

Scilab Textbook Companion for  
Design With Operational Amplifiers And  
Analog Integrated Circuits  
by S. Franco<sup>1</sup>

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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)=%.3 f 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)=%.4 f 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=%.2 f kohms", (Ri/1000));
18
19 printf("\nRo=%. f ohms", Ro);
20
21 printf("\nA=%.2 f 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 Vo=-(Rf/R1)Vi-(Rf/R2)(-15)=-10Vi+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 =%.5 f",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 Atempr=1/Atemp;
24
25 A=(-R2/R1)*Atempr; //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*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 // 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 ctempr=1+Trec;
54
55 ctemp=1/ctempr;
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 Feedback

```
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 vO=-(R2/R1)*vI; ///Output Voltage
18
19 iL=-vO/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 iO=i2+iL; ///Output Current
26
27 iCC=IQ;
28
29 iEE=iCC+iO;
```

```

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=%0.2 f 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 across 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 across 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 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 RA=RB=25kohm then there would be
    a drop of 5V accross each component(RA,RB and
    potentiometer) which will make VA=10V and VB=-10V
    . Hence RA and RB 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 RL=1*10^3; //Load Resistance
26

```

```

27 vS=10; //Source voltage
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); //Ouput 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.

```

## Inverting Amplifier driven into saturation waveforms

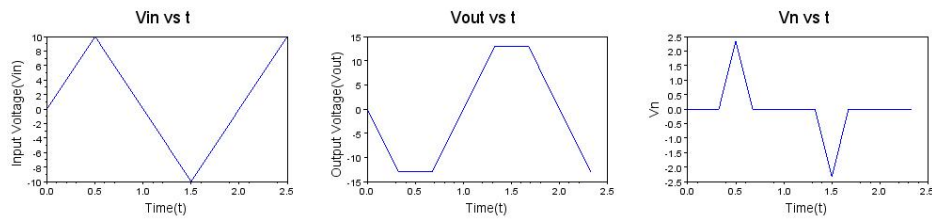


Figure 1.1: Inverting Amplifier driven into saturation

```
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);
96

```

```

97 plot(to2,vo2);
98
99 plot(to2i,vo2i);
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);
173
174 plot(tN11,vN11);
175
176 plot(tN12,vN12);
177
178 plot(tNi2,vNi2);
179
180 plot(tN21,vN21);
181
182 plot(tN22,vN22);
183
184 plot(tNi3,vNi3);
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 Conveter

```
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 Characteristics 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=%0.1 f kohms", R1*10^(-3));
29
30 printf("\nR2=%0.1 f kohms", R2*10^(-3));
31
32 printf("\nR3=%0.1 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>=%.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>=%.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)=%.3 f 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*10^3;
8
9 R3=R1;
10
11 R2=100*10^3;
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=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 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  $A_{\max}=1+\frac{2R_3}{R_4+0} \rightarrow (1-A_{\max})R_4+2R_3=0$ ....(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)=%.2 f ohms",R1);
16
17 T2=100;
18
19 R2=R0*(1+alpha*T2);
20
21 printf("\nR(100 deg Celsius)=%.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=%0.2 f ohms",dR);
20
21 printf("\nPercentage Deviation=%0.2 f 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=%0.1 f kohms",R1*10(-3));
30
31 printf("\nA=%0.1 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)=%.3f V",v01);
48
49 Tchange=v0change/s;
50
51 printf("\nEquivalent Temperature Error=%.2f 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 vO=0 V. Then supply a
    known strain, preferably near the full scale, and
    adjust R3 for the desired value of vO.");
```

---



# 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);
```

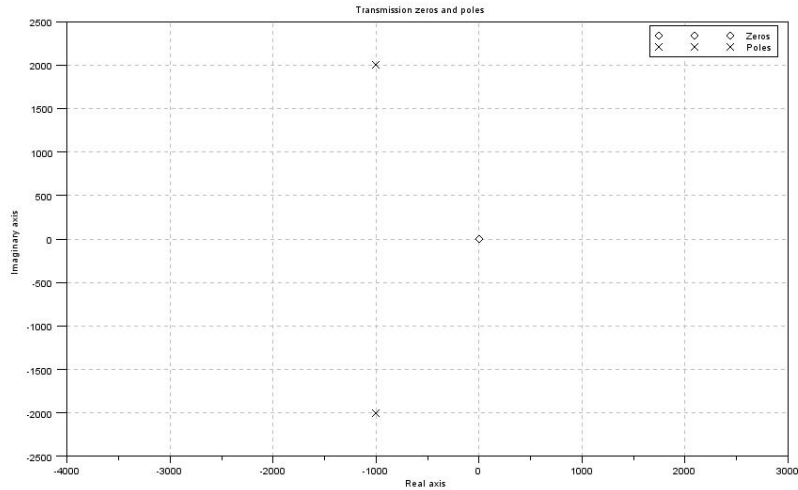


Figure 3.1: Pole Zero Response of Transfer Function

```

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*109);
38
39 printf("\nC2=%0. f nF",C2*109);

```

---

### 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*103;
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*10^3; // Assumption
24
25 R3=R2;
26
27 R4num=R2*(w0^2);
28
29 R4den=Q*abs((w0^2)-(wz^2));
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*10^9);
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 Causer 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",R12*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/((w0^2)*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
    *10^12);
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*103;
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=%0.2 f nF",C4new*10^9);
72
73 printf("\nC5new=%0.2 f nF",C5new*10^9);
74
75 printf("\nL2new=%0.2 f H",L2new);
76
77 printf("\nL4new=%0.2 f H",L4new);
78
79 printf("\n\nThe elements for GIC :");
80
81 printf("\nR1=R3=R4=R5=%0.2 f kohms",R1*10^(-3));
82
83 printf("\nR2=R6=%0.2 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("\nC1=%.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 vppmin=-1;
36
37 vppmax=1;
38
39 vomin=-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*10^3;
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*10^3); // 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 I



```

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=%.2 f kohms",R1*10^(-3));
36
37 printf("\nR2=%.2 f kohms",R2*10^(-3));
38

```

```

39 printf("\nRp=%0.2 f kohms",Rp*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 II

```

1 //Example 5.9(a)
2
3 clear;
4
5 clc;
6
7 As=5;
8
9 Vs=15;
10
11 R1=25.5*103; //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 II

```

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=%0. f ohms", RA+1);
48
49 printf("\nRB=%0. 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=%0. f kohms",RA*10^(-3));
60
61 printf("\nRB=%0. f kohms",RB*10^(-3));
62
63 printf("\nRC=%0. 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*10^3)
    ;
```

---

### 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 emax=0.01;
16
17 fmax((((1/(1-emax))^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

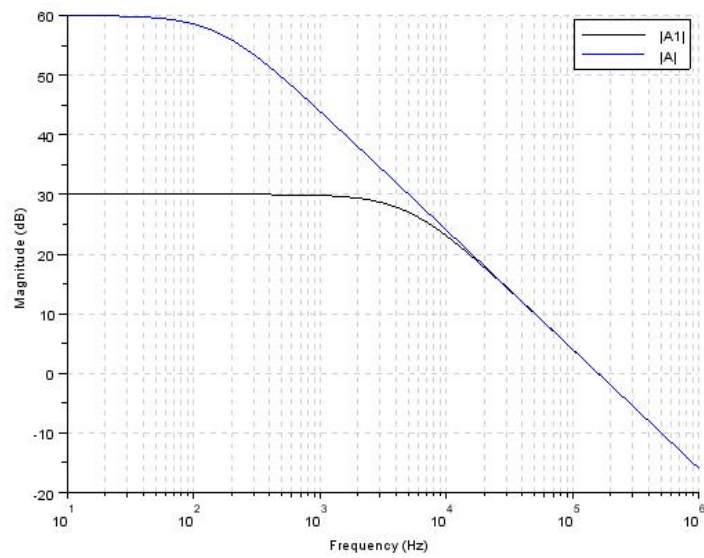


Figure 6.1: Gain Bandwidth Tradeoff

```

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*10^3;
8
9  R1=2*10^3;
10
11 R2=18*10^3;
12
13 b=R1/(R1+R2);
14
15 A0=- (1+(R2/R1))*R;
16
17 a0=2*10^5;
18
19 ft=1*10^6;
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*10^3);

```

## Step Response of the Circuit

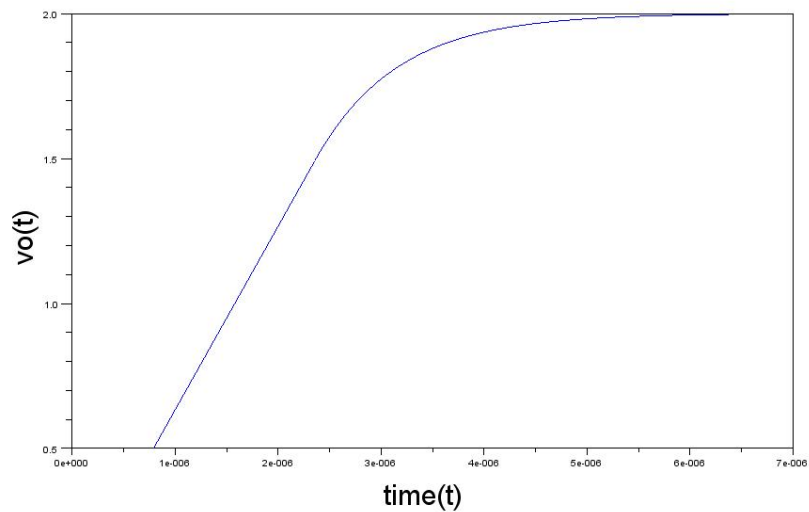


Figure 6.2: Effect of Slew Rate Limiting

```
42
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*106;
12
13 R1=3*103;
14
15 R2=12*103;
16
17 A0=-(R2/R1);
18
19 b=R1/(R1+R2);
20
21 a0=2*105;
22
23 ft=1*106;
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;
44
45 plot(t12,vo3);
46

```

```

47 t11=[tau:2*10(-8):t1+tau];
48
49 vo1=SR*(t11-tau);
50
51 t22=[t1+tau:2*10(-8):7*10(-6)];
52
53 vo2=Voinf+((V1-Voinf)*exp(-(t22-t1-tau)/tau));
54
55 plot(t11,vo1);
56
57 plot(t22,vo2);
58
59 xlabel("time(t)","fontsize",6);
60
61 ylabel("vo(t)","fontsize",6);
62
63 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*106;
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*10^3;
12
13 SR=0.5*10^6;
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*10^3;
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-Hre1er)^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=%
    .2f",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=%0.2 f pF",Ceq*10^12);
20
21 printf("\niN=%0.2 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
    *10^6);
```

---

### 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=%.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=%.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  binfreq=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/binfreq)*ft;
22
23  enw=4.5*10(-9);
24
25  Enoe=binfreq*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 configuration

```
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** Stabalizing 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=%f ohms",Rs);
30
31 printf("\n      Cf=%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*103;
16
17 ro=100;
18
19 f1=100*103;
20
21 f2=1*106;
22
23 f3=10*106;
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=%0.1 f ohms",Rc);
26
27 printf("\n      Cc=%0.3 f 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=%0.3 f 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 Follower

```

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 kohms",R1*10^(-3));
38
39 printf("\nR2=%g kohms",R2*10^(-3));
40
41 printf("\nR3=%g kohms",R3*10^(-3));
42
43 printf("\nR4=%g 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=%g. 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*10^9);

```

---

**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*10^3;
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*10^3;
20
21 Rsym=5*10^3;
22

```

```

23 Rre=R-(Rsym/2);
24
25 Rthd=100*10^3;
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*10^3;
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*10^9);
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*103;
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*103;
28
29 RC=100*103;
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*1012);
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=-((Rsm*rx)/(Rsm+rx));
30
31 loadrper=loadr*(100/6.5);
32
33 printf("(a) Rs=%f ohms",Rsm+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=%g. f ohms",R);
36
37 printf("\n\n(b) TC(Io)=%g. f nA/V",delIo*109);
38
39 printf("\n      Ro(min)=%g.2 f Mohms",Romin*10(-6));
40
41 printf("\n\n(c) VL<=%g. 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=%0.1 f" ,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=%g. f ohms",R7-2);
28
29 printf("\nR8=%g. 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=%.2 f ohms",R);
38
39 printf(",%.2 f W",PR);
40
41 printf("\nVoltage Compliance=%.2 f V",VLmax);
42
43 printf("\nMinimum Equivalent Resistance=%.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=%0.1f 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=%0.1f uH",L*10^6);
28
29 printf("\nAt full load the coil must withstand Ip=%0.1f A",Ip);
30
31 printf(" and Irms=%0.1f A",Irms);
32
33 printf("\nMinimum Load Current (Iomin)=%0.1f 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=%0.f percent",
        effper);
56
57 printf("\nEfficiency of Linear Regulator=%0.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*10^3;
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*103;
50
51 R2=10*103;

```

```
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=%g kohms",R2*10^(-3));
66
67 printf("\nR3=%g ohms",R3);
68
69 printf("\nR4=%g kohms",R4*10^(-3));
70
71 printf("\nC1=%g pF",C1*10^12);
72
73 printf("\nC2=%g nF",C2*10^9);
74
75 printf("\nC3=%g 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 oscillator

```

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=%0. f kohms",R1*10^(-3));
30
31  printf("\nR2=%0. f kohms",R2*10^(-3));
32
33  printf("\nR3=%0.1 f kohms",R3*10^(-3));
34
35  printf("\nC=%0.2 f 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=%0.2 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 Transconducatace 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=%0.1d uA/V", gm1*10^6);
22
23 printf("\n      gm2=gm3=%0.1d uA/V", gm2*10^6);
24
25 R=1/gm1;
26
27 L=C2/(gm2*gm3);
28
29 printf("\n\n(b) R=%0.1f kohms", R*10^(-3));
30
31 printf("\n      L=%0.1f 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 w0=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)=%.1f [",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)=%.4f cos(",ve3mod);
60
61 printf("%.2 ft",wm);
62

```



```
63 printf("%.2f) 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=%0.2f kohms",R1*10^(-3));
26
27 printf("\n      R2=%0.2f kohms",R2*10^(-3));
28
29 printf("\n      C=%0.1f 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=%0.2f 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=%d ms",tau*10^(3));
46
47 printf("\nPM=%f deg",PM+12);
48
49 printf("\nC2=%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));

```

---