Scilab Textbook Companion for Analog Integrated Circuits by R. S. Tomar[1]

Created by
Saleem Ahmed
B.Tech
Electrical Engineering
Uttarakhand Technical University
College Teacher
None
Cross-Checked by
Chaya Ravindra

July 7, 2014

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

Book Description

Title: Analog Integrated Circuits

Author: R. S. Tomar

Publisher: Umesh Publications, New Delhi

Edition: 2

Year: 2007

ISBN: 81-88114-72-3

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.

Contents

List of Scilab Codes

Chapter 1

Constant Current Sources

Scilab code Exa 1.1 Design a current mirror circuit

```
//Ex 1.1
clc;
clear;
close;
format('v',5);
Iout=8;//micro A
VBE=0.7;//V
Beta=80;//unitless
VCC=20;//V
IREF=Iout*(1+2/Beta);//micro A
R=(VCC-VBE)/IREF;//Mohm
disp(IREF,"Reference current(micro A)");
disp(R,"Resistance required(Mohm)");;
```

Scilab code Exa 1.2 Design a current mirror circuit

```
//Ex 1.2
clc;
```

```
clear;
close;
format('v',5);
Iout=1;//mA
VBE=0.7;//V
Beta=100;//unitless
VCC=30;//V
IREF=Iout*(1+2/Beta);//mA
R=(VCC-VBE)/IREF;//kohm
disp(IREF,"Reference current(mA)");
disp(R,"Resistance required(kohm)");;
```

Scilab code Exa 1.3 Design a current source

```
//Ex 1.3
clc;
clear;
close;
format('v',5);
Iout=0.5;//mA
Beta=50;//unitless
VEB=0.7;//V
VCC=5;//V
IREF=Iout*(1+2/Beta);//mA
R=(VCC-VEB)/IREF;//kohm
disp(IREF,"Reference current(mA)");
disp(R,"Resistance required(kohm)");;
```

Scilab code Exa 1.4 Design a current mirror circuit

```
//Ex 1.4
clc;
clear;
```

```
close;
format('v',5);
Iout=8;//micro A
Beta=100;//unitless
VBE=0.7;//V
VCC=20;//V
IREF=Iout/(1+2/Beta/(1+Beta));//micro A
R=(VCC-2*VBE)/IREF;//Mohm
disp(IREF,"Reference current(micro A)");
disp(R,"Resistance required(Mohm)");;
```

Scilab code Exa 1.5 Modified current mirror circuit

```
//Ex 1.5
clc;
clear;
close;
format('v',7);
Iout=60;//micro A
VBE=0.7;//V
Beta=150;//unitless
VCC=30;//V
IREF=Iout*(1+2/Beta/(1+Beta));//micro A
R=(VCC-2*VBE)/IREF;//Mohm
disp(IREF,"Reference current(micro A)");
disp(R*1000,"Resistance required(kohm)");;
```

Scilab code Exa 1.6 Find Iout

```
//Ex 1.6
clc;
clear;
close;
```

```
format('v',5);
VBE=0.7;//V
Beta=120;//unitless
VCC=10;//V
R=5.6;//kohm
//KCL at node x : IREF=IC1+I1;//as Beta>>1
//KCL at node y : I1=IC2+IB3;//as Beta>>1
IREF=(VCC-VBE)/R;//mA
//as IREF=2*IC+IB3=IC*(2+1/Beta)=2*IC;//as Beta>>1
IC=IREF/2;//mA
Iout=IC;//mA
disp(Iout,"Output current(mA)");
```

Scilab code Exa 1.7 Design a widlar current source

```
//Ex 1.7
clc;
clear;
close;
format('v',5);
Iout=6;//micro A
IREF=1.2;//mA
VBE2=0.7;//V
VT=26;//mV
Beta=120;//unitless
VCC=20;//V
R=(VCC-VBE2)/IREF;//kohm
disp(R,"Value of resistance R(kohm)")
IC1=Iout;//micro A
IC2=(IREF-IC1*10^-3/Beta)/(1+1/Beta);//mA
RS=1/(IC1*10^-6)*VT*10^-3*log(IC2*1000/IC1);//ohm
disp(RS/1000,"Value of resistance RS(kohm)");
```

Scilab code Exa 1.8 Design a widlar current source

```
//Ex 1.8
clc;
clear;
close;
format('v',6);
IREF=1;//mA
Io2=20;//micro A
Io3=40;//micro A
VBE1=0.7;//V
VT=26;//mV
VCC=10;//V
VEE=-10;//V
R=(VCC-VBE1-VEE)/IREF;//kohm
disp(R,"Value of resistance R(kohm)");
RE2=VT/Io2*log(IREF*1000/Io2);//kohm
disp(RE2,"Value of resistance RE2(kohm)");
RE3=VT/Io3*log(IREF*1000/Io3);//kohm
disp(RE3,"Value of resistance RE3(kohm)");
VBE2=VBE1-RE2*Io2/1000;//V
disp(VBE2,"Value of Base emitter voltage of
    transistor Q2(V)");
VBE3=VBE1-RE3*Io3/1000;//V
disp(VBE3,"Value of Base emitter voltage of
    transistor Q3(V)");
```

Scilab code Exa 1.9 Calculate Current

```
//Ex 1.9
clc;
clear;
close;
format('v',5);
Beta=100;//unitless
```

```
VBE=0.715;//V
R=5.6;//kohm
RC=1;//kohm
VCC=10;//V
VCB1=0;//V(Q1 will act as diode)
IREF=(VCC-VBE)/R;//mA
//KCL at node x : IREF=IC1+2*IB;
//KCL at node y : I1=IC2+IB3;//as Beta>>1
IREF=(VCC-VBE)/R;//mA
//as IREF=2*IC1/Beta+IC1
IC1=IREF/(1+2/Beta);//mA
IC2=IC1;//mA
IC3=IC1;//mA
disp(IC1,"Collector current in each transistor, IC1=
   IC2=IC3 in mA");
IRC=IC1+IC2+IC3;//mA
disp(IRC,"Current through RC(mA)");
```

Scilab code Exa 1.10 Determine IC1 and IC2

```
//Ex 1.10
clc;
clear;
close;
format('v',5);
Vout=5;//V
Beta=180;//unitless
R=22;//kohm
VCC=10;//V
VBE=0.7;//V
IREF=(VCC-VBE)/R;//mA
IC=(IREF-VBE/R)/(1+2/Beta);//mA
RC=(VCC-Vout)/IC;//kohm
disp(IC,"IC1 & IC2 in mA are ");
disp(RC,"RC in kohm is ");
```

```
//Answer in the book is wrong.
```

Chapter 2

Differentials Aplifiers

Scilab code Exa 2.1 Output Voltage

```
//Ex 2.1
clc;
clear;
close;
format('v',5);
v1=7; //mV
v2=9; //mV
Ad=80; //dB
CMRR=90; //dB
vid=v2-v1; //mV
vcm=(v1+v2)/2; //mV
Ad=10^(Ad/20); // unitless
CMRR=10^(CMRR/20); // unitless
vout=Ad*(vid+vcm/CMRR)/1000; //V
disp(vout,"Output Voltage(V)");;
```

Scilab code Exa 2.2 Output Voltage and percent error

```
////Ex 2.2
clc;
clear;
close;
format('v',7);
v1=50;//micro V
v2=55;//micro V
Ad=2*10^5;//unitless
CMRR=80;//dB
vid=v2-v1;//micro V
vcm=(v1+v2)/2;//mV
CMRR=10^(CMRR/20);//unitless
vout=Ad*(vid+vcm/CMRR)/10^6;//V
disp(vout,"Output Voltage(V)");;
Verror=vout-Ad*vid/10^6;//V
disp(Verror,"Error Voltage(V)");
error_p=(Verror/vout)*100;//% error
disp(error_p,"Percentage error(%)");
//Percentage error answer is not correct in the book
    .
```

Scilab code Exa 2.3 Current Ad Ac CMRR

```
////Ex 2.3
clc;
clear;
close;
format('v',6);
IT=1;//mA
VCC=15;//V
RE=50;//kohm
RC=15;//kohm
Beta=120;//unitless
alfa=Beta/(Beta+1);//unitless
Vid=6;//mV
```

```
VT=26;//mV
//Part (a)
iC1=alfa*IT/(1+exp(-Vid/VT));//mA
iC2=IT-iC1;//mA
disp(iC2,"dc Collector current through transistors(
   mA)");
//Part (b)
iC=IT/2;//mA(let iC1=iC2=iC)
re=VT/iC;//ohm(let re1=re2=re)
Ad=-RC*1000/re;//unitless
Acm=-RC*1000/(re+2*RE*1000);//unitless
Acm=abs(Acm);////unitless
CMRR=abs(Ad/Acm);////unitless
disp(Ad,"Ad");
disp(Acm,"Acm");
CMRR=20*log10(CMRR);//dB
disp(CMRR,"CMRR(dB)");
```

Scilab code Exa 2.4 Gain and CMRR

```
////Ex 2.4
clc;
clear;
close;
format('v',6);
RC=2;//kohm
RE=4.3;//kohm
VEE=5;//V
VBE=0.7;//V
IT=(VEE-VBE)/RE;//mA
VT=26;//mV
re=2*VT/IT;//ohm
Ad=-RC*1000/2/re;//unitless
disp(Ad,"Ad");
Acm=-RC*1000/(re+2*RE*1000);//unitless
```

```
disp(Acm,"Acm");
CMRR=abs(Ad/Acm);////unitless
disp(CMRR,"CMRR");
```

Scilab code Exa 2.5 Operating point Gain and Resistance

```
////Ex 2.5
clc;
clear;
close;
format('v',5);
Beta=100;//unitless
VBE=0.715;VD1=0.715;//V
VZ=6.2;//V
VT=26;//mV
IZt=41;//mA
VCC=10;//V
VEE=10;//V
RE=2.7;//kohm
RC=4.7;//kohm
VB=-VEE+VZ+VD1;//V
VE=VB-VBE;//V
IE3=(VE-(-VEE))/(RE);//mA
IT=IE3;//mA
ICQ=IT/2;//mA(let ICQ1=ICQ2=ICQ)
VCEQ=VCC+VBE-ICQ*RC;//V
Q=[ICQ VCEQ];//[mA V](Q point)
disp(Q,"Q point (ICQ(mA), VCEQ(V)) is ");
re=2*VT/IT;//ohm
Ad=-RC*1000/re;//unitless
Rid=2*Beta*re/1000;//kohm
disp(Ad,"Ad");
disp(Rid,"Rid(kohm)");
```

Scilab code Exa 2.6 Gain and input resistance

```
////Ex 2.6
clc;
clear;
close;
format('v',6);
Beta=100;//unitless
VBE=0.7;//V
VCC=10;//V
VEE=10;//V
VT=26;//mV
RC=2.7;//kohm
R=2.2;//kohm
IExt=(VEE-VBE)/R;//mA
IC3=IExt;IT=IExt;;//mA
ICQ=IT/2;//mA
re=2*VT/IT;//ohm(let re1=re2=re)
Ad=-RC*1000/re;//unitless
Rid=2*Beta*re/1000;//kohm(let Rid1=Rid2=Rid)
disp(Ad,"Differntial moe gain, Ad");
disp(Rid,"Differntial input resistance, Rid(kohm)");
```

Scilab code Exa 2.7 Q point and voltage gain

```
////Ex 2.7
clc;
clear;
close;
format('v',7);
Beta=100;//unitless
VBE=0.7;//V
```

```
VD1=0.7;VD2=0.7//V
VCC=15;//V
VEE=15;//V
VT=26;//mV
RE=560;//ohm
RC=6.8;//kohm
R=220;//ohm
VB=-VEE+VD1+VD2;//V
VE=VB-VBE;//V
IE3=(VE-(-VEE))/RE*1000;//mA
IT=IE3;//mA
ICQ=IT/2;//mA
VCEQ=VCC+VBE-ICQ*RC;//V
Q=[ICQ VCEQ];//[mA V](Q point)
disp(Q,"Q point (ICQ(mA), VCEQ(V)) is ");
re=2*VT/IT;//ohm
Ad=-RC*1000/re;//unitless
disp(Ad,"Differntial moe gain, Ad");
//Answer in the book is wrong for Q point.
```

Scilab code Exa 2.8 RC RE Rid Rid

```
////Ex 2.8
clc;
clear;
close;
format('v',5);
ICQ=200;//micro A
Beta=1000;//unitless
Ad=180;//unitless
CMRR=80;//dB
VT=26;//mV
re=VT/(ICQ/1000);//ohm(Let re=re1=re2)
RC=Ad*re/1000;//kohm
CMRR=10^(CMRR/20);//untless
```

```
RE=(CMRR-1)*re/2/1000; //kohm
disp(RE,RC,"Value of RC & RE(kohm)");
Rid=2*Beta*re/1000; //kohm(Let Rid=Rid1=Rid2)
disp(Rid,"Differntial input resistance, Rid(kohm)");
Ric=(Beta+1)*(re+2*RE*1000)/10^6; //Mohm
disp(Ric,"Common mode input resistance, Ric(Mohm)");
```

Scilab code Exa 2.9 Operating point Gain and Resistance

```
////Ex 2.9
clc;
clear;
close;
format('v',5);
Beta=110; //unitless
VBE=0.7; //V
VT=26; //mV
VCC=10; //V
VEE=10; //V
RC=1.8; //kohm
R=3.9; //kohm
IExt=(VCC-VBE-(-VEE))/R; //mA
IT=IExt;; //mA
ICQ=IT/2; //mA
V1=0;V2=0; //V
VE=-2*VBE; //V
VC=VCC-ICQ*RC; //V
VCEQ=VC-VE; //V
Q=[ICQ VCEQ]; //[mA V](Q point)
disp(Q,"Q point (ICQ(mA), VCEQ(V)) is ");
re=2*VT/IT; //ohm(let re1=re2=re)
reD=2*re; //ohm
Ad=-RC*1000/reD; //unitless
disp(Ad,"Differntial moe gain, Ad");
BetaD=Beta^2; //unitless
```

```
Rid=2*BetaD*reD/1000;//kohm(let Rid1=Rid2=Rid)
disp(Rid,"Differntial input resistance, Rid(kohm)");
//Answer for Ad is wrong(+ve) in the book while it is negative.
```

Scilab code Exa 2.10 Differential input resistance

```
////Ex 2.10
clc;
clear;
close;
format('v',9);
Beta=100;//unitless
VBE=0.7;//V
R=18.6;//kohm
VT=26;//mV
VCC=5;//V
VEE=5;//V
IExt=(VCC-VBE-(-VEE))/R;//mA
IT=IExt;;//mA
re=2*VT/IT;//ohm(let re1=re2=re)
Rid=2*Beta*re/1000;//kohm(let Rid1=Rid2=Rid)
disp(Rid,"Differntial input resistances, Rid1=Rid2(kohm)");
```

Scilab code Exa 2.11 Gain and input resistance

```
////Ex 2.11
clc;
clear;
close;
format('v',6);
Beta=100;//unitless
```

```
VBE=0.7;//V
RC=2.7;//kohm
R=2.2;//kohm
VT=26;//mV
VCC=10;//V
VEE=10;//V
IExt=(VEE-VBE)/R;//mA
IT=IExt;;//mA
IE=IT/2;//mA(Let IE1=IE2=IE)
re=2*VT/IT;re1=re;re2=re;re3=re;re4=re//ohm
reD=re1+re2;//ohm
BetaD=Beta^2;//unitless
Ad=-RC*1000/reD;//unitless
disp(Ad,"Differential voltage gain, Ad")
Rid=2*BetaD*reD/1000;//kohm(let Rid1=Rid2=Rid)
disp(Rid,"Differntial input resistances, Rid1=Rid2(
    kohm)");
//Answer in the bok is not accurate.
```

Chapter 3

Operational Amlifiers and their Parameters

Scilab code Exa 3.1 Open loop gain

```
//Ex 3.1
clc;
clear;
close;
format('e',8);
fBW=4;//MHz
fo=10;//Hz
AOL=fBW*10^6/fo;//unitless
disp(AOL,"Open loop gain is");
```

Scilab code Exa 3.2 Time taken

```
//Ex 3.2
clc;
clear;
close;
```

```
format('v',5);
V1=-10;//V
V2=10;//V
SR=0.5;//V/micro second
delta_Vo=V2-V1;//V
delta_t=delta_Vo/SR;//micro second
disp(delta_t,"Time taken by op-amp is(micro second)");
```

Scilab code Exa 3.3 Maximum Voltage

```
//Ex 3.3
clc;
clear;
close;
format('v',6);
SR=0.6;//V/micro second
f=100;//kHz
Vm=(SR/10^-6)/(2*%pi*f*1000);//V
disp(Vm,"Maximum voltage, Vm is(V)");
```

Scilab code Exa 3.4 Maximum Frequency

```
//Ex 3.4
clc;
clear;
close;
format('v',5);
SR=0.5;//V/micro second
Vm=10;//V
f=100;//kHz
fm=(SR/10^-6)/(2*%pi*Vm);//Hz
disp(fm/1000,"Maximum frequency, fm is(kHz)");
```

Scilab code Exa 3.5 Slew rate

```
//Ex 3.5
clc;
clear;
close;
format('v',5);
delta_t=0.3/2;//micro second
V1=-3;//V
V2=3;//V
delta_Vo=V2-V1;//V
SR=delta_Vo/delta_t;//V/micro second
disp(SR,"Slew rate is(V/micro second)");
```

Scilab code Exa 3.6 Close Loop Voltage Gain

```
//Ex 3.6
clc;
clear;
close;
format('v',5);
SR=2;//V/micro second
delta_Vin=0.8;//V
delta_t=10;//micro second
Acl_max=SR/(delta_Vin/delta_t);//unitless
disp(Acl_max,"Maximum close loop voltage gain is");
```

Scilab code Exa 3.7 Limiting Frequency

```
//Ex 3.7
clc;
clear;
close;
format('v',5);
SR=6;//V/micro second
//Part (i)
Vm=1;//V
fm=(SR/10^-6)/(2*%pi*Vm);//Hz
disp(fm/1000,"part (i) Maximum frequency, fm is(kHz)
    ");
//Part (i)
Vm=10;//V
fm=(SR/10^-6)/(2*%pi*Vm);//Hz
disp(fm/1000,"part (ii) Maximum frequency, fm is(kHz
    )");
```

Chapter 4

Opamps with negative feedback

Scilab code Exa 4.1 Bandwidth with feedback

```
////Ex 4.1
clc;
clear;
close;
format('v',9);
AOL=2*10^5;//unitless
fo=5;//Hz
ACL=100;//unitless
SF=AOL/ACL;//unitless
fodash=SF*fo;//Hz
disp(fodash/1000,"Bandwidth with feedback(kHz)");
```

Scilab code Exa 4.2 Acl Rif Rof fodash

```
////Ex 4.2
clc;
clear;
close;
```

```
format('v',6);
AOL=2*10^5;//unitless
Ri=1.5;//kohm
Rf=12;//kohm
Rio=1;//Mohm
Ro=100;//ohm
fo=5;//Hz
Beta=Ri/(Ri+Rf);//unitless
SF=(1+AOL)*Beta;//unitless
ACL=AOL/SF;//unitless
disp(ACL,"Value of ACL");
//In case of ideal opamp
ACL=1+Rf/Ri;//unitless
disp(ACL,"In case of ideal opamp, Value of ACL");
Rif=Rio*SF;//kohm
disp(Rif,"Value of Rif(Mohm)");
disp("This is a large value can be assumed as infity
    resistance.");
format('v',5);
Rof=Ro/SF;//mohm
disp(Rof*1000,"Value of Rof(mohm)");
fodash=SF*fo;//Hz
disp(fodash/1000,"Bandwidth with feedback, fo_dash(
    kHz)");
//Answer for Rif in the book has mistake of unit.
```

Scilab code Exa 4.3 Impedence and gain

```
////Ex 4.3
clc;
clear;
close;
format('v',9);
AOL=%inf;//unitless
Rio=%inf;//ohm
```

```
Ri=1;//kohm
Rf=15;//kohm
SF=%inf;//unitless;//as SF=1+AOL*Beta
Beta=Ri/(Ri+Rf);//unitless
ACL=1/Beta;//unitless
disp(Rio,"Input impedence(ohm) for ideal opamp is ")
    ;
disp(ACL,"Gain of the circuit , ACL");
```

Scilab code Exa 4.4 Input and output impedence

```
////Ex 4.4
clc;
clear;
close;
format('v',9);
AOL=400;//unitless
Rio=500;//kohm
Ro=75;//ohm
ACL=100;//unitless
SF=AOL/ACL;//unitless
Rif=Rio*SF;//kohm
disp(Rif/1000,"Input impedence, Rif(Mohm)");
Rof=Ro/SF;//ohm
disp(Rof,"Output impedence, Rof(ohm)");
```

Scilab code Exa 4.5 Non Inverting Amplifier

```
////Ex 4.5
clc;
clear;
close;
format('v',5);
```

```
ACL=200; // unitless
AOL=2*10^5; // unitless
Rio=2; //Mohm
Ro=75; //ohm
Ri=1; //kohm(Assumed)
SF=AOL/ACL; // unitless
Beta=(SF-1)/AOL; // unitless
Rf=Ri*(1-Beta)/Beta; //kohm
disp(Ri,"Input impedence, Rif(kohm)");
disp(Rf,"Feedback impedence, Rf(kohm)");
```

Scilab code Exa 4.6 Close Loop Voltage Gain

```
////Ex 4.6
clc;
clear;
close;
format('v',5);
AOL=50; // unitless
Beta=0.8; // unitless
deltaAOL=-20; //%(Change in open loop gain)
deltaBeta=15; //%(Change in feedback factor)
AOLnew=AOL+AOL*deltaAOL/100; // unitless (AOL after change)
Betanew=Beta+Beta*deltaBeta/100; // unitless (Beta after change)
ACL=AOLnew/(1+AOLnew*Betanew); // unitless
disp(ACL,"Close loop gain, ACL");
```

Scilab code Exa 4.7 Acl Rif Rof

```
////Ex 4.7
clc;
```

```
clear;
close;
format('v',5);
AOL=500;//unitless
Rio=300;//kohm
Ro=100;//ohm
ACL=AOL/(1+AOL);//unitless
Rif=Rio*(1+AOL)/1000;//Mohm
Rof=Ro/(1+AOL);//ohm
disp(ACL,"Close loop gain, ACL");
disp(Rif,"Value of Rif(Mohm)");
disp(Rof,"Value of Rof(ohm)");
```

Scilab code Exa 4.8 Output Voltage

```
////Ex 4.8
clc;
clear;
close;
format('v',5);
Iin=1;//mA
Rf=1;//kohm
IB=0;//for ideal opamp
If=Iin-IB;//mA
Vout=-If*Rf;//V
disp(Vout,"Output Voltage(V)");
```

Scilab code Exa 4.9 Variation in output Voltage

```
////Ex 4.9
clc;
clear;
close;
```

```
format('v',5);
I2=1;//mA
Rf=4.7;//kohm
//Case 1st
I1=500;//micro A
Vout1=-I1*10^-6*Rf*10^3;//V
disp(Vout1,"For 500 micro A current, Output Voltage(
    V)");
//Case 2nd
I2=1;//mA
Vout2=-I2*10^-3*Rf*10^3;//V
disp(Vout2,"For 1 mA current, Output Voltage(V)");
deltaVout=Vout2-Vout1;//V
disp(deltaVout,"Variation in Output Voltage(V)");
```

Scilab code Exa 4.10 Gain and impedence

```
////Ex 4.10
clc;
clear;
close;
format('v',5);
AOL=2*10^5;//unitless
Rio=2;//Mohm
Ro=75;//ohm
Ri=1;//kohm
Rf=10;//kohm
ACL=-AOL*Rf/(Rf+Ri+AOL*Ri);//unitless(Exact)
disp(ACL,"Exact close loop voltage gain");
ACL=-Rf/Ri;//unitless(Approximate)
disp(ACL,"Approximate close loop voltage gain");
Beta=Ri/(Ri+Rf);//unitless
SF=1+AOL*Beta;//unitless
Rif=Rio*10^6/SF;//ohm
disp(Rif,"Input impedence after feedback(ohm)");
```

Scilab code Exa 4.11 Gain and Bandwidth

```
////Ex 4.11
clc;
clear;
close;
format('v',5);
Ri=2;//kohm
Rf=200;//kohm
//For 741C
fo=5;//Hz
AOL=2*10^5;//unitless
UGB=1;//MHz
ACL=-AOL*Rf/(Rf+Ri+AOL*Ri);//unitless(Exact)
disp(ACL,"Close loop voltage gain");
fodash=fo*AOL/-ACL;//Hz
disp(fodash/1000,"Bandwidth, fo_dash(kHz)");
```

Scilab code Exa 4.12 Calculate Gain

```
////Ex 4.12
clc;
clear;
close;
format('v',6);
Beta=0.06;//feedback factor
fo=100;//Hz
AOL=40000;//unitless(at dc)
SFdc=1+AOL*Beta;//sacrifice factor at dc
f=1;//kHz
f=f*10^3;//Hz
```

```
SF1=1+AOL*Beta/sqrt(1+f^2/fo^2);//sacrifice factor
   at 1 kHz
//(a)
ACL=AOL/SFdc;//(unitless)exact close loop gain at dc
disp(ACL,"Exact close loop gain at dc");
//(b)
ACL=1/Beta;//(unitless)approximate close loop gain
   at dc
disp(ACL,"Approximate close loop gain at dc");
//(c)
AOL=3980;//unitless(at dc)
ACL=AOL/SF1;//(unitless)exact close loop gain at 1
   kHz
disp(ACL,"Exact close loop gain at 1kHz");
```

Scilab code Exa 4.13 Input and output impedence

```
////Ex 4.13
clc;
clear;
close;
format('v',5);
Beta=0.04;//feedback factor
AOL=5000;//unitless(at dc)
Rio=40;//kohm
Ro=1;//kohm
SF=1+AOL*Beta;//sacrifice factor at dc
Rif=Rio/SF*1000;//ohm
disp(Rif,"Input impedence(ohm)");
Rof=Ro*1000/SF;//ohm
disp(Rof,"Output impedence(ohm)");
```

Chapter 5

Linear Applications of OPamps

Scilab code Exa 5.1 Output Voltage

```
//Ex 5.1
clc;
clear;
close;
format('v',5);
V1=2;V2=3;V3=4;V4=5;//V
R1=10;R2=15;R3=22;R4=50;//kohm
Rf=10;//kohm
Vout=-Rf/R1*V1-Rf/R2*V2-Rf/R3*V3-Rf/R4*V4;//V
disp(Vout,"Output voltage of the circuit(V)");;
```

Scilab code Exa 5.2 Resistor R1 and R2

```
//Ex 5.1
clc;
clear;
close;
format('v',5);
```

```
Rf=240;//kohm
//Vout=-4*Vx+3*Vy;
//case 1st
Vy=0;//V(But Vx is not=0)
//Vox=-Rf/R1*Vx=-4*Vx
R1=Rf/4;//kohm
//case 2nd
Vx=0;//V(But Vy is not=0)
//Voy=(1+Rf/R1)*R2*Vy/(R1+R2)=3*Vy
R2=3/(1+Rf/R1)*R1/((1-3/(1+Rf/R1)))
disp(R1,"Resistance R1(kohm)");
disp(R2,"Resistance R2(kohm)");
```

Scilab code Exa 5.3 Output Voltage

```
//Ex 5.3
clc;
clear;
close;
format('v',5);
V1=-2;V2=3;//V
R1=50;R2=100;//kohm
Rf=250;//kohm
//I1+I2=If with IB=0 & Vx=0
Vout=-(V1/R1+V2/R2)*Rf;//V
disp(Vout,"Output Voltage(V)");
```

Scilab code Exa 5.4 Output Voltage

```
//Ex 5.4
clc;
clear;
close;
```

```
format('v',5);
V1=-2;V2=3;//V
R1=12;R2=12;R3=10//kohm
Rf=12;Ri=12;//kohm
Rt=2;//kohm
Vyx=200*10^-6;//V
Vout=Rf/Ri*(1+2*R3/Rt)*Vyx;//V
disp(Vout*1000,"Output Voltage(mV)");
```

Scilab code Exa 5.5 Instrumentation Amplifier

```
//Ex 5.5
clc;
clear;
close;
format('v',4);
Ad=5:200;//Gain
R1max=50;//kohm(Potentiometer)
R4=10;R3=10;//kohm
//Case 1st : Ad=Admin &R1=R1max
R1=R1max;//kohm
R2=(min(Ad)-1)/2*R1max
//Case 2nd : Ad=Admax &R1=R1min
R1min=2*R2/(max(Ad)-1);//kohm
disp(R2,"Resistance R2(kohm)");
disp(R1min,"Minimum value of resistance R1(kohm)");
```

Scilab code Exa 5.6 Gain and Impedence

```
//Ex 5.6
clc;
clear;
close;
```

```
format('v',8);
R3=1;//kohm
Rt=5;//kohm
Ri=1.8;R1=1.8;//kohm
Rf=18;R2=18;//kohm
Vs=15;//V
AoL=2*10^5;//Gain(for 741C)
Rio=2//Mohm
Ro=75//Mohm
fo=5;//Hz
fBW=1;//MHz
Ad=Rf/Ri*(1+2*R3/Rt);//differential gain
disp(Ad,"Differential gain");
Beta=(R3+Rt)/(2*R3+Rt);//unitless
Rix=Rio*10^6*(1+AoL*Beta);//ohm
disp(Rix,"Input impedence, Rix(ohm)");
Rof=Ro/(1+AoL/Ad);//ohm
disp(Rof,"Output impedence, Rof(ohm)");
//Answer in the book is wron for Rix.
```

Scilab code Exa 5.8 Output Voltage

```
//Ex 5.8
clc;
clear;
close;
format('v',8);
Ri=10;//kohm
Rf=15;//kohm
Vs=9;//V
//Part (a)
Ra=120;Rb=120;Rc=120;Rd=120;//ohm
Vx=0;Vy=0//V(as Bridge is balanced)
Vout=(Vy-Vx)*Rf/Ri;//V
disp(Vout,"(a) Output Voltage(V)");
```

```
//Part (b)
Ra=120;Rb=120;Rc=120;Rd=150;//ohm
Vx=Rb*Vs/(Ra+Rb);//V
Vy=Rc*Vs/(Rc+Rd)//V
Vyx=Vy-Vx;//V
Vout=(Vy-Vx)*Rf/Ri;//V
disp(Vout,"(b) Output Voltage(V)");
```

Scilab code Exa 5.9 Output Voltage

```
//Ex 5.9
clc;
clear;
close;
format('v',8);
Vin=2;//V
Rf=2*2/(2+2)+2;//kohm
R1=1;//kohm
Vout=-Rf/R1*Vin;//V
disp(Vout,"Output Voltage(V)");
```

Scilab code Exa 5.11 Resistor Ri and Rf

```
//Ex 5.11
clc;
clear;
close;
format('v',4);
G=20;//dB(Gain)
f3dB=2;//kHz
Cf=0.05;//micro F
Rf=1/(f3dB*1000*2*%pi*Cf/1000000)/1000;//kohm
G=10^(G/20);//Gain(unitless)
```

```
Ri=Rf*1000/G;//ohm
disp(Rf,"Resistance Rf(kohm)");
disp(Ri,"Resistance Ri(ohm)");
```

Scilab code Exa 5.13 Output of opamp

```
//Ex 5.13
clc;
clear;
close;
format('v',4);
t2=50;//ms(After open the switch)
R=40;//kohm
C=0.2;//micro F
V2=3;//V
Vin=5;//V
//For Ideal op-amp V1=V2
t1=0;//s
Vout1=V2;//V
V1=V2;//V
t2=t2*10^-3;//s
Vout2=-1/(R*10^3*C*10^-6)*integrate('Vin-V1','T',0,
    t2)+Vout1;//V
//Here we have t=0 switch closed Vout=3V
t=[t1*1000 t2*1000];//ms
Vout=[Vout1 Vout2];//V
plot(t,Vout);
title('Vout Vs time after switch is opened');
xlabel('t(ms)');
ylabel('Vout(V)');
```

Scilab code Exa 5.14 Output Voltage

```
//Ex 5.14
clc;
clear;
close;
format('v',4);
R1=1;//kohm
R2=1;//kohm
R3=1;//kohm
Rf=R2+R3;//kohm
Vin=1;//V
//Capacitor remains open circuited for steady state
   in both cases.
Vout=-Rf/R1*Vin;//V
disp(Vout,"Output Voltage(V)");
```

Scilab code Exa 5.16 Design required circuit

```
//Ex 5.16
clc;
clear;
close;
format('v',4);
//From the given equationVout=-integrate('5*Vx+2*Vy
   +4*Vz','t',0,t) :
R1Cf=1/5;R2Cf=1/2;R3Cf=1/4;
disp("Various design parameters are : ");
Cf=10;//micro F////Chosen for the design
disp(Cf,"Capacitance(micro F)");
R1=R1Cf/(Cf*10^-6)/1000;//kohm
R2=R2Cf/(Cf*10^-6)/1000;//kohm
R3=R3Cf/(Cf*10^-6)/1000;//kohm
disp(R1,"Resistance R1(kohm)");
disp(R2,"Resistance R1(kohm)");
disp(R3,"Resistance R1(kohm)");
```

Scilab code Exa 5.17 Output of opamp

```
//Ex 5.17
clc;
clear;
close;
format('v',4);
f=10;//kHz
Rf=3.2;//kohm
Ci=0.001;//micro F
dt=5;//micro seconds
dVin=5-(-5);//V(When voltage changes from -5V to +5V)
Vout=-Rf*1000*Ci*10^-6*dVin/(dt*10^-6);//V
disp(Vout,"When voltage changes from -5V to +5V, The output Voltage(V)");
dVin=-5-(+5);//V(When voltage changes from +5V to -5V)
Vout=-Rf*1000*Ci*10^-6*dVin/(dt*10^-6);//V
disp(Vout,"When voltage changes from +5V to -5V, The output Voltage(V)");
```

Scilab code Exa 5.18 Design a differentiator

```
//Ex 5.18
clc;
clear;
close;
format('v',5);
fmin=200;//Hz
fmax=1;//kHz
fa=fmax;//kHz
```

```
disp("Various design parameters are : ");
Ci=0.05;//micro F////Chosen for the design
disp(Ci,"Capacitance Ci(micro F)");
format('v',4);
fb=10*fa;//kHz
Rf=1/(2*%pi*fa*10^3*Ci*10^-6)/1000;//kohm
disp(Rf,"Resistance Rf(kohm)");
Ri=1/(2*%pi*fb*10^3*Ci*10^-6);//ohm
disp(Ri,"Resistance Ri(ohm)");
format('v',6);
Cf=Ri*Ci/(Rf*10^3);//micro F
disp(Cf,"Capacitance Cf(micro F)");
```

Scilab code Exa 5.19 Design a differentiator

```
//Ex 5.19
clc;
clear;
close;
format('v',5);
fmax=100;//Hz
fa=fmax;//Hz
disp("Various design parameters are : ");
Ci=0.1;//micro F////Chosen for the design
disp(Ci,"Capacitance Ci(micro F)");
Rf=1/(2*%pi*fa*Ci*10^-6)/1000;//kohm
disp(Rf,"Resistance Rf(kohm)");
disp("Use f=15 kohm");
fb=15*fa;//kHz
Ri=1/(2*%pi*fb*Ci*10^-6)/1000;//kohm
disp(Ri,"Resistance Ri(kohm)");
disp("Use Ri=1 kohm");
format('v',6);
Cf=Ri*Ci/Rf;//micro F
disp(Cf,"Capacitance Cf(micro F)");
```

```
//Answer in the book is not accurate for Cf.
```

Scilab code Exa 5.20 Rf Ri and Cf

```
//Ex 5.20
clc;
clear;
close;
format('v',5);
f=50;//Hz
T=1/f;//s(Period)
Ci=0.05;//micro F
RiCi=0.01*T;//Given
Ri=RiCi/(Ci*10^-6)/1000;//kohm
disp(Ri,"Resistance Ri(kohm)");
//Vout=-.002*dVin/dt given
//On comparing with Vout=-Rf*Ci*dVin/dt
RfCi=0.002;//on comparing
Rf=RfCi/(Ci*10^-6)/1000;//kohm
disp(Rf,"Resistance Rf(kohm)");
Cf=Ri*Ci/Rf;//micro F
format('v',6);
disp(Cf,"Capacitance Cf(micro F)");
```

Chapter 6

Oscillators and waveform generators

Scilab code Exa 6.1 Design a RC phase shift oscillator

```
//Ex 6.1
clc;
clear;
close;
format('v',6);
f0=600;//Hz//Oscillating Frequency
disp("Various design parameters are :-");
C=0.05;//micro F//Chosen for the design
disp(C,"Capacitance(micro F)");
format('v',5);
R=1/(2*%pi*f0*sqrt(6)*C*10^-6);//ohm
R=R/1000;//kohm
disp(R,"Resistance R(kohm)");
disp("We can use R=2.2 kohm for design purpose.")
//To avoid loading effect
Ri=10*R;//kohm//Ri>=10*R
Ri=ceil(Ri);//kohm
disp(Ri,"Resistance Ri(kohm)");
Rf=29*Ri;//kohm//Rf>=29*Ri
```

```
disp(Rf,"Resistance Rf(kohm)");
disp("We can use Rf=640 kohm for design purpose.")
Rf=640;//kohm
//Balancing the circuit
Rom=Rf*Ri/(Rf+Ri);//kohm
Rom=ceil(Rom);//kohm
format('v',6);
disp(Rom,"Resistance Rom(kohm)");
```

Scilab code Exa 6.3 Design a wein bridge oscillator

```
//Ex 6.3
clc;
clear;
close;
format('v',5);
f0=12;//kHz//Oscillating Frequency
disp("Various design parameters are :-");
C=0.01;//micro F//Chosen for the design between 0.01
    & 1 micro F
disp(C,"Capacitance(micro F)");
R=1/(2*%pi*f0*1000*C*10^-6);//ohm
R=R/1000;//kohm
disp(R,"Resistance R(kohm)");
format('v',5);
Ri=3*R/2;//kohm//Ri>=3*R/2
disp(Ri,"Resistance Ri(kohm)");
disp("We can use Ri=2.2 kohm for design purpose.")
Ri=2.2;//kohm
Rf=2*Ri;//kohm
disp(Rf,"Resistance Rf(kohm)");
disp("We should use Rf=4.7 kohm for design purpose."
  )
```

Scilab code Exa 6.5 Design a wein bridge oscillator

```
//Ex 6.5
clc;
clear;
close;
format('v',5);
f0=2;//kHz//Oscillating Frequency
disp("Various design parameters are :-");
C=0.05;//micro F//Chosen for the design
disp(C,"Capacitance(micro F)");
R=1/(2*%pi*f0*1000*C*10^-6);//ohm
R=R/1000;//kohm
disp(R,"Resistance R(kohm)");
format('v',5);
Ri=3*R/2;//kohm//Ri>=3*R/2
format('v',4);
disp(Ri,"Resistance Ri(kohm)");
disp("We can use Ri=2.2 kohm for design purpose.")
Rf=2*Ri;//kohm
disp(Rf,"Resistance Rf(kohm)");
disp("We should use 5k pot for Rf.")
```

Scilab code Exa 6.6 Frequency of oscillation

```
//Ex 6.6
clc;
clear;
close;
format('v',6);
//Data given
R1=1;//kohm
```

```
R2=1;//kohm
R=1;//kohm
C=4.7;//micro F
f0=1/(2*%pi*R*10^3*C*10^-6);//Hz//Oscillating
    Frequency
disp(f0,"Oscillation frequency(Hz)");
```

Scilab code Exa 6.7 Design a quadrature oscillator

```
//Ex 6.7
clc;
clear;
close;
format('v',5);
f0=200;//Hz//Oscillating Frequency
disp("Various design parameters are :-");
C=0.05;//micro F//Chosen for the design
disp(C,"Capacitance(micro F)");
R=0.159/(f0*C*10^-6);//ohm
R=R/1000;//kohm
disp(R,"Resistance R(kohm)");
disp("We should use R=510 kohm for the design.")
R=510;//kohm
C1=C;C2=C;C3=C;//micro F
disp(C3,C2,C1,"Capacitance C1, C2 & C3(micro F)");
R2=R;R3=R;//kohm
disp(R3,R2,"Resistance R2, R3(kohm)");
disp("1000k pot can be used.")
//Answer for R is calculated wrong in the textbook.
```

Scilab code Exa 6.8 Causes of distortion

```
//Ex 6.8
```

```
clc;
clear;
close;
format('v',5);
Rf=570;//kohm
Ri=15;//kohm
A=Rf/Ri;//Gain of the circuit
Amin=29;//Minimum Gain requirement of RC phase shift
    oscillator
deltaA=(A-Amin)/Amin*100;//%(Exceeding Gain)
disp(deltaA,"Gain is exceeded by(%) ");
disp("It will cause distortion at output.");
```

Scilab code Exa 6.9 Frequency of oscillation

```
//Ex 6.9
clc;
clear;
close;
format('v',6);
disp("Part (a)");
L1=25;//micro H
L2=10;//micro H
Rf=22;//kohm
C=0.01;//micro F
LT=L1+L2;//micro H
fr=1/(2*%pi*sqrt(C*10^-6*LT*10^-6));//Hz
fr=fr/1000;//kHz
f0=fr;///kHz
disp(f0,"Oscillation frequency(kHz)");
Ri=Rf/(L1/L2);//kohm
disp(Ri,"Resistance Ri(kohm)");
disp("Part (b)");
C1=220;//pF
C2=680;//pF
```

```
Rf=22;//kohm
L=1;//mH
CT=C1*C2/(C1+C2);//pF
fr=1/(2*%pi*sqrt(L*10^-3*CT*10^-12));//Hz
fr=fr/1000;//kHz
f0=fr;///kHz
f0=round(f0);//kHz
disp(f0,"Oscillation frequency(kHz)");
Ri=Rf/(C1/C2);//kohm
disp(Ri,"Resistance Ri(kohm)");
```

Scilab code Exa 6.10 Design a square wave generator

```
//Ex 6.10
clc;
clear;
close;
format('v',6);
f0=1;///kHz
Vsat=14;//V
disp("Various design parameters are :-");
C1=0.05;//micro F//Chosen for the design
disp(C1,"Capacitance(micro F)");
Rf=1/(2*f0*10^3*C1*10^-6)/1000;//kohm
disp(Rf,"Resistance Rf(kohm)");
//R2=0.86*R1 and Rf=R1||R2
R2byR1=0.86;//from R2=0.86*R1
R2=Rf*(1+R2byR1);//kohm
R1=R2/R2byR1;//kohm
disp(R1,"Resistance R1(kohm)");
disp("Use R1=22 kohm for the design.");
disp(R2,"Resistance R2(kohm)");
```

Scilab code Exa 6.11 Find Rf and C

```
//Ex 6.11
clc;
clear;
close;
format('v',6);
T=10;//ms//(Time period)
f0=1/(T*10^-3);//Hz
C=0.05;//micro F//Chosen for the design
//Formula : f0=1/{2*Rf*C*log(1+2*R2/R1)}
Rf=1/(f0*2*C*10^-6*log(1+2))/1000;//kohm//By putting
    R1=R2 for this case
Rf=round(Rf);//kohm
disp(Rf,"Resistance Rf(kohm)");
disp(C,"Capacitance for the design(micro F)");
```

Scilab code Exa 6.12 Frequency of output

```
//Ex 6.12
clc;
clear;
close;
format('v',6);
R1=4.7;//kohm
R2=3.3;//kohm
Rf=2;//kohm
C=0.1;//micro F
f0=1/2/(Rf*1000)/(C*10^-6)/log(1+2*R2/R1)/1000;//kHz
disp(f0,"Frequency of output signal(kHz)");
```

Scilab code Exa 6.13 Triangular wave generator

```
//Ex 6.13
clc;
clear;
close;
format('v',6);
f0=1.5;//kHz
Vout=6;//V////peak to peak
Vsat=13.5;//V
disp("Various design parameters are : ");
R2=10;//kohm///choosen for the design
R1=R2*2*Vsat/Vout;//kohm
disp(R1,"R1(kohm)");
disp(R2,"R2(kohm)");
disp("Use R1=50 kohm for the design");
//Let Cf=0.05 micro F for the design
Cf=0.05;//micro F
disp(Cf,"Cf(micro F)");
Ri=R1*1000/(f0*1000)/4/(Cf*10^-6*R2*1000)/1000;//
    kohm
disp(Ri,"Ri(kohm)");
```

Scilab code Exa 6.14 Peak output voltage

```
//Ex 6.14
clc;
clear;
close;
format('v',4);
//Data given
R1=6.8;//kohm
Ri=100;//kohm
R2=1.5;//kohm
Cf=0.01;//micro F
Vsat=14;//V
Vo_pp=2*R2/R1*Vsat;//V////Peak to peak output of
```

```
triangular wave
disp(Vo_pp,"Peak to peak output of triangular wave(V)");
format('v',5);
f0=R1*1000/(4*Ri*10^3*Cf*10^-6*R2*10^3)/1000;//kHz// Oscillating Frequency
disp(f0,"Oscillation frequency(Hz)");
```

Scilab code Exa 6.15 Triangular wave generator

```
//Ex 6.15
clc;
clear;
close;
format('v',4);
//Data given
f0=1;//kHz
Vo_pp=7;//V
Vsat=14;//V
disp("Various design parameters are :-");
//Let R2=10;//kohm for the design
R2=10;//kohm
R1=2*R2*Vsat/Vo_pp;//kohm
disp(R1,"R1(kohm)");
disp(R2,"R2(kohm)");
//Choose Cf=0.1 micro F for the design
Cf=0.1;//micro F
disp(Cf,"Cf(micro F)");
Ri=R1*10^3/(4*f0*10^3*Cf*10^-6*R2*10^3)/1000;//kohm
disp(Ri,"Ri(kohm)");
```

Scilab code Exa 6.16 Frequency of output

```
//Ex 6.16
clc;
clear;
close;
format('v',4);
//Data given
tau=1;//ms(time period)
R1byR2=1.8:0.2:9;//range of R1/R2
Beta_min=1/(1+min(R1byR2));//minimum value of Beta
Beta_max=1/(1+max(R1byR2));//maximum value of Beta
Tmax=2*tau*log((1+Beta_min)/(1-Beta_min));//ms////For minimum value of Beta
fmin=1/(Tmax*10^-3);//Hz
Tmin=2*tau*log((1+Beta_max)/(1-Beta_max));//ms////For maximum value of Beta
fmax=1/(Tmin*10^-3)/1000;//kHz
disp("Frequency range is "+string(fmin)+" Hz to "+string(fmax)+" kHz.");
```

Scilab code Exa 6.17 Series and parallel resonant frequencies

```
//Ex 6.17
clc;
clear;
close;
format('v',4);
//Data given
Ls=3;//H
Cs=0.05;//pF
Rs=2;//kohm
Cm=10;//pF
fS=1/2/%pi/sqrt(Ls*Cs*10^-12)/1000;//kHz
disp(fS,"Series resonant frequency(kHz)");
CT=Cm*Cs/(Cm+Cs);//pF////Equivalent capacitance
fP=1/2/%pi/sqrt(Ls*CT*10^-12)/1000;//kHz
```

```
disp(fP,"Parallel resonant frequency(kHz)");
```

Scilab code Exa 6.18 Design a function generator

```
//Ex 6.18
clc;
clear;
close;
format('v',5);
//Data given
f0=5;//kHz
D=60;//%////duty cycle
VCC=12;//V
//As D=t1/(t1+t2)
t2BYt1=1/(D/100)-1;//ratio of t1 & t2
//RB/(2*RA-RB)=t2/t1
RAbyRB=(1/t2BYt1+1)/2;//Ratio of RA & RB
disp("Various design parameters are :");
//Let CT=0.05 micro F for this design choosing
   between 0.01 & 1 microo F
CT=0.05;//micro F
disp(CT,"CT(micro F)");
RA=1/(f0*10^3)/(5/3)^2/(CT*10^-6)/1000;//kohm
disp(RA,"RA(kohm)");
RB=RA/RAbyRB;//kohm
disp(RB,"RB(kohm)");
```

Scilab code Exa 6.19 V0 V7 I and fo

```
//Ex 6.19
clc;
clear;
close;
```

```
format('v',6);
//Data given
Rf=15;//kohm
RT1=4.7;//kohm
R1=56;//kohm
R2=6.8;//kohm
R3=10;//kohm
R4=1;//kohm
R5=1;//kohm
CB=1;//micro F
CT=0.05;//mic
VCC=15;//V
V1=-15;//V////Voltage given through the resistance(
    R1) 56 kohm
disp("Part (i)");
Vin=2;//V
Vo=Rf/R1*(-V1)-Rf/R2*Vin;//V
disp(Vo,"Voltage Vo(V)");
N_VCC=0;//V////-VCC////voltage given to the 12th pin
    of IC
V7=N_VCC+3;//V
disp(V7,"Voltage V7(V)");
I=(V7-Vo)/RT1;//mA
disp(I,"Current I(mA)");
Rmult=R4*R5/(R4+R5)+R3;//kohm////on pin 3
disp(Rmult,"Total resistance on pin 3, Rmult(kohm)")
    ;
format('v',4);
f0=0.32*I*10^-3/(CT*10^-6)/1000;//kHz
disp(f0,"Oscillation frequency(kHz)");
disp("Part (ii)");
format('v',4);
Vin=5;//V
Vo=Rf/R1*(-V1)-Rf/R2*Vin;//V
disp(Vo,"Voltage Vo(V)");
N_VCC=0;//V////-VCC////voltage given to the 12th pin
    of IC
V7=N_VCC+3;//V
```

```
disp(V7,"Voltage V7(V)");
I=(V7-Vo)/RT1;//mA
format('v',6);
disp(I,"Current I(mA)");
Rmult=R4*R5/(R4+R5)+R3;//kohm////on pin 3
disp(Rmult,"Total resistance on pin 3, Rmult(kohm)")
    ;
f0=0.32*I*10^-3/(CT*10^-6)/1000;//kHz
disp(f0,"Oscillation frequency(kHz)");
```

Chapter 7

The 555 timer

Scilab code Exa 7.1 Monostable Multivibrator

```
////Ex 7.1
clc;
clear;
close;
format('v',9);
th=4;//ms
VCC=10;//V
C=0.05;//micro F(choosen between 0.01<=C<=1)
R=th*10^-3/(1.1*C*10^-6)/1000;//kohm
C1=0.01;//micro F(assumed)
C2=0.01;//micro F(choosen between 0.01<=C<=1)
R2=th*10^-3/(10*C2*10^-6)/1000;//kohm
C3=10;//micro F
disp("Design values are : ");
disp(C,"Capacitance C(micro F)");
disp(R,"Resistance R(kohm)");
disp(C1,"Capacitance C1(micro F)");
disp(C2,"Capacitance C2(micro F)");
disp(R2,"Resistance R2(kohm)");
disp(C3,"Capacitance C3(micro F)");
//Answer of R2 is wrong in the book.
```

Scilab code Exa 7.2 Value of R

```
////Ex 7.2
clc;
clear;
close;
format('v',9);
ft=2;//kHz
C=0.01;//micro F
T=1/ft;//ms
n=3;//for divide-by-3 circuit
th=(0.2+(n-1))*T;//ms
R=th/(1.1*C);//kohm
disp(R,"Value of Resistance R(kohm)");
```

Scilab code Exa 7.3 Astable Multivibrator

```
////Ex 7.3
clc;
clear;
close;
format('v',9);
fo=2;//kHz
D=70;//%(duty cycle)
T=1/fo;//ms
VCC=12;//V
tC=D*T/100;//ms
tD=T-tC;//ms
C=0.05;//micro F(choosen between 0.01<=C<=1)
RB=tD*10^-3/(0.69*C*10^-6)/1000;//kohm
RA=tC*10^-3/(0.69*C*10^-6)/1000-RB;//kohm
```

```
disp("Design values are : ");
disp(C,"Capacitance C(micro F)");
disp(RA,"Resistance RA(kohm)");
disp(RB,"Resistance RB(kohm)");
```

Scilab code Exa 7.4 Design a square wave generator

```
////Ex 7.4
clc;
clear;
close;
format('v',9);
fo=2;//kHz
D=50;//%(duty cycle)
T=1/fo;//ms
VCC=10;//V
tC=D*T/100;//ms
tD=T-tC;//ms
C=0.1;//micro F(choosen between 0.01<=C<=1)
RB=tD*10^-3/(0.69*C*10^-6)/1000;//kohm
RA=T*10^-3*1.45/(C*10^-6)/1000-RB;//kohm
disp("Design values are : ");
disp(C,"Capacitance C(micro F)");
disp(RA,"Resistance RA(kohm)");
disp(RB,"Resistance RB(kohm)");
disp("RA & RB should be equal for 50% duty cycle.")
```

Scilab code Exa 7.5 Astable Multivibrator

```
////Ex 7.5
clc;
clear;
close;
```

```
format('v',9);
fo=2;//kHz
D=40;//%(duty cycle)
T=1/fo;//ms
VCC=10;//V
tC=D*T/100;//ms
tD=T-tC;//ms
C=0.22;//micro F(choosen between 0.01<=C<=1)
RB=tD*10^-3/(0.69*C*10^-6)/1000;//kohm
RA=T*10^-3*1.45/(C*10^-6)/1000-RB;//kohm
disp("Design values are : ");
disp(C,"Capacitance C(micro F)");
disp(RA,"Resistance RA(kohm)");
disp(round(RB),"Resistance RB(kohm)");
```

Scilab code Exa 7.6 Astable Multivibrator

```
////Ex 7.6
clc;
clear;
close;
format('v',9);
fo=700;//Hz
D=50;//%(duty cycle)
T=1/fo*1000;//ms
VCC=10;//V
tC=D*T/100;//ms
tD=T-tC;//ms
C=0.05;//micro F(choosen between 0.01<=C<=1)
RB=tD*10^-3/(0.69*C*10^-6)/1000;//kohm
RA=T*10^-3*1.45/(C*10^-6)/1000-RB;//kohm
disp("Design values are : ");
disp(C,"Capacitance C(micro F)");
disp(round(RA),"Resistance RA(kohm)");
disp(round(RB),"Resistance RB(kohm)");
```

Scilab code Exa 7.7 Astable Multivibrator

```
////Ex 7.7
clc;
clear;
close;
format('v',9);
fo=800;//Hz
D=60;//%(duty cycle)
T=1/fo*1000;//ms
VCC=10;//V
tC=D*T/100;//ms
tD=T-tC;//ms
C=0.047;//micro F(choosen between 0.01<=C<=1)
RB=tD*10^-3/(0.69*C*10^-6)/1000;//kohm
RA=tC*10^-3*1.45/(C*10^-6)/1000-RB;//kohm
disp("Design values are : ");
disp(C,"Capacitance C(micro F)");
disp(round(RA),"Resistance RA(kohm)");
disp(round(RB),"Resistance RB(kohm)");
```

Chapter 8

Frequency Synthesizers and PLL

Scilab code Exa 8.1 Lock Capture and pullin range

```
////Ex 8.1
clc;
clear;
close;
format('v',9);
VCC=6;//V
VEE=6;//V
RT=4;//kohm
CT=330;//pF
C=240;//pF
fo=0.3/(RT*1000*CT*10^-12)/1000;//kHz
disp(fo,"Free running frequency(kHz)");
Vplus=(VCC-(-VEE))/2;//V
deltafL=8*fo/Vplus;//kHz
disp(deltafL,"Lock Range(+ve & -ve in kHz)");
//For LM 565
R=3.6;//kohm
deltafC=sqrt(deltafL*1000/(2*%pi*R*1000*C*10^-12))
    /1000;//kHz
```

```
disp(deltafC,"Capture Range(+ve & -ve in kHz)");
deltafP=2*deltafC/2;//kHz
disp(deltafP,"Pull-in Range(kHz)");
```

Scilab code Exa 8.2 Design a FM demodulator

```
////Ex 8.2
clc;
clear;
close;
format('v',9);
fo=450;//kHz
deltafL=240;//kHz(+ve & -ve)
deltafC=40;//kHz(+ve & -ve)
Vplus=8*fo/deltafL;//V
//Vplus=(VCC-(-VEE))/2 but |VCC|=|-VEE|
VCC=Vplus;//V
VEE=Vplus;//V
disp(VCC,"For the design |VCC|=|-VEE| in Volt");
RT=4.7;//kohm(Assumed for design)
R=3.6;//kohm
CT=0.3/(RT*1000*fo*1000)*10^12;//pF
C=1/((deltafC*10^3)^2*(2*%pi*R*10^3)/(deltafL*1000))*10^9;//nF
disp(RT,"Value of RT(kohm)");
disp(CT,"Value of CT(pF)");
disp(C,"Value of C(nF)");
//Answer in the book is not accurate.
```

Scilab code Exa 8.3 Clock frequency and no of bits

```
////Ex 8.3
clc;
```

```
clear;
close;
format('v',9);
fmax=160;//kHz
fr=4;//Hz(Resolution)
M=2.4;//unitless
fclk=M*fmax;//kHz
disp(fclk,"Clock frequency(kHz)");
N=log(fclk*1000/fr)/log(2);//no. of bits
disp(round(N),"No. of bits");
```

Chapter 9

Active Filters

Scilab code Exa 9.2 First order low pass filter

```
//Ex 9.2
clc;
clear;
close;
format('v',5);
fH=1;//kHz
Ap=2;//Pass band gain
disp("Various design parameters are :-");
C=0.05;//micro F//Chosen for the design
disp(C,"Capacitance(micro F)");
format('v',4);
R=1/(2*%pi*fH*1000*C*10^-6)/1000;//kohm
disp(R,"Resistance R(kohm)");
//Ap=1+Rf/Ri
RfBYRi=Ap-1;//Rf=Ri here
//R=Rf||Ri
Ri=2*R;//kohm
Rf=Ri;//kohm
disp(Ri,"Resistance Ri(kohm)");
disp(Rf,"Resistance Rf(kohm)");
```

Scilab code Exa 9.3 Find Bandwidth

```
//Ex 9.3
clc;
clear;
close;
format('v',5);
f0=800;//Hz
//For Butterworth filter : f0=fH=f_3dB
fH=f0;//Hz
f_3dB=f0;//Hz
BW=fH;//Hz
disp(BW,"Bandwidth(Hz)");
```

Scilab code Exa 9.4 First order low pass filter

```
//Ex 9.4
clc;
clear;
close;
format('v',5);
fH=2;//kHz(Cutoff frequency)
Ap=1;//Pass band gain
disp("Various design parameters are :-");
C=0.05;//micro F//Chosen for the design between 0.01
    & 1 micro F
disp(C,"Capacitance(micro F)");
format('v',4);
R=1/(2*%pi*fH*1000*C*10^-6)/1000;//kohm
disp(R,"Resistance R(kohm)");
Rdash=R;///kohm(To eliminate the effect of offset)
disp(Rdash,"Resistance R*(kohm)");
```

Scilab code Exa 9.5 Convert Cutoff frequency

```
//Ex 9.5
clc;
clear;
close;
format('v',4);
f0=1;//kHz(Cutoff frequency)
f0dash=1.5;//kHz(Cutoff frequency)
disp("Various design parameters are :-");
//For Butterworth filter
fH=f0;//kHz
fHdash=f0dash;//kHz
K=f0/f0dash;//ratio
R=3.2;//kohm
Rdash=K*R;//kohm
disp(Rdash,"Resistance Rdash(kohm)");
disp("Use Rdash=2.2 kohm");
format('v',5);
C=0.05;//micro F//Chosen for the design
disp(C,"Capacitance(micro F)");
format('v',4);
fHdash=1/(2*%pi*Rdash*1000*C*10^-6)/1000;//kHz
disp(fHdash,"Cutoff frequency(kHz)");
```

Scilab code Exa 9.6 First order high pass filter

```
//Ex 9.6
clc;
clear;
close;
```

```
format('v',5);
fL=400;//Hz
Ap=2;//Pass band gain
disp("Various design parameters are :-");
C=0.05;//micro F//Chosen for the design between 0.01
    & 1 micro F
disp(C,"Capacitance(micro F)");
R=1/(2*%pi*fL*C*10^-6)/1000;//kohm
format('v',4);
disp(R,"Resistance R(kohm)");
disp("Use R=8.2 kohm");
//Ap=1+Rf/Ri
RfBYRi=Ap-1;//Rf=Ri here
//R=Rf||Ri
Ri=2*R;//kohm
Rf=Ri;//kohm
disp(Ri,"Resistance Ri(kohm)");
disp(Rf,"Resistance Rf(kohm)");
```

Scilab code Exa 9.7 Retune the high pass filter

```
//Ex 9.7
clc;
clear;
close;
format('v',5);
fL=400;//Hz
fLdash=800;//Hz
K=fL/fLdash;//ratio
disp("Various parameters for retuning are :-");
R=8.2;//kohm
Rdash=K*R;//kohm
disp(Rdash,"Resistance Rdash(kohm)");
disp("Use Rdash=4.2 kohm");
Rf=2*Rdash;//kohm
```

```
Ri=2*Rdash;//kohm
disp(Ri,"Resistance Ri(kohm)");
disp(Rf,"Resistance Rf(kohm)");
```

Scilab code Exa 9.8 Second order Butterworth filter

```
//Ex 9.8
clc;
clear;
close;
format('v',6);
f0=3;//kHz(Critical frequency)
Ap=4;//Pass band gain
//For Butterworth filter using sallen key
alfa=1.414;klp=1;//constant
fH=f0;//kHz
f_3dB=f0;//kHz
disp("Various design parameters are :-");
C1=0.01;//micro F//Chosen for the design
disp(C1,"Capacitance C1(micro F)");
C2=alfa^2*C1/4;//micro F
disp(C2,"Capacitance C2(micro F)");
disp("Use C2=0.004 micro F");
C2=0.004;// micro F
R=1/(2*%pi*fH*10^3*sqrt(C1*10^-6*C2*10^-6))/1000;//
   kohm
format('v',4);
disp(R,"Resistance R(kohm)");
disp("Use R=8.2 kohm");
R=8.2;//kohm
//For offset minimization
Rdash=2*R;//kohm
disp(Rdash,"Resistance R*(kohm)");
RfBYRi=Ap-1;//Rf=Ri here
//Ri=10 kohm chosen for design
```

```
Ri=10;//kohm
Rf=RfBYRi*Ri;//kohm
disp(Ri,"Resistance Ri(kohm)");
disp(Rf,"Resistance Rf(kohm)");
```

Scilab code Exa 9.9 Second order Butterworth filter

```
//Ex 9.9
clc;
clear;
close;
format('v',5);
f0=2;//kHz(Critical frequency)
Ap=5;//dc gain
//For Butterworth filter using sallen key
alfa=1.414;klp=1;//constant
fH=f0;//kHz
f_3dB=f0;//kHz
Ap1=3-alfa;//gain
RfBYRi=Ap1-1;//ratio
disp("Various design parameters are :-");
C=0.05;//micro F//Chosen for the design
disp(C,"Capacitance C(micro F)");
R=klp/(2*%pi*fH*10^3*C*10^-6)/1000;//kohm
disp(R,"Resistance R(kohm)");
disp("Use R=1.6 kohm");
//For offset minimization
//2*R=Rf||Ri=Rf/(RfBYRi+1)
Rf=2*R*(RfBYRi+1);//kohm
disp(Rf,"Resistance Rf(kohm)");
Ri=Rf/RfBYRi;//kohm
format('v',4);
disp(Ri,"Resistance Ri(kohm)");
//Ap=4;//dc gain in this case
Ap=4;//dc gain
```

```
Ap2=Ap/Ap1;//remainimg gain after 2nd order
   butterworth filter
RfdashBYRidash=Ap2-1;//ratio
//Ridash=10;//kohm chosen for design
Ridash=10;//kohm
disp(Ridash,"Resistance Ridash(kohm)");
Rfdash=RfdashBYRidash*Ridash;//kohm
disp(Rfdash,"Resistance Rfdash(kohm)");
```

Scilab code Exa 9.10 Second order low pass filter

```
//Ex 9.10
clc;
clear;
close;
format('v',5);
f0=2;//kHz(Critical frequency)
fH=f0;//kHz
f_3dB=f0;//kHz
//For Butterworth filter using sallen key
alfa=1.414;klp=1;//constant
Ap=3-alfa;// band pass gain
RfBYRi=Ap-1;//ratio
disp("Various design parameters are :-");
C=0.05;//micro F//Chosen for the design
disp(C,"Capacitance C(micro F)");
format('v',4);
R=1/(2*%pi*fH*10^3*C*10^-6)/1000;//kohm
disp(R,"Resistance R(kohm)");
//For offset minimization
//2*R=Rf||Ri=Rf/(RfBYRi+1)
Rf=2*R*(RfBYRi+1);//kohm
disp(Rf,"Resistance Rf(kohm)");
Ri=Rf/RfBYRi;//kohm
disp(Ri,"Resistance Ri(kohm)");
```

```
//Answer in the book is not accurate. Some
   calculation mistake is there while working for
   offset minimization.
```

Scilab code Exa 9.11 Low pass bessel filter

```
//Ex 9.11
clc;
clear;
close;
format('v',5);
f0=2;//kHz(Critical frequency)
fH=f0;//kHz
f_3dB=f0;//kHz
//For Bessel filter of 2nd order
alfa=1.73;klp=0.785;//constant
Ap=3-alfa;// band pass gain
RfBYRi=Ap-1;//ratio
disp("Various design parameters are :-");
C=0.05;//micro F//Chosen for the design
disp(C,"Capacitance C(micro F)");
format('v',4);
R=klp/(2*%pi*fH*10^3*C*10^-6)/1000;//kohm
disp(R,"Resistance R(kohm)");
//For offset minimization
//2*R=Rf||Ri=Rf/(RfBYRi+1)
Rf=2*R*(RfBYRi+1);//kohm
disp(Rf,"Resistance Rf(kohm)");
Ri=Rf/RfBYRi;//kohm
disp(Ri,"Resistance Ri(kohm)");
```

Scilab code Exa 9.12 Second order low pass filter

```
//Ex 9.12
clc;
clear;
close;
format('v',5);
f0=.12;//kHz(Cutoff frequency)
fH=f0;//kHz
//For Butterworth filter of 2nd order
alfa=1.414;klp=1;//constant
Ap=3-alfa;// band pass gain
RfBYRi=Ap-1;//ratio
disp("Various design parameters are :-");
C=0.33;//micro F//Chosen for the design choosing between 0.01 & 1 micro F
disp(C,"Capacitance C(micro F)");
format('v',4);
R=klp/(2*%pi*fH*10^3*C*10^-6)/1000;//kohm
disp(R,"Resistance R(kohm)");
disp("Use R=3.9 kohm");
//For offset minimization
//2*R=Rf||Ri=Rf/(RfBYRi+1)
Rf=2*R*(RfBYRi+1);//kohm
disp(Rf,"Resistance Rf(kohm)");
Ri=Rf/RfBYRi;//kohm
disp(Ri,"Resistance Ri(kohm)");
```

Scilab code Exa 9.13 Second order low pass filter

```
//Ex 9.13
clc;
clear;
close;
format('v',5);
fL=20;//Hz(Cutoff frequency)
//For Butterworth filter of 2nd order
```

```
alfa=1.414;klp=1;//constant
Ap=3-alfa;// band pass gain
RfBYRi=Ap-1;//ratio
disp("Various design parameters are :-");
C=0.22;//micro F//Chosen for the design choosing
   between 0.01 & 1 micro F
disp(C,"Capacitance C(micro F)");
format('v',4);
R=klp/(2*%pi*fL*C*10^-6)/1000;//kohm
disp(R,"Resistance R(kohm)");
//For offset minimization
//R=Rf||Ri=Rf/(RfBYRi+1)
Rf=R*(RfBYRi+1);//kohm
disp(Rf,"Resistance Rf(kohm)");
Ri=Rf/RfBYRi;//kohm
Ri=floor(Ri);//kohm
disp(Ri,"Resistance Ri(kohm)");
```

Scilab code Exa 9.14 Third order low pass butterworth filter

```
//Ex 9.14
clc;
clear;
close;
format('v',5);
fH=2;//kHz(Cutoff frequency)
Ap=4;//Pass band gain
disp("Butterworth filter of 3rd order can be
   obtained by cascading of first and second order
   high pass filter.");
//Butterworth polynomial is (s+1)*(s^2+s+1)
alfa=1;//for sallen key
Ap2=3-alfa;//gain for 2nd order filter
Ap1=Ap/Ap2;//gain for 1st order filter
//Design parameters for 1st order filter :
```

```
disp("Various design parameters for 1st order filter
    are :-");
C=0.01;//micro F//Chosen for the design
disp(C,"Capacitance C(micro F)");
R=1/(2*%pi*fH*10^3*C*10^-6)/1000;//kohm
disp(R,"Resistance R(kohm)");
disp("Use R=8.2 kohm");
R=8.2;//kohm
//Ap1=Rf/Ri+1 ; with Ap1=2 we have Rf=Ri
Rf=2*R;//kohm
Ri=2*R;//kohm
disp(Ri,Rf,"Resistance Rf & Ri(kohm)");
format('v',6);
//Design parameters for 2nd order filter :
kLp=1/alfa;//unitless
//Ap2=Rfdash/Ridash+1 ; with Ap2=2 we have Rfdash=
    Ridash
disp("Various design parameters for 2nd order filter
    are :-");
C=0.033;//micro F//Chosen for the design
disp(C,"Capacitance C(micro F)");
format('v',4);
R=kLp/(2*%pi*fH*10^3*C*10^-6)/1000;//kohm
disp(R,"Resistance R(kohm)");
Rf=2*R;//kohm
Ri=2*R;//kohm
disp(Ri,Rf,"Resistance Rfdash & Ridash(kohm)");
```

Scilab code Exa 9.15 Design a band pass filter

```
//Ex 9.15
clc;
clear;
close;
format('v',6);
```

```
fL=200;//Hz
fH=1; //kHz
Ap=4;//Pass band gain
fc=sqrt(fH*1000*fL);//Hz(Cutoff frequency)
BW=fH*1000-fL;//Hz
Q=fc/BW;//Quality Factor
disp(Q,"Quality factor is ");
disp("As Q<12, it is a wide band filter.");
Ap1=2;//Pass band gain for high pass section
disp("Various design parameters for high pass section are :-");
C=0.033;//micro F//Chosen for the design
disp(C,"Capacitance C(micro F)");
format('v',4);
R=1/(2*%pi*fL*C*10^-6)/1000;//kohm
disp(R,"Resistance R(kohm)");
//Ap1=Rf/Ri+1 ; with Ap1=2 we have Rf=Ri
Rf=2*R;//kohm
Ri=2*R;//kohm
disp(Ri,Rf,"Resistance Rf & Ri(kohm)");
Ap2=2;//Pass band gain for low pass section
disp("Various design parameters for low pass section are :-");
format('v',6);
C=0.033;//micro F//Chosen for the design
disp(C,"Capacitance C(micro F)");
format('v',4);
K=fL/(fH*1000);//unitless
Rdash=K*R;//kohm
disp(Rdash,"Resistance Rdash(kohm)");
//Ap1=Rf/Ri+1 ; with Ap1=2 we have Rf=Ri
Rf=2*Rdash;//kohm
Ri=2*Rdash;//kohm
disp(Ri,Rf,"Resistance Rf & Ri(kohm)");
disp("Use Rf=Ri=10 kohm");
```

Scilab code Exa 9.16 Design a band pass filter

```
//Ex 9.16
clc;
clear;
close;
format('v',5);
disp("Part(a)");
fc=1.2;//kHz
Q=4;//Quality Factor
Ap=10;//Pass band gain
disp("Here 2*Q^2=32>AP=10, hence it can be designed using single op-amp.");
disp("Various design parameters are :-");
C=0.05;//micro F//Chosen for the design
disp(C,"Capacitance C(micro F)");
//fc/Q=1/(%pi*R2*C)
R2=Q/(fc*1000)/%pi/(C*10^-6)/1000;//kohm
disp(R2,"Resistance R2(kohm)");
disp("Use R2=22 kohm");
format('v',5);
R1=R2/(2*Ap);//kohm
disp(R1,"Resistance R1(kohm)");
R3=R1*1000/(4*%pi^2*R1*1000*R2*1000*(C*10^-6)^2*(fc*1000)^2-1);//ohm
disp(R3,"Resistance R3(ohm)");
disp("Use R3=460 ohm");
disp("Part(b)");
R3=460;//ohm
fc_new=1.5;//kHz
fc_old=1.2;//kHz
R3new=R3*(fc_old/fc_new)^2;//ohm
disp("Resistance R3 should be changed from "+string(R3)+" ohm to "+string(R3new)+" ohm");
```

```
///Answer for R3 is wrong in the book
```

Scilab code Exa 9.17 Design a band pass filter

```
//Ex 9.17
clc;
clear;
close;
format('v',5);
fL=3;//kHz
fH=3.6;//kHz
Ap=-6;//Pass band gain
fc=sqrt(fH*fL)*1000;//Hz
BW=(fH-fL)*1000;//Hz
Q=fc/BW;//Quality factor
disp(Q,"Quality factor is ");
disp("Here 1<=Q<=12 criteria fulfills , hence it can
   be designed using single op-amp.");
disp("Various design parameters are :-");
C=0.01;//micro F//Chosen for the design
disp(C,"Capacitance C(micro F)");
//fc/Q=1/(%pi*R2*C)
format('v',4);
R2=1/%pi/(BW)/(C*10^-6)/1000;//kohm
disp(R2,"Resistance R2(kohm)");
format('v',5);
R1=-R2/(2*Ap);//kohm
disp(R1,"Resistance R1(kohm)");
R3=R1*1000/(4*%pi^2*R1*1000*R2*1000*(C*10^-6)^2*(fc)
   ^2-1);//ohm
disp(R3,"Resistance R3(ohm)");
disp("Design Verification : ");
disp(2*Q^2>abs(Ap),"(i) Is 2*Q^2>|Ap| ?");
disp("For op-amp 741, GBW=1 MHz");
GBW=1;//MHz
```

```
disp(GBW*10^6>20*Q^2*fc,"Is GBW*10^6>20*Q^2*fc ?");
disp("2nd criteria failed. The op-amp should have
   higher GBW product. Use LF411");
```

Scilab code Exa 9.18 Design a band pass filter

```
//Ex 9.18
clc;
clear;
close;
format('v',5);
Ap=-10;//Pass band gain
Q=22;//Quality factor
fc=50;//Hz
R=60;//dB/decade(Roll off rate)
disp("Roll off rate of single op-amp=20 dB/decade.
   No. of stages will be 3. Desired design can be
   obtained by cascading three stages.");
n=3;//no. of op-amps(as single op-amp has 20 dB/
   decade)
fc1=fc;//Hz
fc2=fc;//Hz
fc3=fc;//Hz
Q1=Q*sqrt(2^(1/n)-1);//Quality factor of each stage
Q2=Q1;//Quality factor
Q3=Q1;//Quality factor
Ap1=-(-Ap)^(1/n);//Band pass gain of each stage
Ap2=Ap1;//Band pass gain
Ap3=Ap1;//Band pass gain
//Design of a single op-amp
C=0.1;//micro F//Chosen for the design
disp("Various design parameters for a single stages
   are :");
disp(C,"Capacitance C(micro F)");
format('v',4);
```

```
R2=Q1/%pi/(fc)/(C*10^-6)/1000;//kohm
disp(R2,"Resistance R2(kohm)");
format('v',5);
R1=-R2/(2*Ap1);//kohm
disp(R1,"Resistance R1(kohm)");
format('v',4);
R3=R1/(4*%pi^2*R1*1000*R2*1000*(C*10^-6)^2*(fc)^2-1)
    ;//kohm
disp(R3,"Resistance R3(ohm)");
//Answer for R2 is wrong in the book.
```

Scilab code Exa 9.20 Second order notch filter

```
//Ex 9.20
clc;
clear;
close;
format('v',5);
fNO=50;//Hz
Q=20;//Quality Factor
disp("Various design parameters are :-");
C=1;//micro F//Chosen for the design
disp(C,"Capacitance C(micro F)");
R=1/(2*%pi*fNO)/(C*10^-6)/1000;//kohm
disp(R,"Resistance R(kohm)");
disp("Use R=3.2 kohm");
//Q=(RA+RB)/4/RA
RA=1;//kohm(chosen for the design)
RB=Q*4*RA-RA;//kohm
disp(RA,"Resistance RA(kohm)");
disp(RB,"Resistance RB(kohm)");
```

Chapter 10

Comparators

Scilab code Exa 10.1 Output Voltage

```
////Ex 10.1
clc;
clear;
close;
format('v',5);
t=0:0.01:5;//sec(Assumed)
Vin=5*sin(2*%pi*t);//V
VCC=15;//V
R2=1;//kohm
R1=6.8;//kohm
VEE=-15;//V
Vsat=13;//V
Vref=R2*VCC/(R1+R2);//V
disp(Vref,"Reference Voltage(V)")
disp(Vsat,"If Vin>Vref , Vout (V):");
disp(-Vsat,"If Vin<Vref , Vout (V):");
```

Scilab code Exa 10.2 Upper and Lower Trip points

```
////Ex 10.2
clc;
clear;
close;
format('v',9);
Vsat=7;//V
R1=68;//kohm
R2=82;//kohm
VUTP=R2*Vsat/(R1+R2);//V
VLTP=R2*-Vsat/(R1+R2);//V
disp(VUTP,"Upper trip point(V)");
disp(VLTP,"Lower trip point(V)");
```

Scilab code Exa 10.3 Phase shift

```
////Ex 10.3
clc;
clear;
close;
format('v',9);
//Vin=5*sin(omega*t)
Vm=5;//V
Vsat=7;//V
R1=68;//kohm
R2=82;//kohm
VUTP=R2*Vsat/(R1+R2);//V
fi=asind(VUTP/Vm);//degree
disp(fi,"Phase shift(degree)");
```

Scilab code Exa 10.4 Output Voltage

```
////Ex 10.4
clc;
```

```
clear;
close;
format('v',5);
VZ1=4.7;//V
VZ2=4.7;//V
R1=68;//kohm
R2=15;//kohm
Vout=VZ1+0.7;//V(As one zener diode is always
    forward biased)
VR1=Vout;//V
IR1=VR1/R1*1000;//micro A
IR2=IR1;//micro A
VR2=IR2*10^-3*R2;//V
Vout=VR1+VR2;//V
VUTP=(R2/(R1+R2))*Vout;//V
VLTP=(R2/(R1+R2))*(-Vout);//V
disp(VUTP,"VUTP(V)");
disp(VLTP,"VLTP(V)");
```

Scilab code Exa 10.5 Threshold and hysteresis voltage

```
////Ex 10.5
clc;
clear;
close;
format('v',9);
Vsat=12.5;//V
Vref=-12.5;//V
R1=80;//kohm
R2=20;//kohm
Beta=R2/(R1+R2);//unitless
UTP=Beta*Vsat+(1-Beta)*Vref;//V
LTP=-Beta*Vsat+(1-Beta)*Vref;//V
VH=UTP-LTP;//V
R3=R1*R2/(R1+R2);//kohm
```

```
disp(UTP,"UTP(V)");
disp(LTP,"LTP(V)");
disp(VH," Hysteresis Voltahe, VH(V)");
disp(R3,"Use R3(kohm)");
```

Chapter 11

Non linear applications of opamp

Scilab code Exa 11.1 Output Voltage

```
////Ex 11.1
clc;
clear;
close;
format('v',5);
Vin=12.5;//V
Ri=10;//kohm
IS=10^-13;//A
T=27;//degree C
VT=26;//mV
Vref=Ri*IS*1000;//V
Vout=-VT*10^-3*log(Vin/Vref);//V
disp(Vout,"Output Voltahe, Vout(V)");
```

Scilab code Exa 11.3 Output Voltage

```
////Ex 11.2
clc;
clear;
close;
format('v',7);
R1=10;//kohm
k=1.38*10^-23;//J/K
T=298;//K
q=1.6*10^-19;//C
Kdash=k*T/q;//Kdash=k*T/q assumed for temporary
    calculation
disp("Output Voltahe, Vout(V) is "+string(-Kdash)+"*
    log(Vin/10*10^3)");
```

Scilab code Exa 11.4 Output Voltage

```
////Ex 11.4
clc;
clear;
close;
format('v',5);
R1=10;//kohm
R2=10;//kohm
k=1.38*10^-23;//J/K
T=298;//K
q=1.6*10^-19;//C
Kdash=k*T/q;//Kdash=k*T/q assumed for temporary
    calculation
disp("Output Voltahe, Vout(V) is -R1*(log("+string
    (-1/Kdash)+"*Vin)^-1");
```

Scilab code Exa 11.7 Calculate Output

```
////Ex 11.7
clc;
clear;
close;
format('v',6);
k=1;//for the givn connection
//(a)
Vin=5;//V
Vout=-k*log10(Vin/0.1);//V
disp(Vout,"For 5V input, Output Voltage(V)");
//(b)
Vin=2;//V
Vout=-k*log10(Vin/0.1);//V
disp(Vout,"For 2V input, Output Voltage(V)");
//(c)
Vin=0.1;//V
Vout=-k*log10(Vin/0.1);//V
disp(Vout,"For 0.1V input, Output Voltage(V)");
//(d)
Vin=50;//mV
Vout=-k*log10(Vin/1000/0.1);//V
disp(Vout,"For 50mV input, Output Voltage(V)");
//(a)
Vin=5;//mV
Vout=-k*log10(Vin/1000/0.1);//V
disp(Vout,"For 5mV input, Output Voltage(V)");
```

Scilab code Exa 11.8 Calculate Output

```
////Ex 11.8
clc;
clear;
close;
format('v',6);
k=1;//for the givn connection
```

```
//For 755N module
Rin=10;//kohm
Iref=10;//micro A
Vref=Rin*Iref/1000;//V
//(a)
Vin=5;//V
Vout1=-k*log10(Vin/0.1);//V
Vout=Vref*10^(-Vout1/k);//V
disp(Vout,"For 5V input to log amp, Antilog amp
    Output(V)");
//(b)
Vin=2;//V
Vout1=-k*log10(Vin/0.1);//V
Vout=Vref*10^(-Vout1/k);//V
disp(Vout,"For 2V input to log amp, Antilog amp
    Output(V)");
//(c)
Vin=0.1;//V
Vout1=-k*log10(Vin/0.1);//V
Vout=Vref*10^(-Vout1/k);//V
disp(Vout,"For 0.1V input to log amp, Antilog amp
    Output(V)");
//(d)
Vin=50;//mV
Vout1=-k*log10(Vin/1000/0.1);//V
Vout=Vref*10^(-Vout1/k);//V
disp(Vout*1000,"For 50mV input to log amp, Antilog
    amp Output(mV)");
//(e)
Vin=5;//mV
Vout1=-k*log10(Vin/1000/0.1);//V
Vout=Vref*10^(-Vout1/k);//V
disp(Vout*1000,"For 5mV input to log amp, Antilog
    amp Output(mV)");
```

Chapter 12

Operational Transconductance Amplifier

Scilab code Exa 12.1 f3dB frequency

```
////Ex 12.1
clc;
clear;
close;
format('v',9);
gm=55;//micro U
C=8.75;//pF
f3dB=gm/(2*%pi*C);//MHz
disp(f3dB,"f-3dB frequency(MHz)")
```

Chapter 13

Voltage Regulators

Scilab code Exa 13.1 Regulation

```
////Ex 13.1
clc;
clear;
close;
format('v',6);
deltaVin=4;//V
deltaVout=0.4;//V
Vout=20;//V
LR=(deltaVout/Vout)*100/deltaVin;//%/V(Line
    Regulation)
disp(LR,"Line Regulation(%/V)");
```

Scilab code Exa 13.2 Load Regulation

```
////Ex 13.2
clc;
clear;
close;
```

```
format('v',6);
VNL=18;//V
VFL=17.8;//V
IL=50;//mA
LR=(VNL-VFL)*100/VFL;//%(Line Regulation)
LdR=LR/IL;//%/mA(Load Regulation)
disp(LdR,"Load Regulation(%/mA)");
```

Scilab code Exa 13.3 Calculate Load Current

```
////Ex 13.3
clc;
clear;
close;
format('v',6);
VBE=0.65;//V
RCL=1.2;//ohm
ILmax=VBE/RCL;//A
//For Vout=0, IL=ILmax
IL=ILmax;//A
disp(IL,"Load current(A)");
```

Scilab code Exa 13.4 Determine the output

```
////Ex 13.4
clc;
clear;
close;
format('v',6);
R=20;//kohm
R1=20;//kohm
R2=10;//kohm
VZ=4.7;//V
```

```
Vref=VZ;//V
Vout=Vref*(1+R1/R2);//V
disp(Vout,"Output Voltage(V)");
```

Scilab code Exa 13.5 Design a regulator circuit

```
////Ex 13.5
clc;
clear;
close;
format('v',6);
Vout=15;//V
Vin=20;//V
INL=2;//mA(INL=Iadj+Iref)
Iadj=60;//mA(Assumed)
Iref=INL-Iadj/1000;//mA
Vref=1.25;//V
R1=Vref/Iref*1000;//ohm
VR2=Vout-Vref;//V
R2=VR2/INL*1000;//ohm
disp("Design values are : ");
disp(R1,"Resistance, R1(ohm)");
disp(R2/1000,"Resistance, R2(kohm)");
```

Scilab code Exa 13.6 Calculate Iext

```
////Ex 13.6
clc;
clear;
close;
format('v',6);
RL1=100;//ohm
RL2=1;//ohm
```

```
RCS=7;//ohm
VEB=0.7;//V
Beta=25;//unitless
//For 100 ohm Load
Vout=5;//V(as 7805 used)
IL=Vout/RL1;//A
VRCS=IL*RCS;//V(Voltage across RCS)
//VRCS<VEB, hence Q1 is off
Iout=IL;Iin=IL;//A
Iext=Iout-Iin;//A
disp(Iext,"For 100 ohm load, Output current Iext(A)");
//For 1 ohm Load
Vout=5;//V(as 7805 used)
IL=Vout/RL2;//A
ILmax=IL;//A
VRCS=IL*RCS;//V(Voltage across RCS)
//VRCS>VEB, hence Q1 is on
Iout=(ILmax+Beta*VEB/RCS)/(Beta+1);//A
Iext=ILmax-Iout;//A
disp(Iext,"For 10 ohm load, Output current Iext(A)");
```

Scilab code Exa 13.7 Value of R1

```
////Ex 13.7
clc;
clear;
close;
format('v',6);
RL=1:10;//ohm
R1=5;//ohm
Vref=5;//V
IL=1;//A
IQ=0;//A
```

```
Iref=IL;//A
R1=Vref/Iref;//ohm
disp(R1,"Value of resistor R1(ohm)");
```

Scilab code Exa 13.8 Adjustable Voltage regulator

```
////Ex 13.8
clc;
clear;
close;
format('v',6);
Vout=15:20;//V
Vin=24;//V
VR1=12;//V
Vref=12;//V
I4=0;//A(Assumed)
Iout=1;//A(Assumed)
R1=VR1/Iout;//ohm
//Vout=VR1*(1+R2/R1)
R2min=R1*(min(Vout)/VR1-1);//Putting min Vout
R2max=R1*(max(Vout)/VR1-1);//Putting min Vout
disp(R1,"Resistance R1(ohm)");
disp(R2max,R2min,"Minimum & maximum value of R2(ohm)
    ");
disp("A pot of 10 ohm should be used.");
```

Scilab code Exa 13.9 Regulated Power Supply

```
////Ex 13.9
clc;
clear;
close;
format('v',6);
```

```
Vout=6;//V
IL=100;//mA
Vref=7.15;//V(For LM 723)
Iref=1;//mA(Assumed)
R1=(Vref-Vout)/Iref;//kohm
R2=Vout/Iref;//kohm
disp("Design values are : ");
disp(R1,"R1 should be used 1.2kohm. Calculated R1(
   kohm) is");
disp(R2,"R2 should be used 6.2kohm. Calculated R2(
   kohm)");
R1=1.2;R2=6.2;//kohm
R3=R1*R2/(R1+R2);//kohm
disp(R3,"Resistance R3(kohm)");
RCL=0.65/(IL/1000);//kohm
disp(RCL,"Resistance RCL(kohm)");
```

Scilab code Exa 13.10 Regulated Power Supply

```
////Ex 13.10
clc;
clear;
close;
format('v',6);
Vout=15;//V
IL=50;//mA
Vin=20;//V
PDmax=1;//W(For LM 723)
Iref=3;//mA(From datasheet)
PD=Vout*(IL+Iref);//mW
disp(PD/1000,"Required PD(W)");
disp(PDmax,"PDmax supplie by LM723(mW)");
disp("PD<PDmax, so we can use it.");
Vref=7.15;//V(For LM 723)
R3=1.5;//kohm(choosen)
```

```
R1BYR2=(Vout-Vref)/Vref;
R1=R3*(R1BYR2+1);//ohm
disp(R1,"Resistance R1(kohm)");
R2=R1/R1BYR2;//ohm
disp(R2,"Resistance R2(kohm)");
disp(R3,"Resistance R3(kohm)");
RCL=0.65/(IL/1000);//ohm
disp(RCL,"Resistance RCL(ohm)");
```