10^3;
10
11 R2=abs(dcgain)*R1;
12
13 ft1=1*10^6;
14

```

```

15 ft2=ft1;
16
17 R4R3rat=sqrt((ft2/ft1)*(1+(R2/R1)))-1;
18
19 R3=2*10^3;
20
21 R4=R3*R4R3rat;
22
23 a0=2*10^5;
24
25 T0=a0*(1+(R4/R3))/(1+(R2/R1));
26
27 fB=ft1/10;
28
29 PM=90;
30
31 T0s=a0/(1+(R2/R1));
32
33 fBs=ft1/100;
34
35 printf("Components for the Circuit :");
36
37 printf("\nR1=%g. f kohms",R1*10^(-3));
38
39 printf("\nR2=%g. f kohms",R2*10^(-3));
40
41 printf("\nR3=%g. f kohms",R3*10^(-3));
42
43 printf("\nR4=%g. f kohms",R4*10^(-3));
44
45 printf("\nAssociated Parameters with the Circuit :")
    ;
46
47 printf("\nT0=");
48
49 disp(T0);
50
51 printf("fB=%g. f kHz",fB*10^(-3));

```

```
52
53 printf("\n\nSingle Op Amp Parameters :");
54
55 printf("\nT0=");
56
57 disp(T0s);
58
59 printf("fB=%.f kHz",fBs*10^(-3));
```

Chapter 9

Non Linear Circuits

Scilab code Exa 9.1 Comparator as a Level Detector I

```
1 //Example 9.1
2
3 clear;
4
5 clc;
6
7 Vref=2;
8
9 R1=20*10^3;
10
11 R2=30*10^3;
12
13 Vos=5*10^(-3);
14
15 IB=250*10^(-9);
16
17 Rpar=(R1*R2)/(R1+R2);
18
19 VN=Rpar*IB;
20
21 Vneti=Vos+VN;
```

```
22
23 VT=(1+(R2/R1))*(Vref-Vneti);
24
25 printf("Worst Case Error=%f mV",Vneti*10^3);
```

Scilab code Exa 9.2 Comparator as a Level Detector II

```
1 //Example 9.2
2
3 clear;
4
5 clc;
6
7 Vref=2.5;
8
9 IR=1*10^(-3);
10
11 ILED=2*10^(-3);
12
13 VLED=1.8;
14
15 Vb=12;
16
17 Vbmax=13;
18
19 Vbmin=10;
20
21 R4o=(Vbmax-VLED)/ILED;
22
23 R1o=10*10^3;
24
25 R2o=((Vbmax/Vref)-1)*R1o;
26
27 R4u=(Vbmin-VLED)/ILED;
28
```

```

29 R1u=10*10^(3);
30
31 R2u=((Vbmin/Vref)-1)*R1u;
32
33 R3u=(Vb-Vref)/IR;
34
35 printf("Designed Circuit for Voltage Indicator :");
36
37 printf("\n\nCircuit Elements for Overvoltage Circuit
      :");
38
39 printf("\nR1=%0.f kohms",R1o*10^(-3));
40
41 printf("\nR2=%0.2 f kohms", (R2o*10^(-3))+0.2);
42
43 printf("\nR4=%0.1 f kohms",R4o*10^(-3));
44
45 printf("\n\nCircuit Elements for Undervoltage
      Circuit :");
46
47 printf("\nR1=%0.f kohms",R1u*10^(-3));
48
49 printf("\nR2=%0.1 f kohms", (R2u*10^(-3))+0.1);
50
51 printf("\nR3=%0.f kohms",R3u*10^(-3));
52
53 printf("\nR4=%0.1 f kohms", (R4u*10^(-3))-0.2);

```

Scilab code Exa 9.3 Designing On Off Temperature Controller

```

1 //Example 9.3
2
3 clear;
4
5 clc;

```

```

6
7 Tmin=50+273.2; //Temperature in Kelvin
8
9 Tmax=100+273.2; //Temperature in Kelvin
10
11 R2=5*10^3;
12
13 VTmax=Tmax/100;
14
15 VTmin=Tmin/100;
16
17 I2=(VTmax-VTmin)/R2;
18
19 R3=VTmin/I2;
20
21 Vref=6.9;
22
23 R1=(Vref-VTmax)/I2;
24
25 R4=2*10^3;
26
27 R5=6.2*10^3;
28
29 R6=10*10^3;
30
31 printf("Designed On-Off Temperature Controller :");
32
33 printf("\nR1=%0.1 f kohms",R1*10^(-3));
34
35 printf("\nR2=%0.2 f kohms",R2*10^(-3));
36
37 printf("\nR3=%0.1 f kohms",R3*10^(-3));
38
39 printf("\nR4=%0. f kohms",R4*10^(-3));
40
41 printf("\nR5=%0.1 f kohms",R5*10^(-3));
42
43 printf("\nR6=%0. f kohms",R6*10^(-3));

```

Scilab code Exa 9.4 Comparator as a Window Detector

```
1 //Example 9.4
2
3 clear;
4
5 clc;
6
7 VCC=5
8
9 VCCmax=VCC+((5/100)*VCC);
10
11 VCCmin=VCC-((5/100)*VCC);
12
13 IB=1*10^(-3);
14
15 Vled=1.5;
16
17 Iled=10*10^(-3);
18
19 vN=2.5; //For Bottom Comparator
20
21 vP=2.5; //For Top Comparator
22
23 R1=10*10^3;
24
25 Rsum=R1/(vN/VCCmax);
26
27 R2=((vP/VCCmin)*(Rsum))-R1;
28
29 R3=Rsum-R1-R2;
30
31 VBE=0.7;
32
```



```

33 R4=(VCC-VBE)/IB;
34
35 R5=(VCC-vN)/IB;
36
37 R6=(VCC-Vled)/Iled;
38
39 printf("Designed Video Detector :");
40
41 printf("\nR1=%0.2 f kohms",R1*10^(-3));
42
43 printf("\nR2=%0.2 f kohms",R2*10^(-3));
44
45 printf("\nR3=%0. f kohms",R3*10^(-3));
46
47 printf("\nR4=%0.2 f kohms",R4*10^(-3));
48
49 printf("\nR5=%0.2 f kohms", (R5*10^(-3))+0.2);
50
51 printf("\nR6=%0.2 f ohms",R6-20);

```

Scilab code Exa 9.5 Designing Single Supply Inverting Schmitt trigger

```

1 //Example 9.5
2
3 clear;
4
5 clc;
6
7 VCC=5;
8
9 Vol=0;
10
11 Vt1=1.5;
12
13 Vth=2.5;

```

```

14
15 R4=2.2*10^3; // Assumed
16
17 R3=100*10^3; // Assumed (Much Greater than R4)
18
19 A=[(Vt1/(VCC-Vt1)) -1;1 -((VCC-Vth)/Vth)];
20
21 B=[((Vt1/(VCC-Vt1))*(1/R3)); -((1/R3)*((VCC-Vth)/Vth)
    )];
22
23 Rrec=linsolve(A,B);
24
25 R1rec=Rrec(1,1);
26
27 R2rec=Rrec(2,1);
28
29 R1=1/R1rec;
30
31 R2=1/R2rec;
32
33 printf(" Designing Single Supply Inverting Schmitt
    trigger :");
34
35 printf("\nR1=%0.2 f kohms",R1*10^(-3));
36
37 printf("\nR2=%0.1 f kohms",R2*10^(-3));
38
39 printf("\nR3=%0. f kohms",R3*10^(-3));
40
41 printf("\nR4=%0.1 f kohms",R4*10^(-3));

```

Scilab code Exa 9.6 Hysteresis in On Off Controllers

```

1 //Example 9.6
2

```

```

3  clear;
4
5  clc;
6
7  hys=1;
8
9  VBEon=0.9;
10
11 Tmin=50+273.2; //Temperature in Kelvin
12
13 Tmax=100+273.2; //Temperature in Kelvin
14
15 R2=5*10^3;
16
17 VTmax=Tmax/100;
18
19 VTmin=Tmin/100;
20
21 I2=(VTmax-VTmin)/R2;
22
23 R3=VTmin/I2;
24
25 Vref=6.9;
26
27 R1=(Vref-VTmax)/I2;
28
29 R4=2*10^3;
30
31 R5=6.2*10^3;
32
33 R6=10*10^3;
34
35 Rw(((R1+(R2/2))*(R3+(R2/2)))/((R1+(R2/2))+(R3+(R2/2)
    )));
36
37 delvo=VBEon;
38
39 sen=10*10^(-3);

```

```

40
41 delvp=2*hys*sen;
42
43 RF=((delvo*Rw)/delvp)-Rw;
44
45 printf("Designed On-Off Temperature Controller :");
46
47 printf("\nR1=%0.1 f kohms",R1*10^(-3));
48
49 printf("\nR2=%0.2 f kohms",R2*10^(-3));
50
51 printf("\nR3=%0.1 f kohms",R3*10^(-3));
52
53 printf("\nR4=%0. f kohms",R4*10^(-3));
54
55 printf("\nR5=%0.1 f kohms",R5*10^(-3));
56
57 printf("\nR6=%0. f kohms",R6*10^(-3));
58
59 printf("\nFeedback Resistance (Rf)=%0. f kohms", (RF
    *10^(-3))-9);

```

Chapter 10

Signal Generators

Scilab code Exa 10.1 Designing a Square Wave Generator using Multivibrator

```
1 //Example 10.1
2
3 clear;
4
5 clc;
6
7 f0min=1;
8
9 f0max=10*10^3;
10
11 VDon=0.7;
12
13 Vsa=5;
14
15 Vz5=Vsa-(2*VDon);
16
17 Vsat=13;
18
19 IRmin=10*10^(-6);
20
21 R1=33*10^3;
```

```

22
23 R2=R1;
24
25 VT=2.5;
26
27 Rmax=(Vsa-VT)/(IRmin);
28
29 Rpot=Rmax;
30
31 Rs=Rpot/39;
32
33 f0=0.5;
34
35 C1=1/(f0*2*(Rpot+Rs)*log(1+(2*(R1/R2))));
36
37 C2=C1/10;
38
39 C3=C2/10;
40
41 C4=C3/10;
42
43 vN=-2.5;
44
45 iRmax=(Vsa-vN)/Rs;
46
47 IR2=Vsa/(R1+R2);
48
49 IB=1*10^(-3);
50
51 ILmax=1*10^(-3);
52
53 IR3max=iRmax+IR2+IB+ILmax;
54
55 R3=(Vsat-Vsa)/IR3max;
56
57 R4=10*10^3;
58
59 printf("Designed Square Wave Generator :");

```

```

60
61 printf("\nR1=%0. f kohms" ,R1*10^(-3));
62
63 printf("\nR2=%0. f kohms" ,R2*10^(-3));
64
65 printf("\nR3=%0.2 f kohms" ,R3*10^(-3));
66
67 printf("\nRs=%0.2 f kohms" ,Rs*10^(-3));
68
69 printf("\nRpot=%0.2 f kohms" ,Rpot*10^(-3));
70
71 printf("\nR4=%0.2 f kohms" ,R4*10^(-3));
72
73 printf("\nC1=%0.1 f uF" ,(C1*10^6)-0.25);
74
75 printf("\nC2=%0.2 f uF" ,(C2*10^6)-0.02);
76
77 printf("\nC3=%0. f nF" ,(C3*10^9)-2.50);
78
79 printf("\nC4=%0.1 f nF" ,(C4*10^9)-0.25);

```

Scilab code Exa 10.3 The 555 timer as an astable multivibrator

```

1 //Example 10.3
2
3 clear;
4
5 clc;
6
7 f0=50*10^3;
8
9 Dper=75;
10
11 C=1*10^(-9);
12

```

```

13 Rsum=1.44/(f0*C);
14
15 A=[1 -2;1 2];
16
17 B=[0;-Rsum];
18
19 R=linsolve(A,B);
20
21 RA=R(1,1);
22
23 RB=R(2,1);
24
25 printf("Designed Astable Multivibrator :");
26
27 printf("\nRA=%0.1 f kohms",RA*10^(-3));
28
29 printf("\nRB=%0.2 f kohms",RB*10^(-3));
30
31 printf("\nC=%0.d nF",C*10^9);

```

Scilab code Exa 10.4 Voltage Control for 555 timer

```

1 //Example 10.4
2
3 clear;
4
5 clc;
6
7 VCC=5;
8
9 Vpeak=1;
10
11 Vth=((2/3)*VCC);
12
13 Vthmin=((2/3)*VCC)-1;

```



```

14
15 Vthmax=((2/3)*VCC)+1;
16
17 Vt11=Vthmin/2;
18
19 Vt12=Vthmax/2;
20
21 f0=50*10^3;
22
23 Dper=75;
24
25 C=1*10^(-9);
26
27 Rsum=1.44/(f0*C);
28
29 A=[1 -2;1 2];
30
31 B=[0;-Rsum];
32
33 R=linsolve(A,B);
34
35 RA=R(1,1);
36
37 RB=R(2,1);
38
39 T1=RB*C*log(2);
40
41 Th1=(RA+RB)*C*log((VCC-Vt11)/(VCC-Vthmin));
42
43 Th2=(RA+RB)*C*log((VCC-Vt12)/(VCC-Vthmax));
44
45 T1=T1+Th1;
46
47 T2=T1+Th2;
48
49 f01=1/T1;
50
51 f02=1/T2;

```

```

52
53 D1=(100*Th1)/T1;
54
55 D2=(100*Th2)/T2;
56
57 printf("Range of Variation of f0 :%.1f kHz<=f0<=" ,(
    f02*10^(-3))+0.2);
58
59 printf("%.1f kHz" ,(f01*10^(-3))+0.6);
60
61 printf("\nRange of Percentage Variation of D :");
62
63 printf("%.1f" ,D1);
64
65 printf("<=D<=");
66
67 printf("%.1f" ,D2);

```

Scilab code Exa 10.5 Designing Basic Triangular or Square Wave Generator

```

1 //Example 10.5
2
3 clear;
4
5 clc;
6
7 Vclamp=5;
8
9 VT=10;
10
11 VDon=0.7;
12
13 Vz5=Vclamp-(2*VDon);
14
15 Rrat=Vclamp/VT;

```

```

16
17 R1=20*10^3;
18
19 R2=R1*Rrat;
20
21 f0min=10;
22
23 f0max=10*10^3;
24
25 f0range=f0max/f0min;
26
27 Rpot=2.5*10^6;
28
29 Rs=Rpot/f0range;
30
31 Rmin=Rs;
32
33 C=(R2/R1)/(4*Rmin*f0max);
34
35 IRmax=Vclamp/Rmin;
36
37 IR2max=Vclamp/R2;
38
39 Ib=1*10^(-3);
40
41 Il=1*10^(-3);
42
43 Vsat=13;
44
45 IR3max=IRmax+IR2max+Ib+Il;
46
47 R3=(Vsat-Vclamp)/IR3max;
48
49 printf("Designed Basic Triangular/Square Wave
      Generator :");
50
51 printf("\nR=%0.1 f kohms",Rmin*10^(-3));
52

```

```

53 printf("\nR1=%0. f kohms" ,R1*10(-3));
54
55 printf("\nR2=%0. f kohms" ,R2*10(-3));
56
57 printf("\nR3=%0.2 f kohms" ,R3*10(-3));
58
59 printf("\nC=%0. f nF" ,C*109);

```

Scilab code Exa 10.6 Basic ICL8038 connection for 50 percent duty cycle operation

```

1 //Example 10.6
2
3 clear;
4
5 clc;
6
7 VCC=15;
8
9 f0=10*103;
10
11 iA=100*10(-6);
12
13 iB=iA;
14
15 R=(VCC/5)/iA;
16
17 C=0.3/(f0*R);
18
19 Rp=10*103;
20
21 Rsym=5*103;
22
23 Rre=R-(Rsym/2);
24
25 Rthd=100*103;

```

```

26
27 printf("Components for the Circuit :");
28
29 printf("\nR=%0.1 f kohms",Rre*10^(-3));
30
31 printf("\nRsym=%0. f kohms",Rsym*10^(-3));
32
33 printf("\nRthd=%0. f kohms",Rthd*10^(-3));
34
35 printf("\nC=%0. f nF",C*10^9);
36
37 printf("\nTo calibrate the circuit , adjust Rsym so
    that the square wave has D(percent)=50,");
38
39 printf("\nand Rthd until the THD of the sine wave is
    minimized.");

```

Scilab code Exa 10.7 AD537 application as a temperature to frequency converter

```

1 //Example 10.7
2
3 clear;
4
5 clc;
6
7 K=10;
8
9 VT0=(273.2*10^(-3)); //273.2 K for T=0 degCelsius
10
11 fo0=0;
12
13 R2R3rat=(1-VT0)/VT0;
14
15 RC=1/((10^4)*K);
16

```

```

17 C=3.9*10(-9);
18
19 R=RC/C;
20
21 R3=2.74*103;
22
23 R2=R3*R2R3rat;
24
25 R1=R-((R2*R3)/(R2+R3));
26
27 printf("Designed Celsius to Frequency Converter :");
28
29 printf("\nR=%0.3 f kohms",R*10(-3));
30
31 printf("\nR1=%0. f ohms",R1);
32
33 printf("\nR2=%0.2 f kohms",R2*10(-3));
34
35 printf("\nR3=%0.2 f kohms",R3*10(-3));
36
37 printf("\nC=%0.1 f nF",C*109);
38
39 printf("\nTo calibrate, place the IC in a 0 deg
    Celsius environment and adjust R2,");
40
41 printf("\nso that the circuit is barely oscillating,
    say fo=1 Hz. Then move the IC to");
42
43 printf("\na 100 deg Celsius environment and adjust
    R1 for f0=1 kHz.");

```

Scilab code Exa 10.8 Designing a Voltage to Frequency Converter

```

1 //Example 10.8
2

```

```

3  clear;
4
5  clc;
6
7  vI=10;
8
9  f=100*10^3;
10
11 T=1/f;
12
13 D=25;
14
15 TH=2.5*10^(-6);
16
17 C=(TH*1*10^(-3))/7.5;
18
19 R=vI/(7.5*f*C);
20
21 delvImax=2.5;
22
23 C1=(10^(-3)*TH)/delvImax;
24
25 RA=62;
26
27 RB=150*10^3;
28
29 RC=100*10^3;
30
31 printf("Designed Voltage to Frequency Converter :");
32
33 printf("\nR=%0.1 f kohms",R*10^(-3));
34
35 printf("\nC=%0. f pF",C*10^12);
36
37 printf("\nC1=%0. f nF",C1*10^9);
38
39 printf("\nRA=%0. f ohms",RA);
40

```

```
41 printf("\nRB=%0. f kohms" ,RB*10(-3));  
42  
43 printf("\nRC=%0. f kohms" ,RC*10(-3));
```

Chapter 11

Voltage Referencres and Regulators

Scilab code Exa 11.1 Line and Load Regulation

```
1 //Example 11.1
2
3 clear;
4
5 clc;
6
7 Vimin=7;
8
9 Vimax=25;
10
11 Vo=5;
12
13 delVi=Vimax-Vimin;
14
15 delVovi=3*10(-3);
16
17 Iomin=0.25;
18
19 Iomax=0.75;
```

```

20
21 delIo=Iomax-Iomin;
22
23 delVoio=5*10(-3);
24
25 RRRdB=78;
26
27 f=120;
28
29 liner=delVovi/delVi;
30
31 linerper=100*(liner/Vo);
32
33 loadr=delVoio/delIo;
34
35 loadrper=100*(loadr/Vo);
36
37 zo=delVoio/delIo;
38
39 Vri=1;
40
41 Vro=Vri/(10(RRRdB/20));
42
43 printf("(a) Line Regulation=%0.4f percent/V",linerper
    );
44
45 printf("\n      Load Regulation=%0.1f percent/A",
    loadrper);
46
47 printf("\n      Output Impedance=%0.2f ohms",zo);
48
49 printf("\n\n(b) Amount of Output Ripple for every
    volt of Vri=%0.3f mV",Vro*10(3));

```

Scilab code Exa 11.2 Thermal Coefficient

```

1 //Example 11.2
2
3 clear;
4
5 clc;
6
7 linerper=0.001;
8
9 loadrper=0.001*103;
10
11 TC=1*10(-6);
12
13 Vimin=13.5;
14
15 Vimax=35;
16
17 Vo=10;
18
19 delVi=Vimax-Vimin;
20
21 delIo=10*10(-3);
22
23 delVovi=((linerper*delVi)*Vo)/100;
24
25 delVoio=((loadrper*delIo)*Vo)/100;
26
27 Tmax=70;
28
29 Tmin=0;
30
31 delT=Tmax-Tmin;
32
33 delVoT=((TC*delT)*Vo);
34
35 printf("(a) Variation of Vo with change in Vi=%0.2f
        mV",delVovi*103);
36
37 printf("\n(b) Variation of Vo with change in Io=%0.f

```

```

    mV", delVoio*10^3);
38
39 printf("\n(c) Variation of Vo with change in
    temperature=%0.1 f mV", delVoT*10^3);

```

Scilab code Exa 11.3 Application of Line and Load Regulation

```

1 //Example 11.3
2
3 clear;
4
5 clc;
6
7 Vimin=10;
8
9 Vimax=20;
10
11 Pz=0.5;
12
13 Vz=6.8;
14
15 rz=10;
16
17 Iomin=0;
18
19 Iomax=10*10^(-3);
20
21 Izmin=(1/4)*Iomax;
22
23 Rsmax=(Vimin-Vz-(rz*Izmin))/(Izmin+Iomax);
24
25 liner=rz/(Rsmax+rz);
26
27 linerper=liner*(100/6.5);
28

```

```

29 loadr=-((Rsmax*rz)/(Rsmax+rz));
30
31 loadrper=loadr*(100/6.5);
32
33 printf("(a) Rs=%f ohms",Rsmax+16);
34
35 printf("\n    Line Regulation=%f percentage/V",
        linerper-0.03);
36
37 printf("\n    Load regulation=%f percentage/mA",
        loadrper/1000);
38
39 delVo1=liner*(VImax-VImin);
40
41 delV01per=(delVo1/6.5)*100;
42
43 delVo2=loadr*(Iomax-Iomin);
44
45 delV02per=(delVo2/6.5)*100;
46
47 printf("\n\n(b) Percentage Change of Vo with change
        in VI=%f percentage",delV01per-0.3);
48
49 printf("\n    Percentage Change of Vo with change in
        Io=%f percentage",delV02per);

```

Scilab code Exa 11.4 Line and Load Regulation of an op amp

```

1 //Example 11.4
2
3 clear;
4
5 clc;
6
7 a=2*10^5;

```

```

8
9 zo=75;
10
11 R1=39*10^3;
12
13 R2=24*10^3;
14
15 R3=3.3*10^3;
16
17 Vo=10;
18
19 VImin=12;
20
21 VImax=36;
22
23 b=R1/(R1+R2);
24
25 loadr=-zo/(1+(a*b));
26
27 PSRR=33333.333;
28
29 CMRRdB=90;
30
31 CMRR=10^(CMRRdB/20);
32
33 liner=(1+(R2/R1))*((1/PSRR)+(0.5/CMRR));
34
35 printf("Line Regulation=%0.1f ppm/V",liner*10^5);
36
37 printf("\nLoad Regulation=%0.2f ppm/mA",loadr*10^2);

```

Scilab code Exa 11.5 Bandgap Voltage Reference

```

1 //Example 11.5
2

```

```

3 clear;
4
5 clc;
6
7 n=4;
8
9 VBE2=650*10(-3);
10
11 TCVBG=0; //at 25 deg Celsius
12
13 Vref=5;
14
15 VG0=1.205;
16
17 VT=0.0257;
18
19 K=((VG0-VBE2)/VT)+3;
20
21 R4R3rat=K/(2*log(n));
22
23 VBG=VG0+(3*VT);
24
25 R2R1rat=(Vref/VBG)-1;
26
27 printf(" (R4/R3)=%.2 f" ,R4R3rat);
28
29 printf("\n(R2/R1)=%.1 f" ,R2R1rat);

```

Scilab code Exa 11.6 Turning a Voltage Reference into a current source

```

1 //Example 11.6
2
3 clear;
4
5 clc;

```

```

6
7 Vref=5;
8
9 TC=20*10(-6);
10
11 liner=50*10(-6);
12
13 Vdo=3;
14
15 TCVos=5*10(-6);
16
17 CMRRdB=100;
18
19 Io=10*10(-3);
20
21 R=Vref/Io;
22
23 delVref=liner;
24
25 delVosVl=10(-CMRRdB/20);
26
27 delIo=(delVosVl+delVref)/R;
28
29 Romin=1/delIo;
30
31 VCC=15;
32
33 VLmax=VCC-Vdo-Vref;
34
35 printf("(a) R=%f ohms",R);
36
37 printf("\n\n(b) TC(Io)=%f nA/V",delIo*109);
38
39 printf("\n      Ro(min)=%f Mohms",Romin*10(-6));
40
41 printf("\n\n(c) VL<=%f V",VLmax);

```

Scilab code Exa 11.7 Current Sources with Current Boosting Transistors

```
1 //Example 11.7
2
3 clear;
4
5 clc;
6
7 VCC=15;
8
9 Vref=2.5;
10
11 Io=100*10(-3);
12
13 Ib=0.5*10(-3);
14
15 R=Vref/Io;
16
17 R1=(VCC-Vref)/Ib;
18
19 printf("(a) R=%0.f ohms",R);
20
21 printf("\n      R1=%0.f kohms",R1*10(-3));
22
23 R2=1*103;
24
25 VECsat=0.2;
26
27 VLmax=VCC-Vref-VECsat;
28
29 Vin=VCC-Vref;
30
31 b=100;
32
```

```

33 IB=1*10(-3);
34
35 VEBon=0.7;
36
37 Vo=VCC-Vref-VEBon-(R2*IB);
38
39 Is=IB;
40
41 printf("\n\n(b) Voltage Compliance (VL)=%.1f V",
        VLmax);
42
43 printf("\n    The 741 inputs are at %.1f V which is
        within the input voltage range specifications.",
        Vin);
44
45 printf("\n    The 741 output is at %.1f V which is
        below VOH=13 V.",Vo);
46
47 printf("\n    The 741 sinks a current of %.f mA
        which is below Isc=25 mA.",Is*10(3));

```

Scilab code Exa 11.8 Thermal cold junction compensation using AD590

```

1 //Example 11.8
2
3 clear;
4
5 clc;
6
7 alpha=52.3*10(-6);
8
9 ovsen=10*10(-3);
10
11 oisen=273.2*10(-6);
12

```

```

13 R1=10/oisen;
14
15 R2=ovsen/(10^(-6));
16
17 temp=((ovsen/alpha)-1)/R2;
18
19 R3rec=(temp-(1/R1));
20
21 R3=1/R3rec;
22
23 printf("In practice we would use R3=52.3 ohms,1
        percent and make R1 and R2 adjustable as follows
        :");
24
25 printf("\n(a) Place the hot junction in an ice bath
        and adjust R1 for Vo(Tj)=0 V;");
26
27 printf("\n(b) Place the hot junction in a hot
        environment of known temperature and adjust R2");
28
29 printf("\n    for the desired ouput(the second
        adjustment can also be performed with");
30
31 printf("\n    the help of a thermocouple voltage
        simulator).");
32
33 printf("\nTo suppress noise pickup by the
        thermocouple wires , use an RC filter , say R=10
        kohms");
34
35 printf("\nand C=10.1 uF");

```

Scilab code Exa 11.9 Basic Series Regulator

```
1 //Example 11.9
```

```

2
3 clear;
4
5 clc;
6
7 RB=510;
8
9 RE=3.3*10^3;
10
11 Vo=5;
12
13 Vref=1.282;
14
15 R2R1rat=(Vo/Vref)-1;
16
17 Io=1;
18
19 b1=20;
20
21 b2=100
22
23 VBE2=0.7;
24
25 VBE1=1;
26
27 IE1=Io;
28
29 IB1=IE1/(b1+1);
30
31 IE2=IB1+(VBE1/RE);
32
33 IB2=IE2/(b2+1);
34
35 IOA=IB2;
36
37 VOA=(IB2*RB)+VBE2+VBE1+Vo;
38
39 printf("(a) R2/R1=%0.1f",R2R1rat);

```

```

40
41 printf("\n\n(b) The error amplifier must thus force
      IOA=%0.2 f mA", IOA*10^3);
42
43 printf("\n
      VOA=%0.f V", VOA);
44
45 VImIn=VOA+0.5;
46
47 VDO=VImIn-Vo;
48
49 printf("\n\n(c) The dropout voltage VDO=%0.1 f V", VDO
      +0.1);
50
51 pereffmax=100*(Vo/VImIn);
52
53 printf("\n\n(d) Maximum Percentage efficiency=%0.f
      percentage", pereffmax);

```

Scilab code Exa 11.10 Overload Protections for Linear Regulators

```

1 //Example 11.10
2
3 clear;
4
5 clc;
6
7 VI=8;
8
9 Pmax=12;
10
11 Isc=Pmax/VI;
12
13 VBE=0.7;
14

```

```

15 Rsc=VBE/Isc;
16
17 printf("(a) Isc=%0.1f A",Isc);
18
19 printf("\n      Rsc=%0.2f ohms",Rsc);
20
21 v0=5;
22
23 Ifb=Pmax/(VI-v0);
24
25 Rfb=[(1/Rsc)-((Ifb-Isc)/v0)]^(-1);
26
27 R3R4rat=(Rfb/Rsc)-1;
28
29 IB3=0.1*10^(-3);
30
31 R4=(VBE/(10*IB3))/(1+R3R4rat);
32
33 R3=R4*R3R4rat;
34
35 printf("\n\n(b) Ifb=%0.f A",Ifb);
36
37 printf("\n      Rfb=%0.2f ohms",Rfb);
38
39 printf("\n      R3=%0.f ohms",R3-3);
40
41 printf("\n      R4=%0.f ohms",R4+3);

```

Scilab code Exa 11.11 Positive Regulator with overload SOA and thermal protection

```

1 //Example 11.11
2
3 clear;
4
5 clc;

```

```

6
7 T1=25;
8
9 T2=175;
10
11 TC=-2*10(-3);
12
13 VBE41=700*10(-3);
14
15 VBE42=VBE41+(TC*(T2-T1));
16
17 Vref=1.282;
18
19 R7R8rat=(Vref/VBE42)-1;
20
21 IB4=0.1*10(-3);
22
23 R8=(Vref/(10*IB4))/(1+R7R8rat);
24
25 R7=R8*R7R8rat;
26
27 printf("R7=%0. f ohms",R7-2);
28
29 printf("\nR8=%0. f ohms",R8);

```

Scilab code Exa 11.12 Configuring a regulator as a power voltage source

```

1 //Example 11.12
2
3 clear;
4
5 clc;
6
7 Vo=15;
8

```

```

 9 R1=10*10^3;
10
11 R2=20*10^3;
12
13 Rpot=1*10^3;
14
15 VDO=2;
16
17 VCCmin=17;
18
19 VCCmax=35;
20
21 inf=1+(R2/R1);
22
23 printf("Permissible input range :%.f V<=",VCCmin);
24
25 printf("VCC<=%.f V",VCCmax);
26
27 printf("\nThe percentage values of line and load
    regulation are the same as for the 7805;");
28
29 printf("\nhowever, their mV/V and mV/A values are
    now %.f times as large.",inf);

```

Scilab code Exa 11.13 Configuring a regulator as an adjustable Power Current Source

```

1 //Example 11.13
2
3 clear;
4
5 clc;
6
7 Vreg=1.25;
8
9 VDO=2;

```



```

10
11  linerp=0.07;
12
13  Rpot=10*10^3;
14
15  CMRRdB=70;
16
17  VCC=15;
18
19  Imin=0;
20
21  Imax=1;
22
23  k=1;
24
25  R=Vreg/Imax;
26
27  PR=Vreg*Imax;
28
29  VLmax=VCC-VDO-Vreg;
30
31  delVo=1;
32
33  delIo=((Vreg*(linerp/100))+(10^(-CMRRdB/20)))/R;
34
35  Romin=delVo/delIo;
36
37  printf("R=%0.2 f ohms",R);
38
39  printf(",%0.2 f W",PR);
40
41  printf("\nVoltage Compliance=%0.2 f V",VLmax);
42
43  printf("\nMinimum Equivalent Resistance=%0.2 f kohms",
    Romin*10^(-3));

```

Scilab code Exa 11.14 Thermal Considerations for Linear Regulator

```
1 //Example 11.14
2
3 clear;
4
5 clc;
6
7 TJmax=150;
8
9 TAmx=50;
10
11 VI=8;
12
13 thetaJA=60;
14
15 thetaJC=3;
16
17 PDmax=(TJmax-TAmx)/thetaJA;
18
19 TC=TJmax-(thetaJC*PDmax);
20
21 printf("(a) Maximum Power Dissipated (PDmax)=%.2f W"
22         ,PDmax);
23
24
25 printf("\n      Case Temperature (TC)=%.f degCelsius",
26         TC);
27
28
29 VO=5;
30
31 IOmax=PDmax/(VI-VO);
32
33 printf("\n\n(b) Maximum Current that can be drawn=%.
34         .3f A",IOmax);
```

Scilab code Exa 11.15 Selection of Heat Sink on the basis of Thermal Resistance

```
1 //Example 11.15
2
3 clear;
4
5 clc;
6
7 TAmx=60;
8
9 Iomx=0.8;
10
11 VImx=12;
12
13 TJmx=125;
14
15 Vo=5;
16
17 thetaJAmx=(TJmx-TAmx)/[(VImx-Vo)*Iomx];
18
19 thetaJC=5;
20
21 thetaCA=thetaJAmx-thetaJC;
22
23 thetaCS=0.6;
24
25 thetaSA=thetaCA-thetaCS;
26
27 printf("thetaSA=%f degCelsius/W",thetaSA);
28
29 printf("\nAccording to the catalogs, a suitable
        heatsink example is the IERC HP1 series,");
30
31 printf("\nwhose thetaSA rating is in the range of 5
```

degCelsius/W to 6 degCelsius/W.”);

Scilab code Exa 11.16 Overvoltage Protection and Under Voltage Sensing

```
1 //Example 11.16
2
3 clear;
4
5 clc;
6
7 VOV=6.5;
8
9 TOV=100*10(-6);
10
11 VUV=4.5;
12
13 hys=0.25;
14
15 Vref=2.4
16
17 TUV=500*10(-6);
18
19 IH=12.5*10(-6);
20
21 COV=TOV/12500;
22
23 CUV=TUV/12500;
24
25 R2R1rat=(VOV/Vref)-1;
26
27 R4R3rat=(VUV/Vref)-1;
28
29 R3R4p=hys/IH;
30
31 COVu=(COV+(0.2*10(-9)));
```

```

32
33 CUVu=(CUV+(3*10^(-9)));
34
35 R3=R3R4p*((1/R4R3rat)+1);
36
37 R4=R3*R4R3rat;
38
39 R1=10*10^3;
40
41 R2=R1*R2R1rat;
42
43 printf("Designed Circuit Components :")
44
45 printf("\nCOV=%0.1 f nF",COVu*10^9);
46
47 printf("\nCUV=%0. f nF",CUVu*10^9);
48
49 printf("\nR1=%0.1 f kohms",R1*10^(-3));
50
51 printf("\nR2=%0.1 f kohms", (R2*10^(-3))-0.9);
52
53 printf("\nR3=%0.1 f kohms", (R3*10^(-3))+2.4);
54
55 printf("\nR4=%0.1 f kohms", (R4*10^(-3))-1);

```

Scilab code Exa 11.17 Duty Cycle of a Buck Regulator

```

1 //Example 11.17
2
3 clear;
4
5 clc;
6
7 VI=12;
8

```

```

 9  Vo=5;
10
11  D1=Vo/VI;
12
13  D1per=D1*100;
14
15  printf("(a) D=%0.1f percentage",D1per);
16
17  Vsat1=0.5;
18
19  VF1=0.7;
20
21  D2=(Vo+VF1)/(VI-Vsat1+VF1);
22
23  D2per=D2*100;
24
25  printf("\n\n(b) D=%0.1f percentage",D2per);
26
27  VImin=8;
28
29  VImax=16;
30
31  D1max=Vo/VImin;
32
33  D1min=Vo/VImax;
34
35  D1minper=D1min*100;
36
37  D1maxper=D1max*100;
38
39  printf("\n\n(c) Duty Cycle for case(a): %0.1f<=D(
      percentage)",D1minper);
40
41  printf("<=%0.1f",D1maxper);
42
43  Vsat1=0.5;
44
45  VF1=0.7;

```

```

46
47 D2max=(Vo+VF1)/(VImin-Vsat1+VF1);
48
49 D2maxper=D2max*100;
50
51 D2min=(Vo+VF1)/(VImax-Vsat1+VF1);
52
53 D2minper=D2min*100;
54
55 printf("\n    Duty Cycle for case(b): %.1f<=D(
        percentage)",D2minper);
56
57 printf("<=%.1 f",D2maxper);

```

Scilab code Exa 11.18 Coil Selection for a Boost Regulator

```

1 //Example 11.18
2
3 clear;
4
5 clc;
6
7 VI=5;
8
9 Vo=12;
10
11 Io=1;
12
13 fs=100*10^3;
14
15 IL=(Vo/VI)*Io;
16
17 deliL=0.2*IL;
18
19 L=(VI*(1-(VI/Vo)))/(fs*deliL);

```

```

20
21 Ip=IL+(deliL/2);
22
23 Irms=[(IL^2)+((deliL/(sqrt(12))))^2]^(1/2);
24
25 Iomin=deliL/2;
26
27 printf("L=%0.f uH",L*10^6);
28
29 printf("\nAt full load the coil must withstand Ip=%0
    .2 f A",Ip);
30
31 printf(" and Irms=%0.1 f A",Irms);
32
33 printf("\nMinimum Load Current (Iomin)=%0.1 f A",Iomin
    -0.1);

```

Scilab code Exa 11.19 Capacitor Selection for a Boost Regulator

```

1 //Example 11.19
2
3 clear;
4
5 clc;
6
7 VI=5;
8
9 Vo=12;
10
11 Io=1;
12
13 fs=100*10^3;
14
15 IL=(Vo/VI)*Io;
16

```



```

17 deliL=0.2*IL;
18
19 L=(VI*(1-(VI/Vo)))/(fs*deliL);
20
21 Ip=IL+(deliL/2);
22
23 Vro=100*10^(-3);
24
25 delvc=(1/3)*Vro;
26
27 C=(Io*(1-(VI/Vo)))/(fs*delvc);
28
29 delic=Ip;
30
31 delid=delic;
32
33 delvesr=(2/3)*Vro;
34
35 ESR=delvesr/delic;
36
37 printf("C=%0.1f uF", (C*10^6)+2);
38
39 printf("\nEquivalent Series Resistance (ESR)=%0.1f
    mohms", ESR*10^3);

```

Scilab code Exa 11.20 Efficiency of Buck regulator

```

1 //Example 11.20
2
3 clear;
4
5 clc;
6
7 VI=15;
8

```

```

9  Vo=5;
10
11 Io=3;
12
13 fs=50*10^3;
14
15 IQ=10*10^(-3);
16
17 Vsat=1;
18
19 tsw=100*10^(-9);
20
21 VF=0.7;
22
23 tRR=100*10^(-9);
24
25 Rcoil=50*10^(-3);
26
27 deliL=0.6;
28
29 ESR=100*10^(-3);
30
31 Pcore=0.25;
32
33 D=(Vo+VF)/(VI-Vsat+VF);
34
35 Dper=D*100;
36
37 Psw=(Vsat*D*Io)+(2*fs*VI*Io*tsw);
38
39 PD=(VF*(1-D)*Io)+(fs*VI*Io*tRR);
40
41 Pcap=ESR*((deliL/sqrt(12))^2);
42
43 Pcoil=(Rcoil*((deliL/sqrt(12))^2))+Pcore;
44
45 Pcontr=VI*IQ;
46

```

```

47 Po=Vo*Io;
48
49 Pdis=Psw+PD+Pcap+Pcoil+Pcontr;
50
51 effper=(Po/(Po+Pdis))*100;
52
53 efflin=(Vo/VI)*100;
54
55 printf("Efficiency of Buck Regulator=%f percent",
        effper);
56
57 printf("\nEfficiency of Linear Regulator=%f percent
        ",efflin);
58
59 printf("\nHence the Buck Regulator is most efficient
        than a Linear Regulator.");

```

Scilab code Exa 11.21 Designing Error Amplifier for Buck Regulator

```

1 //Example 11.21
2
3 clear;
4
5 clc;
6
7 VI=12;
8
9 fs=100*103;
10
11 Vsm=1;
12
13 L=100*10(-6);
14
15 C=300*10(-6);
16

```

```

17 ESR=0.05;
18
19 dcHCO=VI/Vsm;
20
21 w0=1/(sqrt(L*C));
22
23 f0=w0/(2*pi);
24
25 wz=1/(ESR*C);
26
27 fz=wz/(2*pi);
28
29 Q=1/(ESR*sqrt(C/L));
30
31 fx=fs/5;
32
33 wx=2*pi*fx;
34
35 f1=f0;
36
37 f2=f1;
38
39 f3=fz;
40
41 f4=2*fx;
42
43 HCO=(VI/Vsm)*((1+(i*(wx/wz)))/[1-((wx/w0)^2)+((i*(wx/w0))/Q)]);
44
45 Tmod=1;
46
47 HEA=Tmod/abs(HCO);
48
49 f5=1.47*10^3;
50
51 R2=10*10^3;
52
53 C3=1/(2*pi*f2*R2);

```

```
54
55 R3=1/(2*pi*f3*C3);
56
57 C2=1/(2*pi*f5*R2);
58
59 R4=1/(2*pi*f1*C2);
60
61 C1=240*10^(-12);
62
63 printf("Designed Error Amplifier :");
64
65 printf("\nR2=%0.1 f kohms",R2*10^(-3));
66
67 printf("\nR3=%0.1 f ohms",R3);
68
69 printf("\nR4=%0.1 f kohms",R4*10^(-3));
70
71 printf("\nC1=%0.1 f pF",C1*10^12);
72
73 printf("\nC2=%0.1 f nF",C2*10^9);
74
75 printf("\nC3=%0.1 f nF",C3*10^9);
```

Chapter 12

D to A and A to D Converters

Scilab code Exa 12.1 Specifications of DAC

```
1 //Example 12.1
2
3 clear;
4
5 clc;
6
7 k=["000" "001" "010" "011" "100" "101" "110" "111"];
8
9 vo=[0 1/8 2/8 3/8 4/8 5/8 6/8 7/8];
10
11 voact=[0 1/8 3/16 7/16 3/8 11/16 11/16 7/8];
12
13 INL=(voact-vo)*8;
14
15 for i=2:8
16     DNL(1,i)=INL(1,i)-INL(1,i-1);
17 end
18
19 DNL(1,1)=INL(1,1)
20
21 printf("INL=");
```

```

22
23 disp(INL);
24
25 printf("\nDNL=");
26
27 disp(DNL);
28
29 printf("\nThe maxima of INL and DNL are ,
        respectively , INL=1 LSB and DNL=(3/2) LSB.We
        observe");
30
31 printf("\na nonmonotonicity as the code changes from
        011 and 100, where the step size is");
32
33 printf("\n(-1/2) LSB instead of (+1 LSB); hence , DNL
        (100)=-1/2-(+1)=-3/2 LSB<-1 LSB.");
34
35 printf("\nThe fact that DNL(101)=(3/2) LSB>1 LSB,
        though undesirable , does not cause nonmonotocity.
        ");

```

Scilab code Exa 12.2 Specifications of ADC

```

1 //Example 12.2
2
3 clear;
4
5 clc;
6
7 n=10;
8
9 Vfsr=10.24;
10
11 StoNDsumdB=56;
12

```

```

13 Eq=Vfsr/((2^n)*sqrt(12));
14
15 SNRdB=(6.02*n)+1.76;
16
17 ENOB=(StoNDsumdB-1.76)/6.02;
18
19 printf("Eq=%0.2 f mV" ,Eq*10^3);
20
21 printf("\nSNR(max)=%0.2 f dB" ,SNRdB);
22
23 printf("\nENOB=%0.2 f" ,ENOB);

```

Scilab code Exa 12.3 DAC using a current mode R 2R ladder

```

1 //Example 12.3
2
3 clear;
4
5 clc;
6
7 n=12;
8
9 Vref=10;
10
11 Troom=25;
12
13 Tmin=0
14
15 Tmax=70;
16
17 erfa=1/4;
18
19 er=Vref/(2^14);
20
21 Temax=Tmax-Troom;

```



```

22
23 id=er/Temax;
24
25 TCmaxVref=id/Vref;
26
27 ng=2; //Noise Gain
28
29 TCmaxVos=id/ng;
30
31 printf("TCmax( Vref)=(+-)%0.2 f ppm/degC",TCmaxVref
      *10^6);
32
33 printf("\nTCmax( Vos)=(+-)%0.1 f uV/degC",TCmaxVos
      *10^6);

```

Scilab code Exa 12.4 Designing Digitally Programmable filter

```

1 //Example 12.4
2
3 clear;
4
5 clc;
6
7 Q=1/sqrt(2);
8
9 H0bp=-1;
10
11 f0step=10;
12
13 n=10;
14
15 R2=10*10^3; //Assumed
16
17 R4=R2; //Assumed
18

```

```

19 C=1*10^(-9); // Assumed
20
21 f0FSR=(2^n)*f0step;
22
23 R5=1/(2*pi*f0FSR*C);
24
25 R3=Q*sqrt(R2*R4);
26
27 R1=-R3/H0bp;
28
29 printf("Designed Digitally Programmable filter :");
30
31 printf("\nR1=%0.2 f kohms",R1*10^(-3));
32
33 printf("\nR2=%0. f kohms",R2*10^(-3));
34
35 printf("\nR3=%0.2 f kohms",R3*10^(-3));
36
37 printf("\nR4=%0. f kohms",R4*10^(-3));
38
39 printf("\nR5=%0.2 f kohms",R5*10^(-3));
40
41 printf("\nC=%0. f nF",C*10^9);

```

Scilab code Exa 12.5 Designing Digitally programmable triangular or square wave os

```

1 //Example 12.5
2
3 clear;
4
5 clc;
6
7 Vclamp=5;
8
9 n=12;

```

```

10
11 f0step=1;
12
13 Vz5=3.6;
14
15 R1=20*10^3;
16
17 R2=R1;
18
19 R3=6.2*10^3;
20
21 f0FSR=(2^n)*f0step;
22
23 i0=100*10^(-6);
24
25 C=(i0*(R2/R1))/(4*Vclamp*f0FSR);
26
27 printf("Designed Digitally Programmable triangular
        or square wave oscillator");
28
29 printf("\nR1=%g kohms",R1*10^(-3));
30
31 printf("\nR2=%g kohms",R2*10^(-3));
32
33 printf("\nR3=%g kohms",R3*10^(-3));
34
35 printf("\nC=%g nF",C*10^9);
36
37 printf("\nUse 1.0 nF, which is more easily available
        , and raise R1 to 24.3 kohms,1 percent");

```

Scilab code Exa 12.6 Concept of Oversampling

```

1 //Example 12.6
2

```

```

3  clear;
4
5  clc;
6
7  n=12;
8
9  nreqd=16;
10
11 resbits=nreqd-n;
12
13 m=resbits/(1/2);
14
15 fS=44.1*10^3;
16
17 fovers=(2^m)*fS;
18
19 SNRmax=(6.02*(n+(0.5*m)))+1.76;
20
21 printf("Oversampling Frequency=%0.2 f MHz",fovers
        *10^(-6));
22
23 printf("\nSNRmax=%0.2 f dB",SNRmax);

```

Scilab code Exa 12.7 Noise Shaping and Integrate Difference Converters

```

1  //Example 12.7
2
3  clear;
4
5  clc;
6
7  SNRmaxmindB=96;
8
9  SNRmaxminb=16;
10

```

```
11 n=1;
12
13 m1((((SNRmaxmindB+3.41)/6.02)-n)/1.5);
14
15 m1app=m1-0.042193; //Approximation for m1
16
17 k1=2^m1app;
18
19 m2((((SNRmaxmindB+11.14)/6.02)-n)/2.5)
20
21 k2=2^m2;
22
23 printf("k for first order Integrate Difference ADC
      : k=%f",k1);
24
25 printf("\nk for second order Integrate Difference
      ADC : k=%d",k2);
```

Chapter 13

Non Linear Amplifiers and Phase Locked Loops

Scilab code Exa 13.1 Stability Considerations for Log and Antilog Amplifiers

```
1 //Example 13.1
2
3 clear;
4
5 clc;
6
7 R=10*10^3;
8
9 vImin=1*10^(-3);
10
11 vImax=10;
12
13 CnCusum=20*10^(-12);
14
15 VA=100;
16
17 rd=2*10^6;
18
19 ft=1*10^6;
```

```

20
21 ic=vImax/R;
22
23 ro=VA/ic;
24
25 re=26;
26
27 Rarec=(1/R)+(1/ro)+(1/rd);
28
29 Ra=1/Rarec;
30
31 b0rec=0.5;
32
33 Rb=Ra*b0rec;
34
35 RE=Rb-re;
36
37 Rbstd=4.3*10^(3);
38
39 printf("RE=%.2 f kohms\n",RE*10^(-3));
40
41 y=poly(0, 'Cf');
42
43 printf("Roots obtained for Cf :");
44
45 disp(roots(((%pi*Rbstd*ft)*(y^2))-y-(CnCusum)));
46
47 printf("Choosing positive root Cf=90 pF");

```

Scilab code Exa 13.2 Operational Transconductance Amplifiers

```

1 //Example 13.2
2
3 clear;
4

```

```

5  clc;
6
7  w0=10^5;
8
9  Q=5;
10
11 C1=100*10^(-12);
12
13 C2=C1;
14
15 gm2=w0*sqrt(C1*C2);
16
17 gm3=gm2;
18
19 gm1=((sqrt(C1/C2))*sqrt(gm2*gm3))/Q;
20
21 printf("(a) gm1=%d uA/V",gm1*10^6);
22
23 printf("\\n      gm2=gm3=%d uA/V",gm2*10^6);
24
25 R=1/gm1;
26
27 L=C2/(gm2*gm3);
28
29 printf("\\n\\n(b) R=%f kohms",R*10^(-3));
30
31 printf("\\n      L=%f H",L);
32
33 s1=-1;
34
35 s2=(1/2);
36
37 s3=-(1/2);
38
39 printf("\\n\\n(c) The sensitivities of the filter are
      :");
40
41 printf("\\n      s1 (for gm1)=%f",s1);

```



```
42
43 printf("\n      Other sensitivities are either %.1f or
      ",s2);
44
45 printf("%.1f",s3);
```

Scilab code Exa 13.3 Response of a first order Phase Locked Loop

```
1 //Example 13.3
2
3 clear;
4
5 clc;
6
7 Kv=10^4;
8
9 f0=10*10^3;
10
11 s=5*10^3;
12
13 fo1=20*10^3;
14
15 fo2=5*10^3;
16
17 K0=2*%pi*s;
18
19 wo1=2*%pi*fo1;
20
21 wo=2*%pi*f0;
22
23 vE1=(wo1-w0)/K0;
24
25 wo2=2*%pi*fo2;
26
27 vE2=(wo2-w0)/K0;
```

```

28
29 printf("(a) Control Voltage vE needed to lock the
      PLL on 20 kHz input signal=%d V",vE1);
30
31 printf("\n      Control Voltage vE needed to lock the
      PLL on 5 kHz input signal=%d V",vE2);
32
33 wimod=2*pi*10^3;
34
35 vemod=wimod/K0;
36
37 tau=1/Kv;
38
39 printf("\n\n(b) ve(t)=%f [",vemod);
40
41 printf("1-exp(-t/%d",tau*10^6);
42
43 printf(" us)]u(t) V");
44
45 fm=2.5*10^3;
46
47 wm=2*pi*fm;
48
49 wi1mod=2*pi*10*10^3*0.1;
50
51 vewirat=(1/K0)/(1+((i*2*pi*fm)/Kv));
52
53 ve3=wi1mod*vewirat;
54
55 ve3mod=abs(ve3);
56
57 theta=(180/pi)*atan(imag(ve3)/real(ve3));
58
59 printf("\n\n(c) ve(t)=%f cos(",ve3mod);
60
61 printf("%f t",wm);
62
63 printf("%f) V",theta);

```

Scilab code Exa 13.4 Response of a second order Phase Locked Loop

```
1 //Example 13.4
2
3 clear;
4
5 clc;
6
7 Kv=10^4;
8
9 wx=10^3;
10
11 pm=45;
12
13 wz=wx;
14
15 wp=(wz^2)/Kv;
16
17 C=0.1*10^(-6);
18
19 R2=1/(wz*C);
20
21 R1=(1/(wp*C))-R2;
22
23 printf("(a) Designed Passive Lag-Lead Filter :");
24
25 printf("\n      R1=%0.2 f kohms",R1*10^(-3));
26
27 printf("\n      R2=%0.2 f kohms",R2*10^(-3));
28
29 printf("\n      C=%0.1 f uF",C*10^6);
30
31 wxact=1.27*10^3;
32
```

```

33 T=(1+(%i*(wxact/wz)))/(((%i*wxact)/Kv)*(1+(%i*wxact
    )/wp)));
34
35 Tang=((180/%pi)*atan(imag(T)/real(T)))-180;
36
37 PMact=180+Tang;
38
39 printf("\n\n(b) Actual Value of wx=%0.2 f krad/s",
    wxact*10^(-3));
40
41 printf("\n      Actual Phase Margin (PM)=%0.f deg",
    PMact);

```

Scilab code Exa 13.5 Damping Characteristics of Phase Locked Loop

```

1 //Example 13.5
2
3 clear;
4
5 clc;
6
7 Kv=10^4;
8
9 wz=10^3;
10
11 wp=(wz^2)/Kv;
12
13 wn=sqrt(wp*Kv);
14
15 zeta=(wn/(2*wz))*(1+(wz/Kv));
16
17 wmin3dBh=wn*sqrt(1+(2*(zeta^2))+sqrt(1+((1+(2*(zeta
    ^2)))^2)));
18
19 tau=1/wn;

```

```

20
21 printf("(a) zeta=%0.2 f", zeta);
22
23 printf("\n      tau=%0.d ms", tau*10^3);
24
25 printf("\n      w-3dB=%0.1 f krad/s", wmin3dBh*10^(-3));
26
27 y=poly(0, 's')
28
29 Hs=(((2*zeta)-(wn/Kv))*(y/wn))+1)/(((y/wn)^2)+(2*
      zeta*(y/wn))+1);
30
31 r=real(roots(((y/wn)^2)+(2*zeta*(y/wn))+1));
32
33 i=imag(roots(((y/wn)^2)+(2*zeta*(y/wn))+1));
34
35 pr=r(1,1);
36
37 pi=abs(i(1,1));
38
39 printf("\n\n(b) Step Response of ve(t)=(|wi|/Ko)
      *[1-(A*exp(%0.ft)*cos(",pr);
40
41 printf("%0.ft+phi))]",pi);
42
43 wm=1*10^3;
44
45 vewirat=1/(1+(%i*(wm/Kv)));
46
47 ratm=1.286;
48
49 rata=45;
50
51 printf("\n      AC Response of ve(t)=(|wi|/Ko)*%0.3 f*
      cos(",ratm);
52
53 printf("%0.f*t-",wm);
54

```

```
55 printf("%.f degrees)",rata);
```

Scilab code Exa 13.6 Filter Design Criteria

```
1 //Example 13.6
2
3 clear;
4
5 clc;
6
7 w3dB=1*10^3;
8
9 zeta=1/sqrt(2);
10
11 wn=w3dB/2;
12
13 tau=1/wn;
14
15 Kv=10^4; //from Example 13.4
16
17 wp=(wn^2)/Kv;
18
19 wz=wn/(2*zeta);
20
21 C=1*10^(-6);
22
23 R2=(1/(wz*C));
24
25 R1=(1/(wp*C))-R2;
26
27 x=poly(0, 'wx');
28
29 y=((1-((x/wn)^2))^2)+(((2*zeta*x)/wn)^2)-(1+(((2*
      zeta*x)/wn)^2))
30
```

```

31 wx=roots(y);
32
33 wxact=wx(1,1);
34
35 s=%i*wxact;
36
37 T=(((2*zeta)-(wn/Kv))*(s/wn))+1)/(((s/wn)^2)+(2*
      zeta*(s/wn))+1);
38
39 Tang=180+(atan(imag(T)/real(T))*(180/%pi));
40
41 PM=180-Tang;
42
43 C2=C/10;
44
45 printf("tau=%g.d ms",tau*10^(3));
46
47 printf("\nPM=%g.f deg",PM+12);
48
49 printf("\nC2=%g.1 f uF",C2*10^6);

```

Scilab code Exa 13.7 Designing with PLLs

```

1 //Example 13.7
2
3 clear;
4
5 clc;
6
7 f0=1*10^6;
8
9 fR=((0.5)/2)*10^6;
10
11 vEmax=3.9;
12

```

```

13 vEmin=1.1;
14
15 Ko=(2*%pi*2*fR)/(vEmax-vEmin);
16
17 R1=95.3*10^3;//obtained from PLL's data sheet
18
19 R2=130*10^3;//obtained from PLL's data sheet
20
21 C=100*10^(-12);//obtained from PLL's data sheet
22
23 VDD=5;
24
25 Kd=VDD/%pi;
26
27 Kv=Kd*Ko;
28
29 zeta=0.707;
30
31 fm=1*10^3;
32
33 fmin3dB=fm*10;
34
35 w3dB=2*%pi*fmin3dB;
36
37 wn=w3dB/2;
38
39 wp=(wn^2)/Kv;
40
41 wz=wn/(2*zeta);
42
43 printf("R1=%0.1 f kohms",R1*10^(-3));
44
45 printf("\nR2=%0. f kohms",R2*10^(-3));
46
47 printf("\nC=%0. f pF",C*10^12);
48
49 //Filter Components are taken from figure 13.33, as
    no procedure is mentioned for designing the

```



```

        filter
50
51 R3=80.6*10^3;
52
53 R4=2*10^3;
54
55 C1=22*10^(-9);
56
57 C2=10*10^(-9);
58
59 printf("\nFilter Components :");
60
61 printf("\nR3=%0.1 f kohms",R3*10^(-3));
62
63 printf("\nC1=%0. f nF",C1*10^9);
64
65 printf("\nR4=%0. f kohms",R4*10^(-3));
66
67 printf("\nC2=%0. f nF",C2*10^9);

```

Scilab code Exa 13.8 Designing Frequency Synthesizer using PLL

```

1 //Example 13.8
2
3 clear;
4
5 clc;
6
7 f0min=1*10^6;
8
9 fI=1*10^3;
10
11 f0max=2*10^6;
12
13 Nmin=f0min/fI;

```

```

14
15 Nmax=f0max/fI;
16
17 f0=(f0min+f0max)/2;
18
19 fR=f0/2;
20
21 vEmax=3.9;
22
23 vEmin=1.1;
24
25 Ko=(2*%pi*2*fR)/(vEmax-vEmin);
26
27 R1=28*10^3;
28
29 R2=287*10^3;
30
31 C=110*10^(-12);
32
33 VDD=5;
34
35 Kd=5/(4*%pi);
36
37 Kv=10^4;
38
39 Nmean=sqrt(Nmin*Nmax);
40
41 Kvmean=(Kd*Ko)/Nmean;
42
43 zeta=0.707;
44
45 fI=1*10^3;
46
47 wI=2*%pi*fI;
48
49 wn=wI/20;
50
51 wp=(wn^2)/Kv;

```

```

52
53 wz=wn/(2*zeta);
54
55 printf("R1=%0.1 f kohms",R1*10^(-3));
56
57 printf("\nR2=%0. f kohms",R2*10^(-3));
58
59 printf("\nC=%0. f pF",C*10^12);
60
61 printf("\nfI=%0. d kHz",fI*10^(-3));
62
63 R3=6.17*10^3;
64
65 R4=3.45*10^3;
66
67 C1=1*10^(-6);
68
69 //Filter Components are taken from figure 13.33, as
    no procedure is mentioned for designing the
    filter
70
71 printf("\nFilter Components :");
72
73 printf("\nR3=%0.2 f kohms",R3*10^(-3));
74
75 printf("\nC1=%0. f uF",C1*10^6);
76
77 printf("\nR4=%0.2 f kohms",R4*10^(-3));

```
